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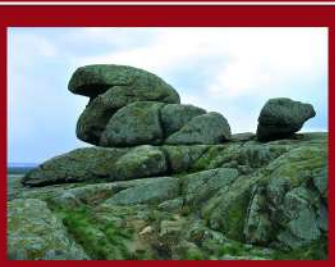

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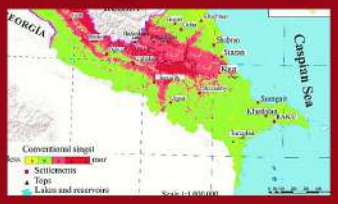

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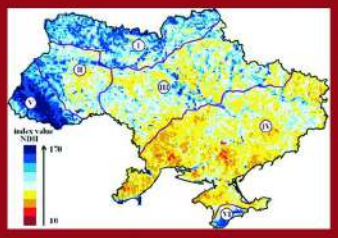

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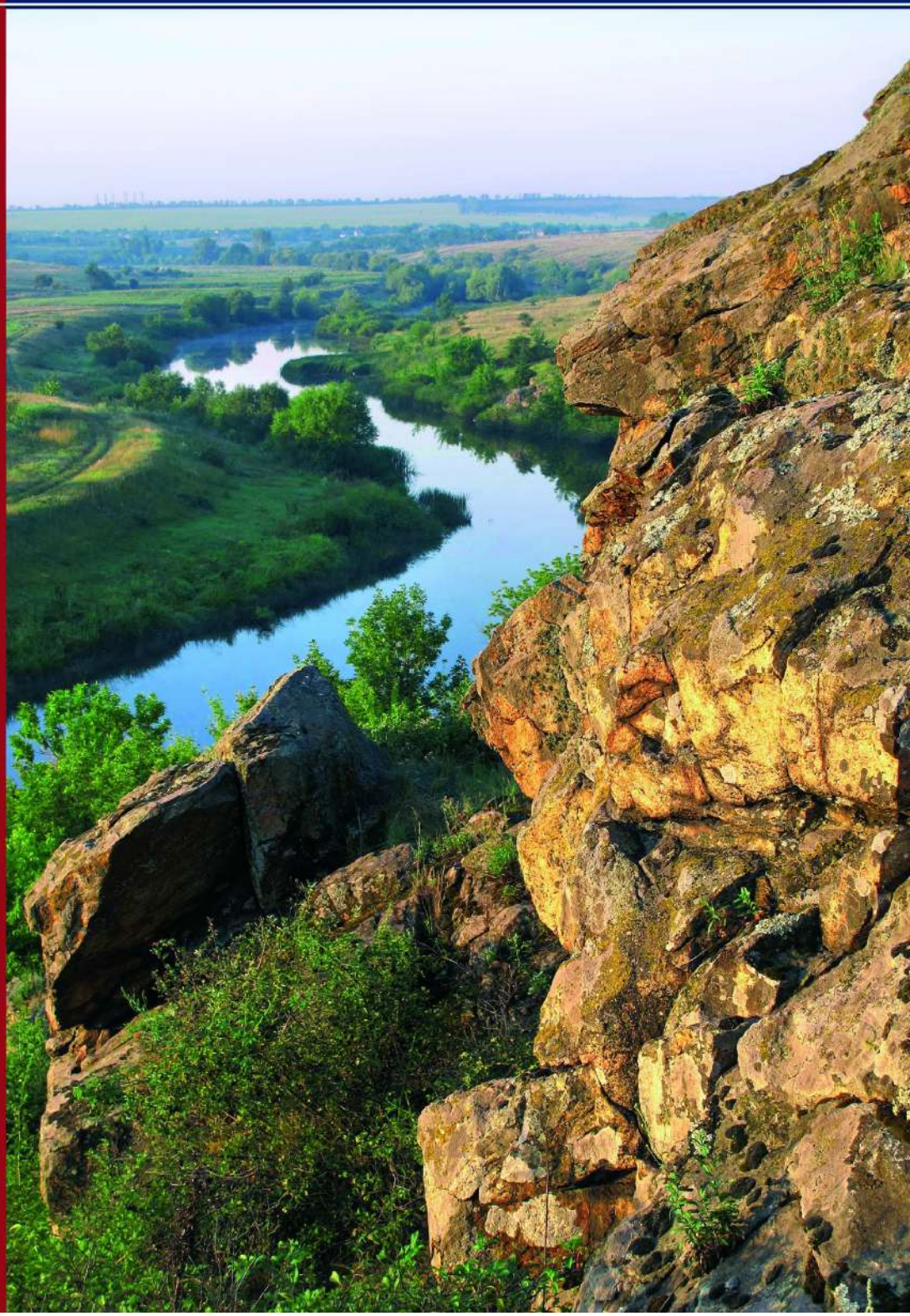

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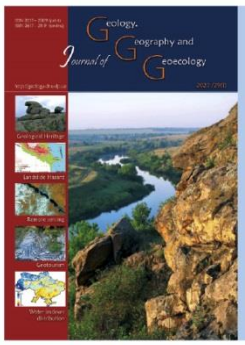

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Geophysical methods for controlling the useful component content as the basis for the quality management system at mining and processing enterprises

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Abstract. The article is devoted to substantiating the possibility of creating a common quality management system for iron ore plants based on geophysical methods of operational quality control for mineral raw materials. Due to the fall in prices on the world markets of iron ore raw materials, the financial and economic situation of the mining and processing enterprises in Ukraine has significantly worsened. Thus, the problem of effective control and quality management in mining has become of maximum importance. The availability of timely and reliable information about the content of the useful component will allow responding quickly, forming an integrated final ore cargo flow of the plant of exact quality required by the mining and concentration complex. The need to create a common quality management system is dictated by the fact that the iron ore has a heterogeneous distribution of the useful component content within the deposit, the extraction and transport equipment operates irregularly, resulting in ore cargo flows of various degrees of integration have significant amplitude and frequency oscillations, both by quality and quantity indicators. The instability of the useful component content in the ore cargo, which is aimed at enrichment, leads to a decrease in concentrate output, increase of losses in the tails, costs increase, decrease of the enterprise profit and decrease of its competitiveness. The mathematical model of ore cargo flow formation, which has a range of limitations on quality characteristics, is given. The structure and functional scheme of the quality management system of the mining and processing plant are substantiated. As a result of theoretical studies, the possibility of using radiometric and magnetometric methods for the operational quality control of the iron ore raw materials in the conditions of mining and processing plants by geophysical devices developed by the staff of the problem-branch laboratory of the Kryvyi Rih National University and Rudpromheofizyka LLC is substantiated. The basic technological characteristics of devices and systems are given, information on their introduction into production is provided. It is concluded that the researches carried out and the devices introduced on their basis have created objective prerequisites for substantiating the quality management system at mining and processing plants. The devices and operational control systems based on geophysical methods allow to cover all major stages of mining and processing, to receive timely and reliable information on the condition and dynamics of changes in the useful component content, to efficiently quality management at mining and processing plants, to increase the enterprises competitiveness and profitability.

Keywords: operational quality control, quality management system, useful component content, ore cargo flow, chemical analysis, logging.

Геофізичні методи контролю вмісту корисного компоненту як основа системи управління якістю гірничо-збагачувальних комбінатів

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Анотація. Стаття присвячена обґрунтуванню можливості створення загальної системи управління якістю залізорудних комбінатів на основі геофізичних методів оперативного контролю якості мінеральної сировини. Внаслідок падіння цін на

світових ринках залізорудної сировини фінансово-економічне становище гірничо-збагачувальних комбінатів України значно погіршилося, тому проблема здійснення ефективного контролю та управління якістю в умовах гірничого виробництва набула максимального значення. Наявність своєчасної та достовірної інформації про вміст корисного компоненту дозволить оперативно реагувати, формуючи інтегрований фінальний рудний вантажопотік комбінату саме такої якості, якої потребує збагачувальний комплекс. Необхідність створення загальної системи управління якістю продиктована тим, що залізорудна сировина має неоднорідний розподіл вмісту корисного компоненту в межах родовища, видобувне та транспортне устаткування працює неритмічно, внаслідок чого рудні вантажопотоки різного ступеню інтеграції мають значні амплітудно-частотні коливання як за якісними, так й за кількісними показниками. Нестабільність вмісту корисного компоненту в рудному вантажопотоці, що спрямовується на збагачення, призводить до зниження виходу концентрату, збільшення втрат у хвостах, підвищення витрат, зниження прибутку підприємства та падіння його конкурентоздатності. Наведено математичну модель формування рудного вантажопотоку, що має діапазонні обмеження по якісних характеристиках, обґрунтовано структуру та функціональну схему системи управління якістю гірничо-збагачувального комбінату. В результаті теоретичних досліджень обґрунтовано можливість застосування радіометричних та магнітометричних методів для здійснення оперативного контролю якості залізорудної сировини в умовах гірничо-збагачувальних комбінатів геофізичними приладами, що розроблені колективом проблемно-галузевої лабораторії Криворізького національного університету та ТОВ «Рудпромгеофізика». Наведені основні технологічні характеристики приладів та систем, надані відомості щодо їх впровадження у виробництво. Зроблено висновки, що проведені дослідження та впроваджені на їх основі у виробництво прилади створили об'єктивні передумови для обґрунтування системи управління якістю гірничо-збагачувальних комбінатів. Пристрої та системи оперативного контролю, які основані на геофізичних методах, дозволяють охопити усі основні етапи гірничого виробництва та переробки, отримувати своєчасну та достовірну інформацію про стан та динаміку змін вмісту корисного компоненту, здійснювати ефективне управління якістю гірничо-збагачувальних комбінатів, підвищити конкурентноздатність та прибуток цих підприємств.

Ключові слова: оперативний контроль якості, система управління якістю, вміст корисного компоненту, рудний вантажопотік, хімічний аналіз, каротаж.

Introduction. In the conditions of fierce competition of the world iron ore producers, against the background of deterioration in mining and technological conditions of development of deposits, quality decrease of raw material base in Ukraine and increase of production cost, the problem of effective control and quality management in mining production has become of maximum importance.

Quality fluctuations of iron-containing raw materials within the deposit, due to the morphology of the ore bodies and the presence of many varieties of ore, lead to instability in the useful component content of the ore cargo flow, which is directed to the mining and concentration complex (Joukov, Azarian, 2017).

It is known that ore-concentration plant (OCP) are high inertial production systems tuned to a specific quality index in a given range of oscillations. Excessive fluctuations in the useful component content in the ore at the inlet of OCP, which go beyond the specified calculation range, lead to a decrease in concentrate output, increase in losses in the tails, increase the cost of processing. That is why the instability in the quality characteristics of iron-containing raw materials causes such negative consequences as the decrease in the profit of the ore-dressing and mining and concentration complex (MCC) and the fall of their competitiveness (Azarian, Joukov, & Stricha, 2017).

Quality control in the mining and processing of iron ores is to determine the useful component content – that is, raw material quality, as well as to establish other characteristics: density, presence and content of harmful impurities, humidity, etc. For technological control, the main indicator is the content of the useful component, i.e. raw material quality.

Quality control can be carried out either by chemical analysis or using geophysical methods of operational control. The main factor distinguishing the first methods from the second is the speed of information retrieval: chemical analysis methods allow to establish qualitative indicators of minerals over a period of 2 hours, which often increases to 4-6 hours under production conditions, and operational control of one sample is carried out, usually within a few seconds to 3 minutes.

Chemical analysis methods are carried out in accordance with the state standard, so information about the quality characteristics obtained using these methods can be included in the quality certificates, which are the official supporting documents for the shipment of iron ore or products of its processing (concentrate, pellets) under internal or external contracts.

Geophysical methods of operational quality control for iron-containing raw materials are used as technological control, however, due to the speed of obtaining information, their results can be used in the management of extraction, transportation and processing. These methods are indirect control methods: their calibration and tuning are based on chemical analysis data. However, the main advantage of geophysical methods of control in the conditions of iron ore deposits development is their promptness, which allows receiving timely and objective

information about the quality of raw materials at different stages of production.

The need to create a common quality management system in mining enterprises is dictated by the fact that iron ore has a heterogeneous distribution of useful component content in the deposit, mining and transportation equipment is not rhythmic, resulting in ore cargo flows of varying degrees of integration, and often significant by quantitative indicators, which is extremely negative for such indicators as the concentrate output, its cost and the losses in the tails. The purpose of the research presented in the article is to substantiate the possibility of using devices of geophysical operational quality control for iron-containing raw materials to create a common quality management system for mining and processing enterprises.

Research methods. The basic methods of mining and the following theories were used to substantiate the quality management system: control, interaction of gamma radiation with rocks, magnetic fields, mathematical statistics and synergetics. Probabilistic and statistical methods were also used, which were applied in the study of the interactions process of gamma-quanta with rocks, as well as in the study of the synergistic effect arising from the combination of operational quality control system with the system of mining and transport dispatching.

Research results and discussions. Modern mining enterprise is a complex system with a developed hierarchical structure, which main purpose is ore extraction. Based on this purpose, requirements for the quality of the raw materials are being formed. The distribution of the useful component content in the mine is often chaotic (Byzov, 1991). However, the final or total ore cargo must have a certain amount of useful component content that does not go beyond the range at any point of time, which is dictated by the requirements of the processing complex.

The mathematical model of control for the formation of the final or total ore flow can be represented in the form of requirements implemented through the quality management system of a mining enterprise. Functional diagram of the ore cargo flow formation is shown in Fig. 1. The total volume of ore is mathematically determined first of all by the capabilities of the ore-dressing complex, and it is a given value:

$$\sum_{}^{N} m_k = m_0, \qquad (1)$$

where m_0– the volume of ore specified at the input of OCP for processing, t

m_k – quantity of ore delivered by transport from the k-th mine, t;

In turn, according to the technological requirements, the useful component content in the ore after averaging should meet the set value, so there is an equality in quality, which relates these characteristics in the ore in the mines and ore flow:

$$\sum_{k=1}^{N} c_k m_k = m_0 \cdot c_0, \qquad (2)$$

where c_0– the specified ore content after averaging,

c_k – useful component content in the ore delivered from the *k*-th mine.

A priori requirement is also the limitation of the ore volumes delivered by transport from the mine in the form of local ore flows:

$$0 \le m_k \le \overline{m}_k, \quad (k = 1,2,\ldots, N) \qquad (3)$$

where m_k – the maximum possible volume of ore delivered by transport from the *k*-th mine, t.

Formulas (1), (2) and (3) represent a mathematical model that is a part of the mining management system of a mining enterprise.

Another formulation of this model is possible, in which condition (2) is replaced by the limitation in the amplitude of oscillations for the useful component content in the ore after averaging, that is, after the formation of the ore flow:

$$c_{\min} \cdot m_0 \le \sum_{k=1}^{N} c_k m_k \le c_{\max} \cdot m_0, \qquad (4)$$

where c_{min}, c_{max} – minimum and maximum allowable content indices of ore cargo useful component, that is, OCP requirements range limits.

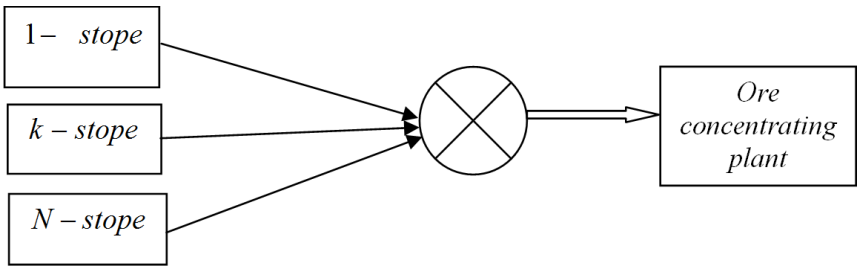

Fig. 1. Functional diagram for the ore cargo formation

It is known that the management process is a specially organized influence on the object of management in order to obtain the desired result. A device or means producing a control signal to a control object is a control device or control means (Meskon, 1998).

In the MCC quality management system for iron-containing raw materials, such a device is a central server, and the object of control is the process of ore flow formation with the values of the useful component content specified within certain limits.

The control signal (command) produced by the control device (server) is transmitted through the communication channels to the production and transportation facilities, thereby influencing the control object. The set of control object, control device (control mean), information means and controls forms the control system (Meskon, 1998).

In Fig. 2 shows a general scheme for collecting and transmitting prompt information on the useful component content in mining and processing enterprises.

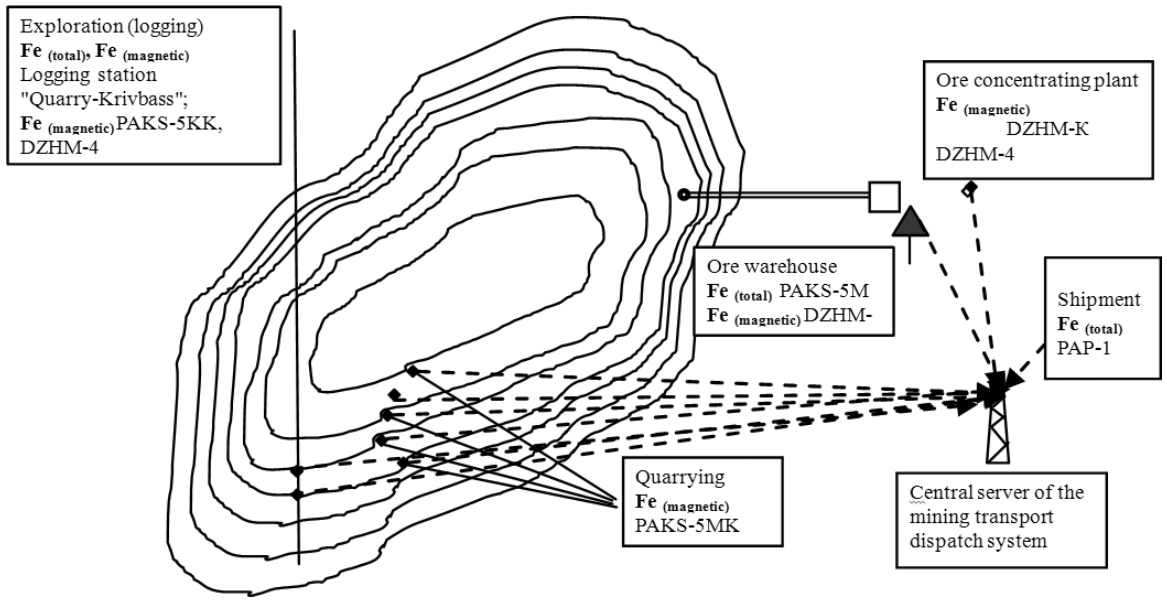

Fig. 2. General scheme of collection and transmission of operational information on the useful component content in the mining and processing enterprises

The quality management of iron-containing raw materials is based on the synergy of control and management systems, consists of quality control systems in mines and transport communications, operational information channels and a central server, which analyzes the situation using the special software, forming a controlling influence in the form of commands to mining and transport means (Azarian, Joukov, 2016). Functional diagram of quality management for iron-containing raw materials is shown in Fig. 3

The functioning of the quality management system is based on the principle applying averaging as a management method based on reliable and timely information about the useful component content in the mines, ore depots and the final cargo flow, which is obtained through operational control.

In the first stage of quality control logging (additional exploration) of the explosive unit is carried out, which is carried out after the completion of drilling, but before the wells are filled. Logging is a detailed study of the section of the well using the descent-lifting of geophysical probe in it. Gamma-gamma logging (GGL) refers to nuclear methods of geophysical exploration. The essence of the method is that the rock is irradiated with a source of gamma radiation, after which there is a secondary (scattered) radiation, which allows more efficient study for the parameters of the rock (Artsybashev, Ivanyukovich, 1975). According to the physical basis of the gamma-gamma method, the magnitude of the integrated flux intensity of scattered gamma radiation, in addition to the effective atomic number, is affected by the density of the investigated medium (ρ). If this parameter does not correlate with the useful component content, due to its change, there will be significant distortions in the final results (Morkun, Azarian, & Azarian, 2015). It has been found that Kryvbas iron ores are characterized by a high correlation between ρ and Fe_{tot}, which is a favorable precondition for the use of

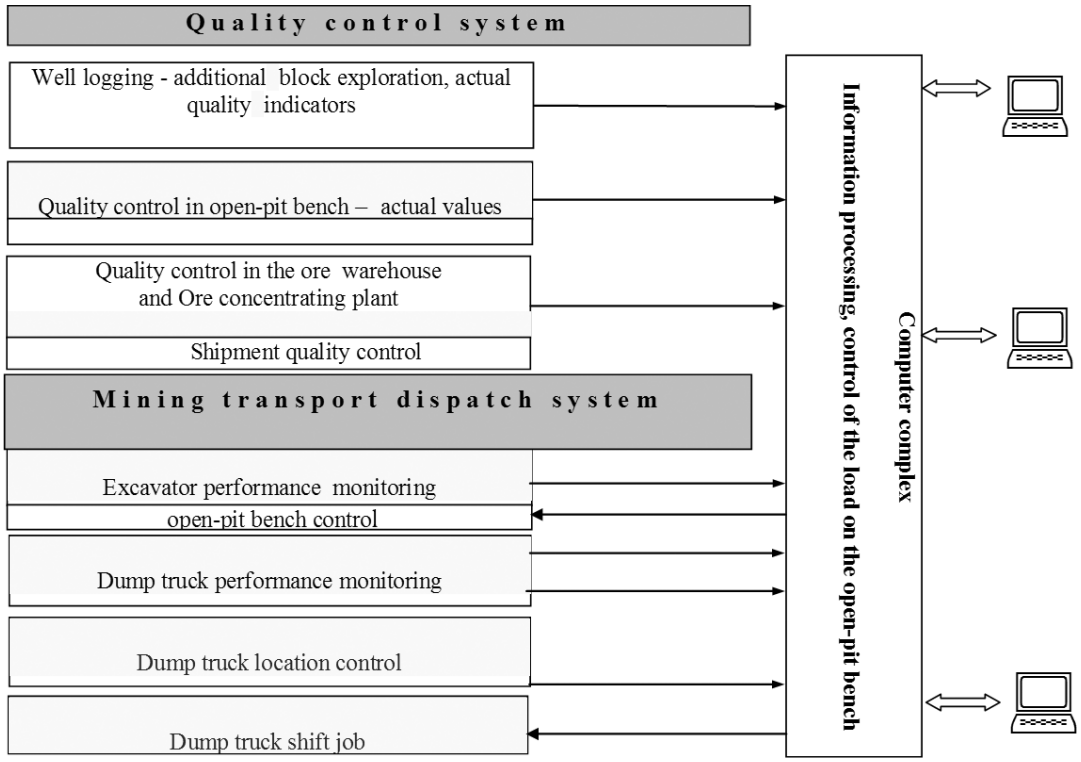

Fig. 3. Functional diagram of quality management for iron-containing raw materials

gamma-gamma logging to determine the total iron in the solid mass. (Morkun, Azarian, & Azarian, 2015)

A significant factor affecting the accuracy of Fe_{tot} determination using gamma-gamma method is the natural humidity of the rocks. According to the statistics, the rich ores of the Kryvyi Rih iron-producing area contain up to 12% H_2O, while the humidity of the main solid ore varieties ranging from 2 to 8% (Azarian, Azarian, & Trachuk, 2016).

Determination of the useful component content using gamma-gamma method is possible not only in the form of logging, but also in piles of blasted rock mass, as well as in laboratory conditions, on pre-prepared samples (crushed and with a particular level of humidity). In the course of the research, it was found that the intensity of the gamma radiation detected by a receiver depends essentially on the magnitude of the distance between the surface of the ore mass layer and the radiation receiver. The nature of the dependence for the intensity on the distance is largely determined by the design parameters of the sensor: the area of the sensitive surface of the radiation receiver, the diameter of the collimation window of the collimator of the radiation source, the relative location of the receiver and source. Based on the fact that the thickness of the ore layer can vary from 0 to 15 cm, with the stationary placement of the device sensor above the conveyor, the air gap between the radiation receiver and the surface of the ore layer will change within the same limits. This process was modeled, and as a result, the intensity of the scattered gamma radiation recorded by the receiver at different values of the air gap was obtained. The analytical dependence was obtained and plotted using these results (Fig. 4) (Azarian, Azarian, & Cherkasov, 2015).

The process simulation used an ore sample with an iron content of 58.39%, which is closest to its average value in the ores subject to control. The analysis of the obtained dependence shows that only within the range H=5±1.5 cm, with some approximation, it can be assumed that the intensity of the registered gamma radiation does not depend on the magnitude of the air gap. In other words, when changing the thickness of the layer within 3 cm, the error made in measuring the iron content does not exceed ±1%. At higher values of change in the air gap, this error reaches the intensity of N≈500 imp/cm or ΔN≈12%/cm, which is equivalent to an error in the iron content of about ≈7–8% (Azarian, Azarian, & Trachuk, 2014).

Equally important is the control of the iron content associated with magnetite, which is also carried out in a solid mass (logging), in the heaps of destroyed rock mass and in laboratory conditions. Without quality control of ferrous quartzites, it is impossible to fully operate the MCC quality management system, given that the ore is mainly enriched by magnetic methods. The study of the factors affecting the quality control of ferrous quartzite begins with the study of the magnetic susceptibility of samples. It was found that the specific magnetic susceptibility of magnetite

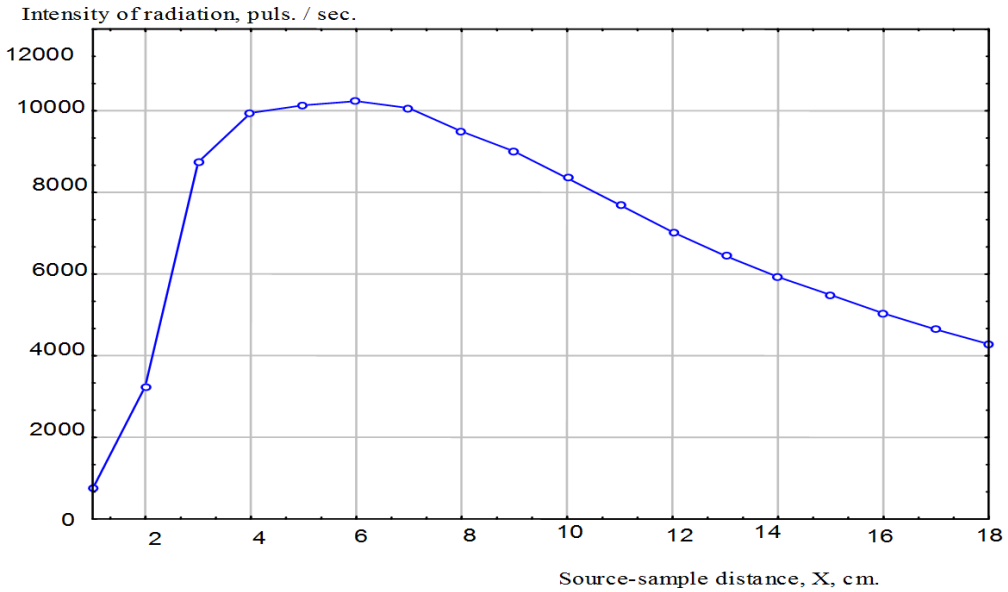

Fig. 4. The dependence of the intensity of the scattered gamma radiation on the distance between the source and the rock mass

(Fe_3O_4) can fluctuate within $(0.63–1.2)\times10^{-3}$ m^3/kg due to the presence of isomorphic impurities of copper, zinc, manganese and other metals (Azarian, Azarian, & Cherkasov, 2010). The shape, structure and size of magnetite grains have a significant influence on the measurement, which affects its magnetic susceptibility and coercive force. In addition, changes in the texture and structure of the ores (magnetite grains in non-magnetic cement or non-magnetic grains in magnetite cement) also affect the magnetic susceptibility of the rock mass. The measurement accuracy is influenced by the change in the conductivity of the magnetite, which ranges from 10^{-1}–10^{-2} cm/m, the conductivity of non-magnetic metals and the humidity of the controlled sample (Dryga, 2013).

In solenoid type coil, a homogeneous magnetic field can be created only at the ratio of the length and diameter $l/d \geq 50$. The change of inductance occurs when the magnetite is introduced into the sensor cavity, or when the probe is placed in a solid mass of ferruginous quartzites (Dryga, Shvydky, 2008). When measuring the qualitative characteristics of ferruginous quartzites, it is imperative to adjust the ambient temperature and to provide a constant current value through the coil of the inductive sensor (Gzogyan, 2013) to ensure the required accuracy level.

The main dependencies reflecting the relationship of resistivity to electric field voltage and ambient temperature are shown in Fig. 5; the dependence of

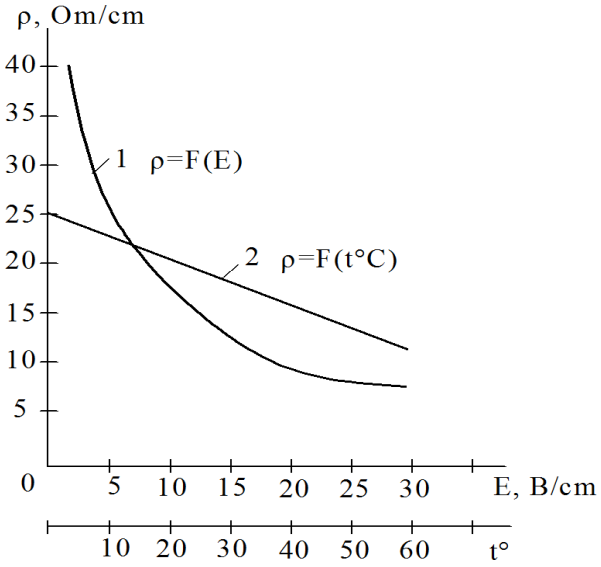

Fig. 5. Dependence of iron ores specific resistance: 1 – from the electric field voltage; 2 – from the temperature

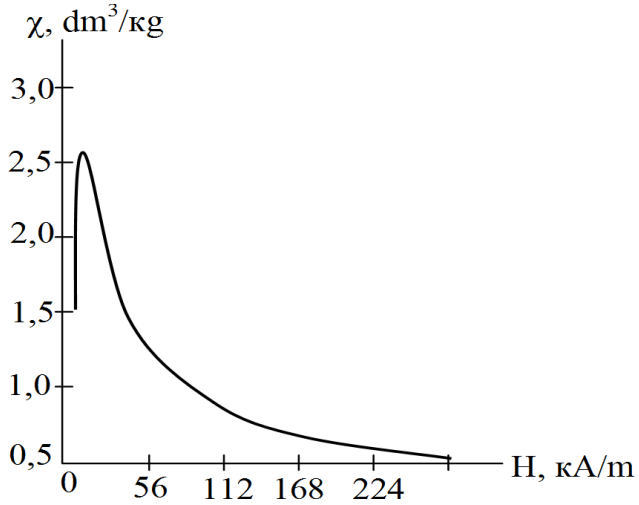

Fig. 6. Dependence of specific magnetic susceptibility χ of the ore on external field magnetization *H*

the specific magnetic susceptibility χ of the ore on the external magnetization of the field *H* – in Fig. 6, the frequency dependence of the specific resistance of magnetite quartzites – Fig. 7. These dependencies were obtained during studies of ferrous quartzites of the Kryvyi Rih iron-producing area (Azarian, Azarian, & Cherkasov, 2013).

Rudpromheofizyka LLC and implemented in the production: PAKS-5 M, PAKS-5 MK, PAKS-5 KK, Quarry-Kryvbas logging station, sensors for magnetic iron DZHM-4 and DZHM-3 M1, powder samples analyzer PAP-1, as well as of continuous quality control systems of total iron on the NAKS-PK conveyor and magnetic iron control – DZHM-K.

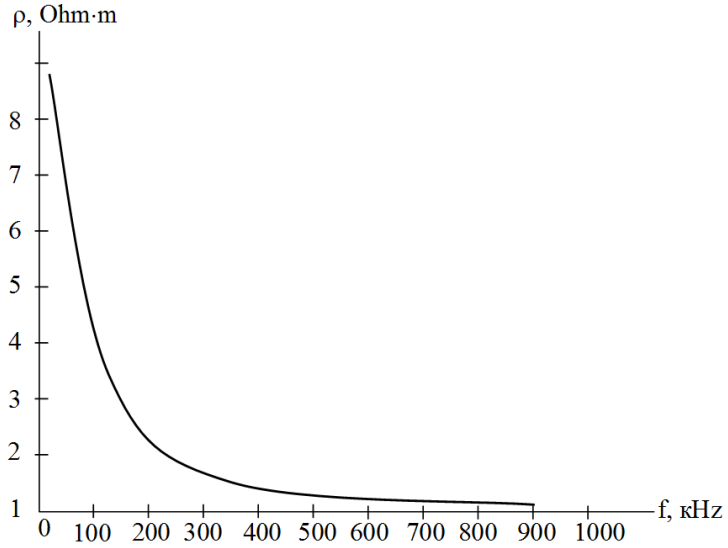

Fig. 7. Frequency dependence of the magnetite quartzites specific resistance

The accuracy of raw material quality measurements for ferruginous quartzites is influenced by the reliability of the correlation between the measured magnetic susceptibility and the magnetite content, as well as the reliability of this relation within individual sections of the deposit (Dryga, 2013).

Hardware of the operational quality control for the content of general and magnetic iron can be geophysical devices, developed by the staff of the problem-branch laboratory of the State Technical University of Kryvyi Rih together with

Well logging is carried out by the Quarry-Kryvbas logging station (Fig. 8). The multifunctional mobile station is used for simultaneous operational control (logging) of the magnetic and total iron content using the method of testing the rock mass in wells up to 100 m deep (Azarian, Vasilenko, Borodavkin, & Boyko, 2001). The principle of action is based on the registration of the secondary (reflected) gamma radiation from the walls of the well and simultaneous control for the change of the magnetic field, which occurs in the solid mass as the probe moves. The

Fig. 8. Quarry-Kryvbas logging station

results of measurements of the useful component content are displayed (as a percentage) on the digital scoreboard of the PAKS radiometer or on the laptop screen. Information on the screen is formed as a table or graph for the dynamics of changes in the useful component content (Azarian, Azarian, Gritsenko, Dryga, & Miroshnik, 2018). The logging step is variable, it is possible to choose from 0.1 to 1.0 m depending on the conditions.

The Quarry-Kryvbas logging station provides:

- the exact connection of the well depth and the corresponding value of the useful component content;
- logging for watered wells;
- automatic data recording (date, current time, well depth, total and magnetic iron content values).

The Quarry-Kryvbas logging station controls the useful component content in the range of 1 ÷ 75%, with an error of ±2.0% for the total iron and ±1.0% for the magnetic iron. Power is supplied from the 12 V on-board network; continuous operation time is not less than 10 hours. Well test after roller-bit drilling in the mines of the Mining Department of PJSC "ArcelorMittal Kryvyi Rih", PJSC "Pivdennyi MCC" and PJSC "Ukrmekhanobr MCC" is being conducted today using the Quarry-Kryvbas logging station.

Logging for magnetic iron can also be carried out separately using a PAKS-5 KK portable device consisting of a measuring console and a log device (Fig. 9).

The criterion for determining the magnetic iron content is the magnetic susceptibility magnitude of the rocks (Azarian, Tsybulevsky, Sharov, Dryga, & Lisovyj, 2008). The device is paired with the PAKS-5. The principle of the device operation is based on

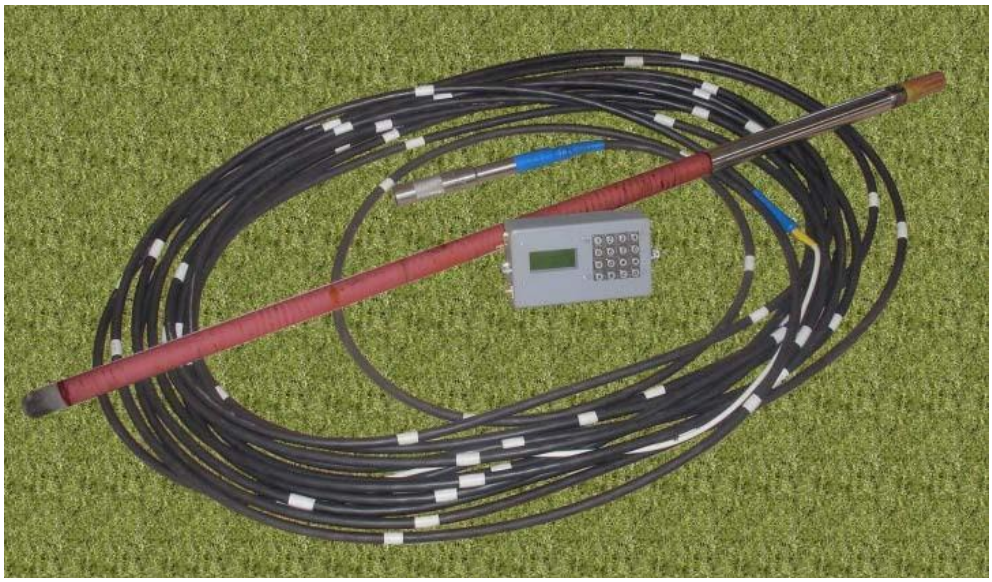

Fig. 9. PAKS-5 KK portable device

the registration of changes in the artificially created magnetic field when moving its probe in ferrous quartzites. The measurement results of the useful component content are displayed (as a percentage) on a digital scoreboard and are automatically stored in the device memory. Logging data allows to construct a distribution model for the useful component content in the block prepared for blasting by explosives, and thus to predict the dynamics of quality change in the further exploitation of the mine. Measurement error is ±1.0%. The PAKS-5 KK portable device is used in the quarries of PJSC "Pivdennyi MCC", PJSC "Inhulets MCC" and in the quarries of the Mining Department of PJSC "ArcelorMittal Kryvyi Rih".

After blasting, the ore mas is mixed, which predetermines the technological control for the iron content related to magnetite in the mine using the PAKS-5 MK device (Azarian, Dryga, Tsybulevsky, & Krivrenko, 2004) (Fig. 10). The principle of its operation is similar to PAKS-5 KK, the index of the useful component content is not investigated in the wells, but on the surface of the mine, in the destroyed rock mass. The depth of the information layer is 0.5 m. The data obtained using PAKS-5 MK is used for current compliance control of actual quality indicators with the calculated data used in the solution of the mixture calculation problem for determining the variable task. The measurement error is ±1.5%.

The PAKS-5 MK portable device is implemented and is successfully operated at PJSC "Pivdennyi MCC", PJSC "Central MCC", PJSC "Inhulets MCC", PJSC "Poltava MCC" and the quarries of the Mining Department of PJSC "ArcelorMittal Kryvyi Rih".

A microprocessor-based NAKS-PK quality and weight control system (Azarian, Byzov, 1993) can be used to control the total iron content in the ore flow on the conveyor ore transportation. The NAKS-PK system is designed for the operational control of total iron content and the mass of mineral raw material with an accuracy of ±1.5%. The operation of NAKS-PK is based on the principle of a local information and measurement network with a central device (server), which uses a computer with special software, and peripheral measurement units (communication terminal) (Fig. 11).

Smart NAKS-PK transmitters are used as communication terminal. Communication of the server with communication terminals is carried out on a two-wire protected physical line using the main line principle. Communication terminals (smart transmitters) NAKS-PK are microprocessor devices providing control for the technological parameters of raw materials and the information exchange with the server system. The principle of their operation is based on the registration of the flow reflected from the surface of the ore mass moving along the conveyor, using the center-shifted or lateral geometry of the relative location of the ionizing radiation sources and detectors. The recorded intensity indicator is converted into the value of the useful component content over the set measurement period. The NAKS-PK control system was introduced and operates in the conditions of the surface complex of PJSC "KZRK", PJSC "SUKHA BALKA" and PJSC "ArcelorMittal Kryvyi Rih" at the entrance to the crushing and sizing plant.

Fig. 10. PAKS-5 MK portable device

Fig. 11. Peripheral measurement unit of the NAKS-PK system

Quality control at the run-of-mines and during the shipment allows consumers to determine the total iron content (using a PAP-1 powder analyzer) and magnetite-related iron (using a magnetic DZHM-4 iron sensor) discretely, with higher accuracy.

A powder samples analyzer is designed to determine total iron content in ferrous metal samples provides accurate measurements at the level of chemical analysis (Fig. 12) (Azarian, Azarian, Gritsenko, Dryga, & Miroshnik, 2017). The measurement time is up to 60 seconds. It should be emphasized that the cost of one analysis performed using PAP-1 is two orders of magnitude lower than using the chemical analysis.

The principle of operation of the powder analyzer is similar to PAKS-5 M, but it has an improved geometry of the measurement area, as well as preliminary grinding of the measured material is performed, which significantly improved the accuracy of control. PAP-1 was applied at the open quarry of PJSC "Ukrmekhanobr MCC", PJSC "Central MCC". From 2018 a new modification of the powder samples analyzer of PAP-2 is applied on the open quarries of PJSC "ArcelorMittal Kryvyi Rih".

The magnetic iron sensor DZHM-4 is intended for the express determination of the mass fraction of magnetite in iron ores (Fig. 13). DZHM-4 enables long-term storage of the obtained results in the database and their processing (the average values determination for the useful component content, graphical representation of the content distribution over time and other data processing operations). The DZHM-4 consists of a magnetic susceptibility sensor, a sample weight sensor, an electronic circuit

Fig. 12. Powder samples analyzer PAP-1

Fig. 13. Magnetic iron sensor DZHM-4

structurally assembled as a monoblock, and a measuring console. The measurement error is ±1.0%.

The magnetic iron sensor DZHM-4 is operated at PJSC "Inhulets MCC", PJSC "Pivdennyi MCC" and the quarries of the Mining Department of PJSC "ArcelorMittal Kryvyi Rih".

At the entrance of the processing plant, before grinding, the magnetic iron content in the ore flow on the conveyor lines is controlled by the DZHM-K

Fig. 14. DZHM-K continuous control system

continuous monitoring system (Fig. 14) (Azarian, Azarian, Dryga, Lisovyj, Tsybulevsky, Sharov, & Shvydky, 2008).

The DZHM-K system provides real-time magnetite content determination, enables long-term storage of the obtained results in the database and their processing (the average values determination for the useful component content, graphical representation of the content distribution over time and other data processing operations). The principle of operation is based on the registration of the signal change from the measuring coil relative to the magnetic field artificially created by induction coil in the measuring area. The DZHM-K system consists of magnetic susceptibility sensors, transducers, electronic boards, ore layer height sensors and central server height and operates on the OCP-1 sections of the Mining Department of PJSC "ArcelorMittal Kryvyi Rih" since 2007. The measurement accuracy is ±1.5%.

Control for the total iron content is carried out by a PAKS-5 M integrated device (Fig. 15). This device has a precision measurement of total iron content lower than the PAP-1 (ПАП-1) powder analyzer (±1.5%), however, it requires less sample preparation and can be used both in laboratories and in main loading and transportation drifts and run-of-mines (Azarian, Azarian, & Trachuk, 2012).

Comparison of the of measurements accuracy of devices and systems for operational quality control, developed in the problem-branch laboratory of Kryvyi Rih National University was carried out using the data of the standard chemical analysis of ore, which

Fig. 15. Integrated device for controlling the total iron content PAKS-5 M

was performed by the State Inspectorate for Quality "Pivdenruda", as well as chemical laboratories of the Mining Department of PJSC "ArcelorMittal Kryvyi Rih", PJSC "Inhulets MCC" and PJSC "Pivdennyi MCC".

Conclusions. Theoretical works on the control and quality management for iron-containing raw materials and the practical development of the scientific team of the problem-branch laboratory of the Kryvyi Rih National University created objective prerequisites for substantiating the quality management system of mining and processing plants. Developed and implemented in the production of operational control devices cover all the basic stages of mining, provide timely and reliable information on the status and dynamics of the changes in the useful component content and to perform effective quality management on its basis and to generate MCC ore cargo traffic according to the requirements of the concentration complex, which gives an opportunity to increase competitiveness and the profit of these enterprises.

Acknowledgement. We thank the Director General of PJSC "KZRK" F.I. Karamanits and Deputy Director General for Mining of PJSC "ArcelorMittal Kryvyi Rih V.I. Tesliuk for facilitating the introduction of operational quality control means for iron-containing raw materials into mining.

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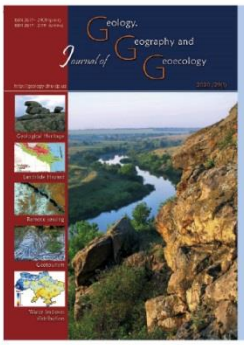

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Geological and geomorphological objects of the Ukrainian Carpathians' Beskid Mountains and their tourist attractiveness

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Abstract. The article explores the geological and geomorphological objects of the Beskidy Ukrainian Carpathians for the further creation of geo-tourist routes. Geo-tourist areas combining several geological and geomorphological objects and establishments of tourist infrastructure are highlighted. Among those objects are Urytskyi, Yamelnytskyi, Skolivskyi, Syniovydnenskyi, Kliuch-Kamianka, Bubnyskyi. Geo-attractions of each area are described in detail: the morphological features of the objects, the structure of rocks composing them, the nature of the rocky surface, as well as the historical and cultural events associated with the objects. The estimation of the tourist attractiveness of geological and geomorphological objects within Beskid region of Ukrainian Carpathians is performed. For this purpose, an assessment methodology has been developed. The methodology is based on the following indicators: the number of geological and geomorphological objects, maximum heights, picturesque, spectacular (objects as an overview of the terrain), accessibility, scientific, cognitive, historical and cultural value, tourist infrastructure, popularity (the number of web pages that highlight search results). The attractive geo-objects' attendance of each district by tourists has been taken into account. It is established that the geological and geomorphological objects of the Urytskyi tourist area of Beskyds are of a greatest attractiveness for the geo-tourism' development (the general indicator of attractiveness is 8.4 points). It has a high historical and cultural value and the highest attendance. The second one is the Bubnyskyi geo-tourist area (7.2 points), where the largest amount of the highest and most spectacular rocks is located. In the third area of a great attractiveness for the development of geo-tourism is Kliuch-Kamianka (6.9 points), within which there is the larger number of various objects than in other regions and the highest online popularity and attendance. The attractiveness of the Skolivskyi geo-tourist district is estimated at 6.6 points. It has seven geo-attractions and is best equipped by the facilities of tourist infrastructure. The attractiveness of the Syniovydnenskyi geo-tourist area's objects is 5.6 points. There are eight geo-attractions here, including outcrops of high scientific and cognitive value. The attractiveness of the Yamelnytskyi region is 4.0 points. There are many different morphological types of rocks here, but the tourist infrastructure is poorly developed. On the basis of the performed estimation of attractiveness, new geo-tourist hiking, bus and motor-cycle routes, including the described geological and geomorphological attractions of the above-mentioned geo-cultural regions of the Beskids, were proposed.

Key words: geological and geomorphological objects, geo-tourism, geo-attraction, tourist attractiveness, Ukrainian Carpathians' Beskid Mountains.

Геолого-геоморфологічні об'єкти Бескидів Українських Карпат та їхня туристична привабливість

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Анотація. У статті досліджено геологічні та геоморфологічні об'єкти Бескидів Українських Карпат з метою організації геотуристичних маршрутів. Виділено геотуристичні райони, які об'єднують кілька геолого-геоморфологічних об'єктів та заклади туристичної інфраструктури. Зокрема, Урицький, Ямельницький, Сколівський, Синьовидненський, Ключа – Кам'янки, Бубниський. Детально описано геоатракції кожного з цих районів: морфологічні особливості, склад та структуру порід, якими складені об'єкти, присутність знаків на поверхні порід, а також зазначено історико-культурні події, пов'язані з об'єктом. Виконано оцінку туристичної привабливості геолого-геоморфологічних об'єктів. Для цього розроблено методику оцінки, яка

базувалась на таких показниках: кількість геолого-геоморфологічних об'єктів, максимальні висоти, мальовничість, видимість (об'єкти як оглядова точка місцевості), доступність, науково-пізнавальна та історико-культурна цінність, туристична інфраструктура, популярність і відвідуваність туристами. Встановлено, що найбільшу привабливість для розвитку геотуризму у Бескидах мають геолого-геоморфологічні об'єкти Урицького туристичного району, який має також високу історику-культурну цінність та високу відвідуваність. Друге місце належить Бубниському геотуристичному району, де знаходиться найбільша кількість найвищих і наймальовничіших скель. Район Ключа-Кам'янки на третьому місці, в межах якого спостерігається найбільша кількість різнотипних об'єктів, найвища інтернет-популярність і відвідуваність. Привабливість Сколівського геотуристичного району вище середньої. Він налічує сім геоатракцій і найкраще забезпечений закладами туристичної інфраструктури. Привабливість об'єктів Синьовидненського геотуристичного району невисока. Тут налічується вісім геоатракцій, серед яких є відслонення, які мають високу науково-пізнавальну цінність. Привабливість Ямельницького району низька, оскільки він маловідомий, тут слабко розвинена туристична інфраструктура, проте багато морфологічних типів скель. На основі виконаної оцінки привабливості, запропоновано нові геотуристичні пішохідні, автобусні і мотовеломаршрути, які включають описані геолого-геоморфологічні атракції у виділених геотуристичних районах Бескидів.

Ключові слова: геолого-геоморфологічні об'єкти, геотуризм, геоатракції, туристична привабливість, Бескиди Українських Карпат.

Introduction. Year by year tourists are becoming more interested in geological and geomorphological sites as an alternative to historical and cultural memorials. Geo-tourism is evolving as a kind of travel connected with sightseeing and investigation of inanimate objects – (Chen, 2015; Cutler, 2010; Dowling, 2011; Hose, 2005; Khomenko, 2018; Newsome, 2005; Ollier, 2012). The main attractions for tourists on these trips are interesting geological and geomorphological sites in combination with the surrounding terrain, reflecting the history of nature and society in a particular area named geosites. The term "geosite" was formed in 1995 as a result of the collaboration of the European Association for the Conservation of Geological Heritage (proGEO) with the International Union of Geological Sciences (IUGS) and UNESCO (Migoń, 2017; Necheş, 2016; Reynard, 2004). In Europe, geosites are being protected; they are included in the system of geoparks, which have been integrated into the Global Network since 2004. Since 2015 to achieve significant progress, environmental education and sustainable local development, they have come under the auspices of UNESCO (Gordon, 2005; Ramsay, 2017). The term "geomorphosites" was introduced (Carton, 2005; Coratza, 2005; Reynard, 2009a) to focus on the conservation of geomorphological sites of ecological, aesthetic, cultural and economic value.

The peculiarities of geoparks' creation and the geo-tourist objects were studied in the works of G. Denysyk, Yu.Zinko, V. Manyuk, O. Shevchuk (Denysyk, 2014; Kravchuk 2012; Manyuk, 2007; Manyuk, 2016; Shevchuk, 2011; Zinko, 2008) etc. However, there are still many geosites requiring detailed investigation and integration into geo-tourist routes.

Ukrainian Carpathians are distinguished by the richness and variety of geological and geomorphological sites (about one hundred ones). This provides the basis for laying out diversified geo-tourist routes for acquaintance with geological, geomorphological, hydrological and complex attractions. One of them is the geo-tourist route "Geo-Carpathians", grounded within the framework of the "International Program of Cross-Border Cooperation Poland - Belarus – Ukraine" and within which scientists I. Bubniak, A. Soliecki and Y. Zinko identified a number of geosites (Bubnjak, 2013; Bubnjak, 2014). One- and two-day tours to the Carpathians, developed by tourism firms, including visits to such geo-attractions as outcrops, rocks, caves, waterfalls, are popular among tourists. However, detailed studies of geological-geomorphological formations in Beskidy as the region with the various geo-attractions, good transport accessibility and developed tourist infrastructure remain relevant. Within this region, we have identified geo-tourist areas, thoroughly researched the morphological indicators of geological-geomorphological sites in them, assessed their tourist attractiveness, and proposed new tourist routes.

According to O. Muzychenko-Kozlovska, "Tourist-attractive territory is a locality that has the potential of tourist resources, modern well-developed material and technical tourism base and accessible and sufficient for the tourist information about this locality, which would meet the needs of tourists and ensure the achievement of maximum social and economic effect of tourism industry development within it" (Muzychenko-Kozlovska, 2000). In assessing the tourist attractiveness of the territory, the requests, the reasons, the tastes and the degree of the different potential tourists' needs satisfaction are taken into account. When selecting indicators for assessment, the functional purpose and importance of each factor, as well as its importance in the overall evaluation should be taken into account. Several types of assessment of natural tourist resources have been developed, in particular: medical and biological (influence of natural factors on the human body); technological (according

to the functional suitability of resources for a certain type of tourism and recreational activity); psychological and aesthetic (emotional impact of the natural landscape on the person) (Fomenko, 2001). Some scientists understand the attractiveness of the territory as a positive image of the region and take into account the following indicators: natural and climatic conditions for recreation and recovery; social stability and security; transport accessibility; economic attractiveness; the spiritual appeal of religious pilgrimage centers; attraction of historical monuments; cultural and educational appeal (Omush, 2001; Pereira, 2010; Pralong, 2005). Some foreign researchers, considering the tourist attractiveness of tourist areas, take into account the following indicators: external and internal flows, the number of nights spent in local accommodation facilities and the average length of visitors' staying (Bujdosó, 2015). UNWTO assesses the tourist attractiveness of a territory on the basis of statistics on tourist flows, tourist expenditures and tourism profits.

The purpose of our research is to evaluate the attractiveness of geological and geomorphological sites in the selected geo-tourist areas of the Ukrainian Carpathians Beskids for geo-tourist trips.

Materials and methods of research. Data on geological and geomorphological attractions have been collected through our own field research over several years. Various geo-tourist objects of the Ukrainian Carpathians Beskids were studied: outcrops, rocks, waterfalls, caves. A number of research methods were applied. Among them are morphological, lithogenetic, structural and geomorphological methods, as well as the method of point tourist attractiveness evaluation, statistical method, complex approach and systematic analysis. Morphological methods are used to determine the morphometric indicators of objects: the height of the rocks, waterfalls ledges, rock outcrops etc. Lithogenetic methods have been used in investigation the peculiarities of the rocks' composition and structure, their influence on the formation of typical objects' morphological features. Structural and geomorphological methods have been used to analyze the tectonic fracture of rocks and their influence on the rocks morphology and weathering.

To assess the attractiveness of geo-tourist sites different methods of foreign and domestic scientists were analyzed (Kubalíková, 2013; Rocha, 2014; Reynard, 2009b; Rybár P, 2010; Serrano, 2005; Štrba, 2014). Foreign publications on the assessment of the basic and additional values of geographic heritage much attention paid to the use of quantitative approach (point, percentage). An example of such approach is the technique of Geosite Assessment Model (GAM) developed and tested by a number of scientists (Vujičić, 2011; Tomić, 2014). This technique consists in a point assessing of geosites (from 0 to 1) considering two criteria: basic (scientific, aesthetic and protective) and additional (functional, tourist) values.

Other assessment criteria, including criteria of internal value, criteria of potential usage and potential threat, and criteria of environmental protection, underpin the methodology of the Spanish geomorphologists V.M. Bruschi and A. Cendrero, which, in addition to the potential assessment, contained the ways of results verifying (Cendrero, 1999; Bruschi, 2005, 2009). These techniques were used by Yu. Zinko and M. Ivanyk to evaluate the geo-tourist and geo-conservation potential of the Dniester Canyon travertine rocks (Zinko, 2016).

We evaluated the tourist attractiveness of geological and geomorphological sites in the selected Beskids geo-tourist areas, taking into account most of the described methods criteria. Our research presents two aspects. One of them consist in an assessment of the existing geological and geomorphological sites attractiveness to which the tourist flows are directed. The other one is the evaluation of the area attractiveness as a tourist center. Ten indicators have been identified and criteria for their evaluation have been developed (table 1).

1. The indicator "Number of geological and geomorphological sites" reflects the number of different formations: geological (outcrops), geomorphological (rocks, peaks, caves), hydrological (lakes), complex (waterfalls) in the geo-tourist areas we have selected. We took into account both formations of different types (geological, geomorphological) and the similar (only geomorphological) ones. One deflection, a group of rocks, a single standing high rock (more than 12 m), a waterfall, and a mountain top were considered as a separate element of the population.
2. The maximum height of objects was determined by measuring with metering tapes, according to GPS data, by climbers, and sometimes by literary sources containing geodetic measurements.
3. "The picturesqueness (aesthetics, landscape) of the object" indicator (Grodzynska, 2014; Klapchuk, 2013). Our studies have taken into account the visual image of an object, its beauty, aesthetic perception, variety, contrast. We appreciated the aesthetics of space with this object.
4. The "Visibility (object as a point of view)" indicator reveals the ability to view the landscape

Table 1. Indicators of tourist attractiveness of the geological and geomorphological sites of the Ukrainian Carpathians Beskids

No	Indicators	Evaluation criteria	Points
1.	Number of geological and geomorphological sites	- large: 11 or more, - average: 6-10 objects, - small: 1-5 objects;	0.8–1 0.4–0.7 0–0.3
2.	The maximum height of objects in a group	- large: 20 m and above, - average: 10-20 m, - small: up to 10 m high;	0.8–1 0.4–0.7 0–0.3
3.	The picturesqueness (aesthetics, landscape) of the object	- high, - average, - low;	0.8–1 0.4–0.7 0–0.3
4.	Visibility (object as a point of view)	- the landscape is traced, - the landscape is closed;	0.6–1 0–0.5
5.	Accessibility (the difficulty of overcoming a route to an object)	- good, - bad;	0.6–1 0–0.5
6.	The scientific value of the object	- significant, - insignificant;	0.6–1 0–0.5
7.	The historical and cultural value of the object	- has value, - does not have;	0.6–1 0–0.5
8.	Tourist infrastructure of the area	- well developed, - average, - poorly developed;	0.8–1 0.4–0.7 0–0.3
9.	Popularity (number of internet search results)	- high (over 100.000 search results), - average (2-100 thousand), - low (less than 2 thousand);	0.8–1 0.4–0.7 0–0.3
10.	Attendance	- high (more than 700 people in one day), - average (100 to 700 people), - low (less than 100 people).	0.8–1 0.4–0.7 0–0.3

from the height of the object, the openness or closeness of the terrain for observation.

5. The "Accessibility (difficulty of overcoming a route to an object)" indicator shows the complexity of the transportation or pedestrian overcoming of the route to the object, the closeness of the object to the solid roads.
6. In determining the "Scientific and cognitive value" indicator, we took into account the multifaceted presentation of the territory's tectonic regime, the history of relief development, sedimentation or lithological features, the ways of its shape evolution.
7. The historical and cultural value of the object was determined by its role in the history and culture of the region, by information about the historical events associated with this geological/ geomorphological object.
8. The tourist infrastructure was evaluated by the number of hospitality establishments in the selected geo-tourist areas.
9. The popularity was determined by the number of web pages that covered the search results for the name of a particular attraction on the Google search engine.
10. Attendance was ascertained according to the Tustan Historical and Cultural Reserve (for the Urytskyi geo-tourist area) and the Skole Beskydy National Park (for the Kliuch-Kamianka geo-tourist area), by the number of residents in accommodation establishments on the selected day off (for Skolivskyi and Syniovydnenskyi geo-tourist area), own field observations and student studies (Bubnyskyi, Yamelnytskyi geo-tourist area). We took into account averages of a few warm weekends of spring-summer-autumn seasons.

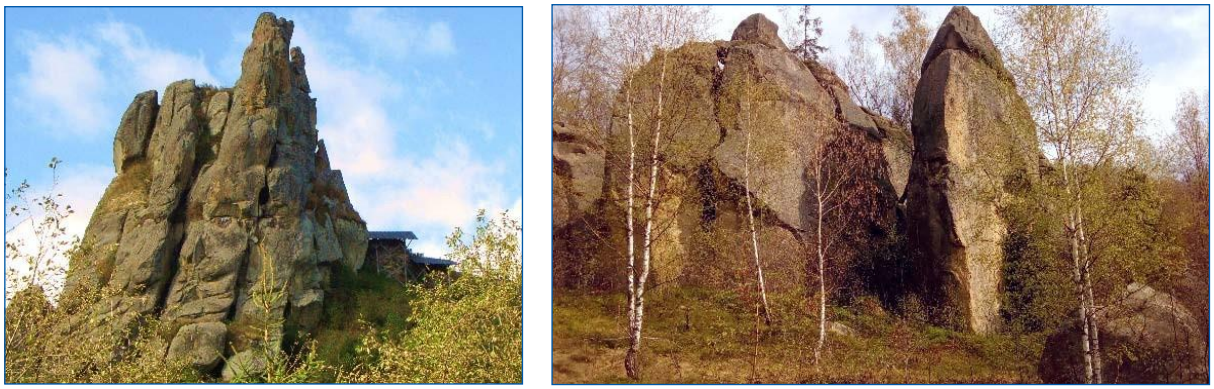
Research results. To evaluate the tourist attractions within the Beskyd region, we have identified geo-tourist areas with several geological and geomorphological sites and nearby tourist facilities. These are Urytskyi, Yamelnytskyi, Skolivskyi, Syniovydnenskyi, Kliuch-Kamianka, Bubnyskyi geo-tourist areas.

The main attraction of the *Urytskyi geo-tourist area* is the rocky outliers including three groups of rocks: Kamin (Stone) or the Tustanskyi Kamin (Tustan Stone), Hostryi Kamin (Sharp Stone), the Zholob (Gutter) and the single rocks Mala (Small) Skelia, Gulka, Krest (Cross) and Bezymianna (Nameless) (Fig. 1a). The most well-known is Tustanskyi Kamin, on which there was Detinets (ancient city-fort) of medieval fortress Tustan (IX-XVI centuries). According

to the scheme of M. Rozko, who carried out detailed measurements and reconstruction of this fortress at the end of the twentieth century, this rock rises above the adjacent valley up to 37 m (Rozko, 1996). The rock is

mines the attractiveness of Uritski rocks for tourists.

Yamelnytskyi geo-tourist area is still poorly known among ordinary tourists. It is best known for rock climbers. The complex consists of five groups



a b

Fig. 1. The top of the Tustsnskyi Kamin rock of in Urytskyi (*a*) and the wall rocks-outliers in the Yamelnytskyi geo-tourist area (*b*)

formed by thick sandstone appearing on the upper surface in the form of the layer triangles. The thinner and longer north-eastern part of the layer is called Velyke Krylo (The Big Wing). The layer from the southwest is more powerful, up to 50 m thick, with the highest peak, and is called the Small Wing. There is a 25 m wide decrease between the Small and the Big Wings, where the Tustan Fortress was located, and the tops of the layer triangle served as its supports. The rock is surrounded by valleys on three sides, and is a dominant element of the area terrain. This rock is the most massive in the rock cluster of Urytskyi massif due to a wide wall-like base. The rocks are composed of sandstones of the Yamna's suite of the Paleocene of the Lower Paleogene age (56–66 million years) (Bayrak, 2011). They are gray, of a small and medium-grained structure, pierced with numerous lithological, tectonic and gravitational cracks. They have underwent significant anthropogenic interventions, such as carved long channels, rounded grooves and various signs on the surface, which was studied by I. Vagilevych more than 100 years ago. The grottoes, small caves also diversify the view of this massive rock. The tour lasts about 1.5 hours. Massive rock with six sharp peaks is called the Hostryi Kamin; it is up to 25 m high, located on the edge of the ridge. The other rocks of the Urytska group are not so massive. In morphology, they resemble pillars that hang above the tree crowns. There are also small objects of interest, such as the Zhertovnyk (Altar), a stone reminiscent the sacrifice table. On the western slope of the Tustanskyi Kamin is the Sviate Jerelo (Holy Spring). The unique history, the richness of surface geological and archeological signs, heterogeneous morphological structure determines the attractiveness of Uritski rocks for tourists.

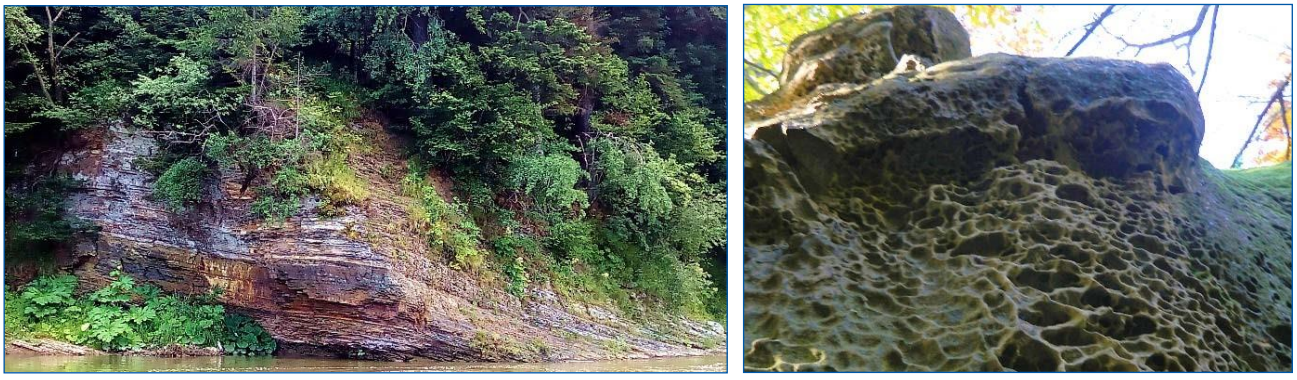
Yamelnytskyi geo-tourist area is still poorly known among ordinary tourists. It is best known for rock climbers. The complex consists of five groups of sandstone rocks and many single rocks – tower-shaped, pillars and cube-shaped cliffs (Mazurski, 1972; Alexandrowicz, 2008). They are formed from sandstones of the Yamna's suite. The most interesting groups are in the northern, northwestern and south-eastern boundary of a village Yamelnytsia (Fig. 1b). By morphology, these are the wall-shaped rocks with flat tops that often have small cliffs, which is why these two-topped rocks are known locally as the Shyyata. The rock walls here are not solid, but are broken by transverse cracks into high cliffs, which are connected to each other at the base. In the northern and northwestern groups the rock tops are accessible, with panoramic views of the surrounding mountain ranges and the height of the rocks is reaching 32 m. In the northwestern group, the rock wall forms a gorge, narrowing to the base of the mountain. A massive rock wall and individual rocks are located on the ridge edge of the southeastern group; their peaks accessible only with climbing equipment. They reach a height of 20 m; the view from the ridge edge is enclosed by a dense forest. The rock wall in this cluster has two through cracks, wide enough to enter and inspect its vaults from the inside and exit to the opposite side of the entrance. There are various traces of the organisms' activity during sedimentation processes on the surface of the rocks. The rocks are attractive for their massiveness, because the length of many rock walls reaches 50 m (southeast) and 100 m (north and northwest). They deeply impress travelers, exceeding their expectations.

Skolivskyi geo-tourist area. It includes the range of Parashka Mountain, the Skolivska Lowland and the Pavliv Stream valley with the adjacent Lopata

(Shovel) Peak. The Parashka Range rises above the surrounding valleys to an elevation of 1268 m and has dominant heights on the left bank of the Opir River. The slopes are steeper in the lower, longitudinal parts, in the upper ones they are sloping. Nearby the highest peak of the Parashka Mountain stand out three smaller, also conical tops: Tymkiv Verkh (1227 m), Zelena (Green) (1217 m), Obroslyi Verkh (1177 m); Korchanka (1178 m) is in a little distance as well. From the northeast side of the ridge, in the valley of the Velyka Richka (Big river) stream, 4 km from the village of Korchyn is the small waterfall Gurkalo, which sprays from a ledge of three meters high, formed by massive sandstone. The absolute height of the waterfall is 570 m. In the valley of the Mala Ricka (Little River) stream, 2.5 km from the village of Korchyn the 10 meters high sandstone cliff called Turkish stone Korchinskyi is located. Rock blocks of up to 8 m and sandstone debris are also observed in the area. The Parashka Ridge is available for simple one- and two-day hikes. Its tourist attraction is clarified by the fact that the forestless tops are occupied by the subalpine meadows with the views on the Komarnytskyi ridge and the hills of the Precarpathian highlands in the north, the Kliuch mountain range and the Arshytsia ridge in the southeast, the Vododilno-Verkhovynskyi ridges of Carpathian Mountains in the south and southwest. The proximity of the settlements from which the tourist routes begin is also attractive. They are town of Skole, villages of Korchyn, Korostiv, Krushelnytsia.

the Pavliv Stream. The famous pedestrian route to Lopata Mountain (1210 m) lies through the valley. The second section of rocks is located between the town of Skole and the village of Korostiv, in the tract of Sviatoslav, where in a construction quarry a bundle of 18 m high-grade flysch formations has been uncovered. The nature and dynamics of sediment formation in the ancient Carpathians deep sea can be traced by the interlayer textures of the rocks' stratum, and the circumstances of sediment accumulation, paleoclimatic conditions can be outline by the surface textures.

Syniovydnenskyi geo-tourist area is characterized by the number of attractive objects for geo-tourism, such as rock outcrops, rocks, modern riverbeds processes and forms. In tectonic aspect at the local level here can be distinguished the Verkhniosyniovydnenska Lowland and the Pobukska Anticline, which limits the Lowland from the east and forms a meridional low ridge. Exactly with this anticlinal are related rocks outputs of different lithological composition and age. In the northern part of the ridge, on the slope of the western exposition at an altitude of 390 m there are sandstone outcrops of the Eocene Vyhodska's suite (average Paleogene, 34-56 million years). They are yellowish-gray in color, of horizontal occurrence, massive at the top, and thinly layered at the bottom. Sandstone outcrops are fractured by vertical and horizontal cracks into massive rectangular sections. The height of outcrops is 7 m. Two km to the south there are the rocks outcrops that form the basis of



a b

Fig. 2. Outcrops of flisch rocks "Skolivska Skelia" (*a*) and forms of cellular weathering on the rocks near Sokolovets Mountain (*b*)

Skolivska Rock is one of an interesting geo-tourist site in the Skolivska Lowland. It consists of the outcrops of the Paleogene flysch of the Bystrytska's suite on the right bank of the Opir River (Fig. 2a), and Carpathian flint on the left one, at the bottom of the river. The height of the outcrops is 7.5 m. Springs of ferrous and hydrogen sulfide water (the spring Verkhnie (Upper)) are beaten in the valley of the Pobukska Anticline. It is an interlayer of black mudstone with thin sandstone layers and siltstones of the Oligocene Menilite's suite. Horizontally wavy texture of the entire thickness is clearly visible. There is a black mudstone scales basin in the lower part. This outcrop was extracted in the twentieth century as an oil shale deposit. Its height is about 25 m. It is located on the right bank of the Opir River, and on

the left, on the floodplain of the river, between the river pebbles can be seen the exits of the Carpathian flint (hornfels). Their layers up to 0.5 m thick lie at an angle to the surface of the floodplain and have whitish and black colors. The flints mark the sole of the Nyzhniomenilite's suite.

The rocks in the Syniovydnenskyi geo-tourist area are low and therefore poorly known. There are several groups of rocks far apart from each other. The first group is located in front of the village of Verkhnie Syniovydne, on the east wing of the Pobuk anticlinal fold. They were named Kniazhi (Prince) Rocks near the village of Tyshivnytsia as they are closest to this village. These are three rocks: Knyazha (Prince), Yaroslavna and Khanska (Khan), which rise to the height of 15-18 m above the Stryi River. According morphology these rocks resemble pyramids, located at the base of the ridge. The peaks are accessible, with a view of the Stryi River valley, the Komarnytskyi ridge, the confluence of the rivers Stryi and Opir. They have a story related to the battle of the Russian prince with the Tatars.

Other rocks clusters are located on the southern slopes of Komarnytskyi ridge, which extends from the village of Nyzhnie Syniovydne to the village of Yamelnytsia. Many rocks are observed near Sokolovets Mountain, where there are three groups of them - southeast, northwest and northeast (Bayrak, 2012). They form the walls at different absolute heights. Their length is up to 100 m. The rocks 12–23 m high do not rise above the forest cover, and, therefore, they are not very attractive to tourists, since the overview of them is insignificant. Only from one point of the southeast group of rocks the Syniovydna hollow and the ridge of the Pobukska Anticline are visible. One edge of the rock bursts down to the beams where they form upright walls. Tops are available. On the surface of some rocks there are unique forms of cellular weathering, which are the largest of all the Beskid rocks forms (Fig. 2 *b*). Another group of rocks on Komarnytskyi Ridge is located near the village of Pozhernytsia. These rocks are also hidden in the forest, low, so poorly known among tourists. Predominant Tower-shaped and cube-shaped rocks are prevailed.

An interesting geomorphological object in the Syniovydnenskyi tourist area is the riverbeds of Stryi and Opir and the place of confluence of the rivers. From the bridges across these rivers the nature of riverbeds processes can be observed, especially, the intense lateral erosion with coastal destruction; the deep erosion manifested in the formation of funnels, molds and rolling; bifurcation, bedding and their causes; the nature of sediment formation and the accumulation of material in the form of riverbed alluvium on the sides, islands and reaches, its size and the nature of the occurrence. More active, with interesting fluvial forms, is the riverbed of the Opir River.

Kliuch-Kamianka geo-tourist area. All the geological and geomorphological sites of the area are connected with the massive sandstone outcrops of the Yamna's suite; they reach the largest width here - 2.2 km, compared to other areas where their width is 200-700 m. The most popular natural site is the waterfall on Kamianka River. It is located on a steep turn of the river bed, 6.5 m high and thus slightly higher than the Gurkalo waterfall near Korchyn. It is more powerful, has three streams and several times wider. Waterfall streams beat sandstone cliffs jutting out from under the water and this fact grounds the total beauty of the waterfall. 500 m above it, on a river section of 250 m in length, there is a cascade of small waterfalls-rapids up to 2 m in height, and the vertical ten-meter wall of massive sandstone outcrops near them gave the name to this section – Kamianka River Gorge.

The unique attraction of the area is the deep precipices formed by the steep walls of the sandstone outcrops, located on the outskirts of the Kliuch Range. Tourists named them "canyons". One of these "canyons" is located to the west and the other to the southeast of the main peak of Kliuch Mountain (929.7 m). These precipitates are of complex tectonic-gravity and tectonic-erosion origin. The primary was the splitting of sandstone into blocks as a result of the tectonic activities in the Carpathians, and the second was the widening of cracks by gravitational subsidence and deepening by erosion processes. The morphometric parameters of the precipices are different. Thus, in the western part the length is 10 m, the depth is 5 m, the width is 2.5 m, and in the south-east - the length is 100 m, the depth is 25 m, the width is 5 m. The surface of the walls is flat, without any signs or indentations. The access to the surface of the sandstones, which are strongly divided by the cracks into separate parts, is connected with the entrances to the vertical caves, formed by the expansion of the sandstone cracks (Fig. 3 *a*). These caves are the largest among the sandstone caves in Ukraine. They are not well explored, reach a considerable depth (up to 50 m), without equipment descent in them is dangerous. On the Kliuch Range are the large scattering of small sandstone cliffs and rocks-outliers. Despite the fact that thousands of tourists come to the waterfall, there are almost no guided tours to the nearby rocks, which are within hour's reach, the path to them is practically unknown. The reason may be that the

a b

Fig. 3. Entrance to one of the vertical sandstone caves on Kliuch Mountain (a) and Bukovetski skladky outcrops (b)

rocks are low; the surrounding area is not visible from them. However, they are unique, have exceptional morphological outlines. Their largest group is located west of Kliuch Mountain. Remarkable single rocks are located here: unique the Sokil (Falcon) 6 m high and the Arka (Arch) (3 m), the rock-cracks with blocks of settling, the cube-shaped rocks and the accumulation of erosion-denudation rocks-outliers. The various forms of rocks can be explained by the heterogeneous structure of the sandstones the rocks are composed from, and by the uneven weathering of their fine-, medium- and large-grained layers. Clusters of rocks contain from 3-4 to 10 units. The largest cluster the tourists used to name the Easter Island or the Ihroteka. These rocks are the highest, 8 m high. They are located in a semicircle, with a deep niche in the center, and exit to the opposite side of the cluster. In general, the rocks are spread over an area of about 0.4 km^2. On the lower slopes of the southern exposition a hydrological site – Zhuravlyne (Cranes) or Mertve (Dead) Lake – is located; it is surrounded by steep slopes of the mountain, which gives it a special attractiveness.

Bubnyskyi geo-tourist area has a great variety of geo-tourist sites. Here are the highest in the Beskids Dovbush rocks, a unique outcrop of flysch rocks "Bukovetski skladky (folds)" and the cascade of waterfalls on the Sukil River. There are rocks of various morphological types: tower-shaped, spire-shaped, cube-shaped rocks, plateau-like clusters of rocks and rocky valley (Mazurski, 1972; Alexandrowicz, 2008). Such diversity is associated with the selective erosion of rocks along cracks in different directions, weathering and turning Yamna's sandstone surface of heterogeneous structure by wind, rain, and snow. The height of the tallest Bronenosets (Battleship) rock is over 35 m, and it is shaped like a sail. On the tower-shaped Bezimenna (Nameless) Rock, there is a round cuboid cliff, resembling the head on the shoulders of the giant. Another spire-shaped rock is named "Tiulpan (Tulip) by a peak similar to this flower. The plateau-like cluster of the rocks known as Main Massif is strongly dismembered by longitudinal tectonic cracks into columnar poles that cause the ribbed surface of the massif. Man-made caves are carved into it and there are narrow aisles that a person can enter. The peak is accessible, offering views of the Kliuch Mountain, the Parashka Mountain and the Bezimenna Rock, the Bronenosets rising above the forest cover, and the rocky valley. In total, there are a dozen single high rocks (20–35 m), a dozen small rocks (6–15 m) and rock scattering (Sluckij, 1984). The rocky valley at the top enters the main massif, where it has a gorge-like shape, and below the stream there are separated rocky cliffs, the height of which gradually decreases, passing into scattering of stones. On the surface of the rocks, in shaded spaces, there are areas with small forms of cellular weathering. Rocks are used for rock climbing, which is very popular here for beginners as well as for stagers.

The Bukovetski skladky outcrops is located 4.3 km southwest of the turn from the main road to Bubnytski Rocks, upstream of the Sukil River. They are presented by the flysch of the Late Cretaceous Stryi's suite (Fig. 3 *b*). These are the original anticlinal and synclinal folds of the flysch rocks that are torn apart by the outcrops. Up to eight anticlinal folds are disclosed. The height of the exposure is 10 m. Both coarse- and medium-layered stratums and thin stratums are observed; they indicate the tectonic regime of the territory unevenness during sedimentation. The outcrops illustrate the folded structure of the Carpathian mountain system, formed as a result of tectonic crags caused the rocks to deform into folds. At a distance of 300 m from these outcrops, upstream of the Sukil River, an interesting incision of flysch rocks underlying monoclinic at an angle of 30 ° can be observed. Below the thicker one there is the

flexure revealed by the river. The height of exposure is 2 m.

Another geo-tourist site of the area is the cascade of waterfalls (rapids) and the scattering of rocks near the village of Kozakivka on the Sukil River. The height of the rapids is up to 2 m. Each side of the riverbed has the largest sandstone block of 3 m high. Rounded recesses called glitomorphosis can be found on the surface of the sandstone. The Sukel River valley is widening in this place, the slopes become flat, there are deep springs in the river, so this area has become a tourist destination.

Beskids of the Ukrainian Carpathians is a region where the tourism infrastructure is unevenly developed. In one place there are a large number of different type's establishments: tourist bases, hotel and restaurant complexes, estates and cottages of green tourism. Most accommodation facilities are located in the town of Skole. Private estates and tourist bases operate in the villages of V. Syniovydne, Dubyna, Korostiv, Korchyn. Other places close to geo-attractions have poorly developed tourism infrastructure. These are Urych, Yamelnytsia, Krushelnytsia, N. Syniovydne, Mezhybrody, Trukhaniv.

Based on the conducted studies, the attractiveness of the selected geo-tourist areas of the Beskids was evaluated (Table 2). The closer the indicator to 10 points is, the higher is the area's attractiveness.

The most attractive for the development of geotourism in Beskidy is the *Urytskyi geo-tourist area*, which has an overall attractiveness of 8.4 points. There are rock groups, individual rocks, and springs in its territory. Two rocks are over 20 m high, with a view of the surrounding countryside, the rest ones are smaller. The rocks are complex-shaped, with sharp, peaks surrounded by forest, and towered above the valley creating a highly aesthetic landscape. They are located close to paved roads, so are well accessible. The scientific and cognitive value of them is determined by the fact that the shape and micro relief of the rock formations' surface reflect their evolution (destruction) under the influence of various types of weathering. They are of high historical and cultural value, since here in IX-XVI there was an ancient Russian fortress Tustan. The tourist infrastructure is poorly developed, with only three lodging estates, but the neighboring resort village of Skhidnytsia provides the accommodation and meals' needs of tourists. Souvenirs and local products are usually sold around the rocks, as well as seasonal food stocks are available. The area is very popular among various tourist groups. Sites are well known to Internet users, and they generate more than 160.000 search results. Attendance, according to the Tustan Historical and Cultural Reserve, averages from 332 to 1085 people per day during the high and medium seasons (not including the number of visitors during the festival).

Bubnyskyi geo-tourist area has a high level of attractiveness (7.2 points). There are the largest amounts of rocks here, some of them have the highest altitude and picturesqueness among all the Beskid rocks. The rocks of the area offer beautiful views of the surrounding countryside. The geological outcrops of the Bukovetski skladky, which illustrates the folded structure of the Carpathians, is of scientific and cognitive value. The Bubnyski rocks are of historical and cultural value due to the movement of the Dovbush opryshkas (mountain outlaws). All objects are away from paved roads. There is practically no tourist infrastructure, the area is of second-rate popularity (the number of search results is more than 9 thousand). Attendance was higher in the last seven to ten years (more than 1 thousand people), and since 2016 the number has fallen to an average of 300

Table 2. Assessment of geo-tourist areas' attractiveness of Beskids (in points)

The name of the area	Number of geo-attractions	Maximal heights	Picturesqueness of objects	Visibility from the object	Object accessibility	Scientific and educational value	Historical and cultural value	Tourist infrastructure	Popularity	Attendance	The overall
Urytskyi	0.6	0.9	1	0.8	1	0.9	1	0.4	0.8	1	8.4
Bubnyskyi	1	1	0.9	0.6	0.4	0.9	0.7	0.3	0.7	0.7	7.2
Kliuch-Kamianka	1	0.3	0.9	0	0.7	0.6	0.7	0.7	1	1	6.9
Skolivskyi	0.4	0.7	0.7	1	0.6	0.2	0.4	1	0.8	0.8	6.6
Syniovydnenskyi	0.5	0.8	0.6	0.5	0.7	0.6	0.1	0.9	0.3	0.6	5.6
Yamelnytskyi	1	0.8	0.6	0.3	0.3	0.3	0	0	0.6	0.1	4.0

people at the weekend during medium season and 500-700 people during high season.

Kliuch-Kamianka geo-tourist area is also quite attractive to tourists with a total potential of 6.9 points. There is the largest number of sites of different type: rocks, gorges, caves, waterfall, and lake. Geological and geomorphological sites have small, with closed views on landscapes. The facilities are accessible to people of average physical condition, with the exception of the waterfall, which is located near the paved road and is accessible to persons in any physical form. The valleys formed as a result of tectonic rock splits and the development of erosion and gravitational processes along them are of scientific and cognitive value. The rocks with unique shapes, the waterfall on the Kamianka River and the Zhuravlyne Lake, are of great landscape value and particular beauty. Kliuch Mountain is of historical and cultural significance because it is related to the activities of Sich Riflemen, as evidenced by the established monument in their honor. The tourist infrastructure is represented by a camp site by the village of Dubyna, four private peasant estates, as well as trade booths and food establishments. The area is known by tourists, the number of search results for the word combination "Kliyuch Mountain" is 6.8 million, while for the "waterfall on the river Kamianka" is about 50 thousand. Thus, according to the Skole Beskydy NPP, for Kamianka waterfall, in particular, it ranges from 343 to 1236 people for one day off during the warm season.

The attractiveness of *Skolivskyi geo-tourism* area is estimated at 6.6 points. There are seven geo-attractions in the area: two peaks, on which tourists ascend, a small waterfall, a rocky cliff, two outcrops, springs. To compare the results with other objects, the maximum heights of the rocks were and the heights of the peaks were not taken into account. The Parashkivskyi Range is characterized by high picturesqueness; it opens panoramas over all geographical directions, what is greatly exiting for tourists. Other attractions have the mediocre aesthetic qualities. The objects are accessible for motorcycle and pedestrian trips; one should get there by ground roads and trails, except for the sites in Skole itself. The events on Mountain Lopata, where in July 1944 the Ukrainian Insurgent Army' soldiers fought with the German-Hungarian troops, have historical and cultural significance. Other values are not directly related to geo-tourist sites: they are Skolivschyna Historical and Local History Museum in Skole and a wooden church built in 1597; near the village of Korchyn Ukrainian Insurgent Army' shelters are known. The tourist infrastructure is well developed: in the town of Skole, the villages of Korchyn and Korostiv there are farmhouses and cottages of rural tourism, catering and entertainment facilities, and in Skole there is a campsite "Hutsulshchyna" (more than 45 in total). The number of Internet search results is also high – more than 400 thousand for the word combination "Mountain Lopata" and 140 thousand for the word "Parashka". Other properties in the area are less well known online. Attendance statistics only indirectly indicate the attractiveness of the area, as it takes into account the number of visitors to accommodation facilities in Skole and Korostiv, with more than 730 people on an average day off. However, there are still amateur groups of tourists who climb Parashka Mountain or Lopata Mountain and are hypothetically taken into account in these statistics.

According to our research, the *Syniovydnenskyi geo-tourist area* is moderately attractive (5.6 points). There are eight geo-attractions (five rock clusters, two outcrops, a river mouth). Rocks and outcrops are average in height, the aesthetics of the space with these objects are lower than in the neighboring areas. You can climb the rocks and the ridge where the outcrops are. An overview of the landscapes is available from the peak of the Tyshivnytsa ridge and rocks, overlooking the Verkhniosyniovydnenska valley, the Komarnytsyi ridge, the Parashka Mountain, and the Stryi valley. Access to geo-attractions is different: three of them are in close proximity to the paved road (Tyshivnytsya rocks, sandstone outcrops, river confluence), the others need to be accessed by ground roads and trails. The outcrops is of a scientific and cognitive value as they reveal the geological structure of the Carpathians; the largest in the Beskids form of rock surface cellular weathering near Sokolivets Mountain is of a great interest as well. Geo-attractions don't have any historical or cultural values, except an eighteenth-century wooden church in the village of Verkhnie Syniovydne is with its own history. The tourist infrastructure is well developed: at the foot of the Komarnytskyi ridge, on the way to the rocks of Sokolovets Mountain and Pozhernytsia Mountain there is a complex of tourist departmental and private bases; at the outcrops of the menilite shales is a geological research and educational station of the Lviv Ivan Franko National University partly accepting tourists; five rural estates and a hotel and restaurant complex in the village of Verkhnie Syniovydne. The area is popular among tourists for one-day amateur trips and as a transit area for more famous geo-attractions. The number of Internet searches results of separate objects is up to 2 thousand. Attendance can also be determined indirectly, by the number of nights

spent in accommodation establishments. It is 100-300 people in the warm season.

Yamelnytskyi geo-tourist area received 4.0 points for its attractiveness. There are many similar geo-tourist sites here like individual rocks and rock clusters more than 20 m high. Some rock peaks are accessible; they open views to unknown surrounding peaks. Rocks clusters in the north of the Jamelnytsia village form picturesque landscapes on the backdrop of wooded ridges, but most of the rocks are closed off from an observer with a forest cover. The rocks are away from the hard-paved roads, scattered on the terrain, so their accessibility is low. The fracture of rocks composed of cliffs and various sedimentary marks on the sandstone surface, is of scientific and cognitive value. The historical and cultural value is evident in the construction of the structures near the rocks of the cover of the UPA soldiers, a wooden church in the village of Yamelnytsia in 1829. Historical and cultural value lies in the presence of UPA soldiers shelters near the rocks, and a wooden church in the village of Yamelnytsia built in 1829. The tourism infrastructure is underdeveloped and only the Gotar campsite is located at the entrance to the village. The number of search results on the Internet system exceeds 20.000. The largest rocks are known for climbers, who organize groups of up to two dozen people here on certain weekends.

In above mentioned geo-tourist areas tourist companies, departments of local state administrations, local forestry propose routes of various kinds, duration and complexity including the described geo-attractions (Fig. 4).

The hiking routes are as follows: 1) village of Korchyn - Gurkalo waterfall - Parashka Mountain - town of Skole; 2) Bubnyski Rocks - village of Trukhaniv (and vice versa - village of Trukhaniv - Bubnyski Rocks); 3) Bubnyski Rocks - Kamianka Waterfall (Kamianka Waterfall - Bubnyski Rocks); 4) village of Trukhaniv - a monument to Sich Riflemen on Kliuch Mountain - Kamianka Waterfall; 5) the town of Skole - Lopata Mountain - the town of Skole.

Popular bus routes: 1) city of Lviv – town of Stryi - Rozgirche rock and cave complex; 2) city of Lviv – town of Truskavets - Urytski rocks; 3) town of Truskavets - Kamianka Falls - town of Skole.

Motor and cycle routes: 1) town of Skole - Kamianka Falls - Bubnytski rocks - village of Trukhaniv - village of N. Siniovydne; 2) town of Skole - Kliuch Mountain - Bubnyski Rocks - town of Bolekhiv - town of Stryi; 3) village of N. Siniovydne - Urytski rocks; 4) Parashka Mountain - Urytski rocks.

Ecological and educational trails: Buchyna, Lopata, Waterfall (Turystychni…).

The geo-geomorphological attractions described in geo-tourist areas of Beskids may be sites of interest in the proposed tourist routes.

Suggested hiking routes (see Figure 4):

1) Yamelnytski Rocks – Komarnytskyi Range, rocks under the Pozhernytsia Mountain and Sokolivets Mountain – geological research and educational station village of V. Syniovydne (outcrops of oil shale) (3 days);
2) Rozgirche rock and cave complex – Tyshivnytsia Rocks – Bubnyski Rocks – Bukovetski Skladky – Sukil Waterfall (3 days);
3) Rozgirche rock and cave complex – Komarnytskyi Range, rocks under the Sokolivets Mountain – Tyshivnytsia Rocks (1 day);
4) Kamianka Waterfall – Kamianka River Gorge – Gorge (Canyon) on Kliuch Range – Pasky, Ark and Sokil Rocks on Kliuch Range – Zhuravlyne Lake (6 hours);
5) sandstone outcrops by village of V. Syniovydne – Gorge (Canyon) on Kliuch Range – a monument to Sich Riflemen on Kliuch Mountain – village of Trukhaniv – Tyshivnytsia Rocks (2 days);
6) waterfall and gorge on Kamianka River – Gorge (Canyon) on Kliuch Range – a monument to Sich Riflemen on Kliuch Mountain – village of Trukhaniv – Tyshivnytsia Rocks (2 days);
7) town of Skole – the Pavliv stream valley with ferrous and sulfur springs – Lopata Mountain – village of Kozakivka – rapids and waterfall on Sukil River – Bukovetski Skladky – Bubnyski Rocks (3 days);
8) town of Skole – the Pavliv stream valley with ferrous and sulfur springs – Lopata Mountain – outcrops (quarry) of flysch rocks by village of Korostiv – Parashka Mountain – town of Skole (1 day);
9) Parashka Mountain – Gurkalo waterfall – Turkish Stone Korchynskyi (1 day);
10) didactic trail in Skole Beskydy National Park (1 day).

Suggested bus routes:

1) Yamelnytsia (Bychkov tract, 17th century Orthodox church with ancient cemetery) – Urych – Skhidnytsia (mineral water springs such as Naftusia, Borjomi) (1–2 days);
2) city of Lviv – Bubnyski Rocks – Bukovetski Skladky – rapids and waterfall on Sukil River – town of Morshyn (2 days);

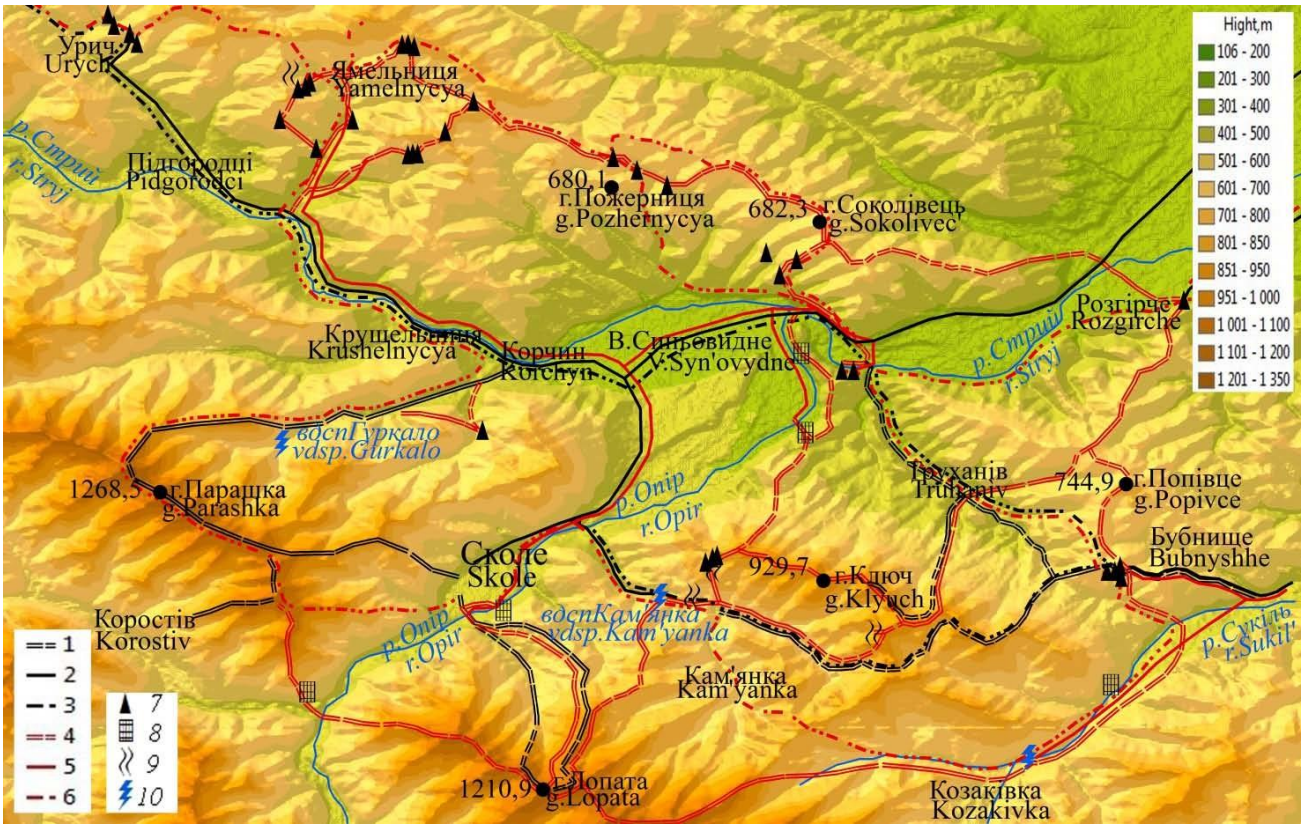


Fig. 4. Geological-geomorphological sites and geo-tourist routes of the Ukrainian Carpathians' Beskids.

Legend. Valid tourist routes: *1* - pedestrian, *2* - bus, *3* - bicycle; Suggested tourist routes: *4* - pedestrian, *5* - bus, *6* - motor-bike. *7* - rocks, *8* - outcrops, *9* - gorges, *10* - waterfalls.

3) city of Lviv – Tyshivnytsia Rocks – sandstone outcrops and oil shale by village of V. Syniovydne – Yamelnytski Rocks (Bychkov tract) – town of Skole (riverbed processes on the Opir River and Skolivska Rock) (2 days).

Suggested motorcycle and bicycle routes:

1) town of Truskavets – Urytski rocks – Yamelnytski Rocks – waterfall in the village of Korchyn – Parashka Mountain – relay on the nameless top – town of Skole (2 days);
2) town of Skole – Kamianka Falls – village of Kozakivka, rapids and waterfall on Sukil River – Bukovetski Skladky – Bubnyski Rocks – village of Trukhaniv – Tyshivnytsia Rocks – village of V. Syniovydne (2 days);
3) town of Stryj – Rozgirche rock and cave complex – Tyshivnytsia Rocks – village of Trukhaniv – Bubnyski Rocks (1–2 days);
4) village of V. Syniovydne – rocks under the Sokolivets Mountain – rocks under the Pozhernytsia Mountain – Yamelnytski Rocks (Matkhov, Danylov, Bychkov tracts) – Urytski rocks – town of Skhidnytsia – town of Truskavets or Yamelnytski Rocks – village of Oriv – town of Truskavets (2 days).

Duration of trip and load on routes are individually designated according to the age, physical conditions, technical ability and wishes of the tourists.

Conclusions. In recent years, the interest of national and foreign tourists to the inanimate nature sites has increased. The Ukrainian Carpathians Beskids accounts a large number of such objects: rocks, outcrops, caves, waterfalls. Most of them have scientific, educational, historical, cultural, landscape, and aesthetic value, so they are promising for geo-tourist trips.

An assessment of the geological and geomorphological sites' attractiveness of the selected tourist areas showed that the higher scores belong to the areas with the high morphological diverse of the objects, with significant morphometric indicators, high landscape value, geological representativeness of the Carpathian structure, with different sedimentation and solar signs on the rock surface. The popularity of the objects in the search results is high, but the tourist infrastructure of the areas is underdeveloped. The attendance of the particular areas is low owing to poor road conditions. A number of hiking trails are laid out in the area researched, but they do not fully cover the area's geo-tourist attractions. That is why we have proposed new pedestrian, auto, motorcycle

and bicycle routes, which will help to increase the Beskids' traffic, promote the development of tourist infrastructure and increase the image of geo-tourism.

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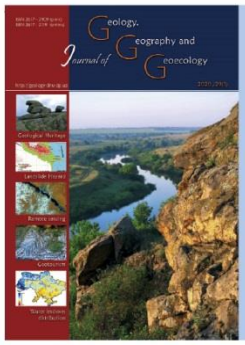

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Specificity of genetic nature and classification characteristics of Zmiiny Island chernozem soils

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Abstract. Even the first researchers of the nature of the small (20.5 hectares) rocky Zmiiny Island in the northwestern Black Sea region visually diagnosed the soil there with black earth. Since 2003, the staff of the Department of Soil Science and Soil Geography of the Odessa National University named by I.U.Mechnikov ONU began the study of factors and processes of soil formation, soils and soil cover of Zmiiny Island territory. It was found out that on the inter-rocky areas of the island under the steppe grassy vegetation on the gravelly-stony eluvium or eluvium-deluvium of dense rocks formed unusually high humus (up to 14-18%) undeveloped and short-profile chernozem soils. However, the diagnostic and classification of these soils remains unclear. The purpose is to characterize the specificity of the genetic nature of the island soils and to determine their diagnostic and classification affiliation, including the World Reference Base for Soil Resources WRB.The materials presented in this article are obtained as a result of our extensive fieldwork and laboratory analysis, research and mapping of soils and soil cover of Zmiiny Island with the application of methodological principles of the process-genetic paradigm.Chernozem soils on the island are formed on a low-strength (25-40, up to 50 cm) rocky-gravelly crust of weathering of dense acidic rocks under the cover of almost virgin steppe herbaceous vegetation and year-round salting from the sea, mainly chlorides and Na sulfates. The soils are short-profile, typical chernozem humus-accumulative type with typical for the chernozem profile genetic horizons, gravel-stony, non-carbonate, almost non-structural, acidic, varyingly saline and solonetinous, but without solonets-ileuvial profile differentiation. The humus content in the upper horizons is very high (10-12, up to 15-18%), it is typical of the chernozem composition of the Chumic acid : Cfulvic acid (2,5-3,3), but with a sharp dominance of the HA-1 fraction (70% and more) and very low content (1-2, up to 3-4%) or lack of typical chernozem HA-2fraction. It is established that there is a tendency to an irreversible constant increase of the chernozem properties and characteristics in soils as the bioproductivity of herbal vegetation increases.For the first time their diagnostic and classification dependence on the system of both domestic and World WRB soil classifications has been determined. The WRB system proposes to refer these soils to the Phaeozem abstract group, with clarification of the classifiers Leptic and Skeletic. The work is practically significant in terms of the integration the Ukrainian soil science in the system of the current international standard of soil classification WRB.

Keywords: Zmiiny Island, chernozem soils and their geographic and genetic features, classification characteristics.

Специфічність генетичної природи та класифікаційна належність чорноземних ґрунтів острова Зміїний

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Анотація. За результатами багаторічних 2003-2018 рр. ґрунтово-генетичних досліджень на о. Зміїний схарактеризовано специфічність умов і процесів утворення, морфології, речовинно-хімічного складу і властивостей тамтешніх чорноземних ґрунтів та тенденцій їхньої сучасної еволюції. Ґрунти пересічно неповнорозвинені і короткопрофільні з потужністю гумусового горизонту до 25 і 25-45 см відповідно. Сформувались на елювії чи елювo-делювії щільних кислих порід під покривом практично незайманою степової трав'яної рослинністю і цілорічного поступання солей з моря, головно хлоридів і сульфатів Na. Ґрунти короткопрофільні, типово чорноземного гумусово-акумулятивного типу з типовими для чорноземного профілю генетичними горизонтами, щебенювато-кам›янисті, некарбонатні, практично безструктурні, кислі, різною мірою засолені і солонцюваті, однак без солонцево-ілювіальної диференціації профілю. Ступінь насиченості основами у нижніх горизонтах профілю лише 30-40%, у верхніх горизонтах більше 50%, що пояснюється максимальним вмістом у верхніх (кореневмісних) горизонтах поглинутих основ, в т.ч. і Кальцію біогенної природи. Дуже високий у верхніх горизонтах вміст гумусу (10-12, до 15-18 %) типово чорноземного складу СГК: СФГ (2,5-3,3), однак із різким домінуванням фракції ГК-1 (70 % і більше) і дуже низьким

вмістом (1-2, до 3-4 %) чи й відсутністю типово чорноземної фракції ГК-2. Результати дослідження оптичних властивостей гумусових речовин засвідчують доволі високу оптичну щільність гумінових кислот, властиву зазвичай ґрунтам чорноземного типу. Встановлено тенденцію до наростання потужності профілю чорноземних ґрунтів острова догори по мірі зростання біопродуктивності трав'яної рослинності. Вперше визначена діагностико-класифікаційна належність ґрунтів о. Зміїний в системі як вітчизняної, так і Світової WRB ґрунтових класифікацій. За системою WRB неповнорозвинені та короткопрофільні чорноземні ґрунти пропонується відносити до реферативної групи Phaeozem з уточненням визначення кваліфікаторами Leptic і Skeletic. Робота практично значима в плані інтеграції української ґрунтознавчої науки в систему нинішнього міжнародного стандарту класифікацій ґрунтів WRB.

Ключові слова: острів Зміїний, чорноземні ґрунти та їхні географо-генетичні особливості, класифікаційна належність.

Introduction.The first researchers of the nature of Zmiiny Island (also Snake or Serpent Island) – namely, a topographer M. Krytskyi as early as in 1823, and professor of Richelieu Lyceum (Odesa) O. Nordman in 1841 – managed to diagnose visually the local soils as "chernozems" (fertile black soils rich in organic matter). The island soils were also classified as chernozems by the I. I. Mechnikov Odessa National University experts who first investigated the genetic origin, material-and-chemical composition and properties of the island soils in the studies conducted during a period from 2003-2005 to 2016-2018. The research has shown that here, in the inter-rock areas of thin rocky-gravelalluvia or alluvium-deluvium of dense siliceous (acid) rocks beneath the steppe herbaceous vegetation, immature and shallow chernozems with the humus horizon thickness up to 25 cm and 25-45 cm, respectively, characterised by specific morphological features, composition and properties, have been formed (Bilanchyn et al., 2008; 2009; 2010; Bilanchyn, 2011; Leonidova, 2013; 2017).

Since the research by V.V. Dokuchaev, the formation and distribution of chernozems is commonly associated with luxuriant grassland and steppe herbaceous vegetation of forest-steppe and typical steppe regions, as well as with semi-arid climate and its well-pronounced seasonal contrasts. Carbonate high-porous loess, loess-like and light-clay loams tend to be the most common soil-forming (parent) materials here. Intensive mineralisation and humification of the litter of luxuriant herbaceous vegetation and its extensive root system during relatively humid and warm spring and early-summer season are followed by polycondensation, which is further thickening of newly formed humic substances during subsequent hot and dry, as well as freezing weather seasons. It results in the formation of dark-brown to black coloured horizon of humus accumulation with high topsoil content of humus and biophile elements (up to 8-10% and above), in particular calcium. The lower part of the chernozem profile usually show carbonate accumulation horizons. The upper horizons of chernozems spread over loess can be distinguished by loose configuration and clumpy-grained structure, neutral or nearly neutral reaction, high Cation Exchange Capacity (up to 40-50 or even 60 mmol·eq/100g) with dominating absorbed calcium (up to 80-90% of capacity) and high availability of plant nutrients.

Indeed, the natural environmental conditions on the small Zmiiny island (only 20.5 ha) in the Black Sea are quite peculiar and distinctly different from the conditions of classic chernozem formation. The surface of the island is composed of siliceous (acid) rocks of considerable hardness with very stony-and-gravelly thin weathering crusts (usually not thicker than 25-40 cm). Hence, the genesis, morphology, material-and-chemical composition and some other properties of the island chernozems can be distinguished by a number of specific features which have been reported in varying detail in our previous publications (Bilanchyn et al., 2008; Bilanchyn, 2011; Leonidova and Bilanchyn, 2017, etc.). Given this, the justification for diagnostics and classification of the island soils as chernozems has been sometimes challenged in the community of Ukrainian soil scientists in recent years. As the current period of the soil science development throughout the world, especially with regard to soil diagnostics and classification, it shows a clear trend towards the adoption of the World Reference Base of Soil Resources - WRB (Charzynski, 2006; Ivanyuk, 2016; Krasilnikov, 2009; Polchina and Nichorich, 2006), the determination of a niche for classification of the Zmiiny Island chernozems within this international classification system was set as one of the objectives of this study.

The issues of diagnostics and classification of soils (in this case chernozem of Zmiiny Island) suggested for consideration and solving in this study remain topical within the framework of the soil science and practice. It was ambition to solve these issues that usually spurred the soil science development heretofore. And the approaches, principles and criteria employed to study, systematise and classify soils still play the pivotal role. Two lines of activity (approaches) still dominate in the international system

of soil diagnostics and classification; either of them can be used depending on the prioritised principles and criteria of soil diagnostics and classification.

The first approach implies the factor-genetic classification of soils introduced by the founder of pedology, V.V. Dokuchaev (Dokuchaev, 1948). Having defined soil as a natural independent body with a specific origin, history of development and external appearance on the land surface, as well as a product of extremely complex interactions of the effects of natural and economic factors, he reasonably believed that it was certain combinations of these factors that were responsible for the formation of relevant genetic types of soils. In particular, chernozem is a zonal soil type for the steppe zones, though its profile thickness varies with certain changes in weather and climate conditions and with regard to one or another relevant relief feature and type of parent soil. For instance, chernozems spread over loess are thicker than those over eluvium of dense rocks, although the configuration profile of chernozem is typical in both cases.

The second approach is the substantive-genetic classification which has been developed and applied predominantly in foreign soil science and practice, particularly in the WRB classification system. This classification approach is based on the substantive-genetic characteristics of soil, namely diagnostic genetic horizons, their material-and-chemical composition and features, as well as quantitatively defined properties, which results from soil formation under given environmental and ecological conditions, though they may essentially manifest themselves in other biomes.

International cooperation and understanding between soil scientists, as noted above, are impossible without comprehensive system for communication. The World Reference Base for Soil Resources (WRB), which forms the basis for the global level of knowledge generalisation in soil science, is commonly recognised as such a working language for soil classification. The first official version of WRB was released at the 16th World Congress of Soil Science in Montpellier in 1998; the second publication was presented at the 18th World Congress of Soil Science in Philadelphia in 2006, and the third edition of this soil classification (World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps, 2014) was published in 2014.

The correlation between national classifications and WRB was the subject of the studies of T.A. Romanova (2004), V. S. Stolbovoy and B.V. Sheremet (2000), P. Charzynski (2006), S.M. Polchina (2005), M. Polupan et al. (2005) and G.S. Ivanyuk (2016).

In Ukraine, most soil scientists traditionally adopt the factor-genetic approach in soil research, diagnostics and classification. However, in recent decades, they tend to shift from purely factorial-genetic approach to soil diagnostics and classification to increasing involvement of their substantive-visual and analytical characteristics (Ivanyuk, 2017; Krasilnikov, 2009, etc.).

With regard to the above, the aim of our study is to characterise the specificity of the genetic origin of the island soils and determine their diagnostic and classification criteria, including those adopted in the World Reference Database for Soil Resources (WRB).

Matherials and methods of research. This paper analyses specificity of the formation of the island chernozem, their specific morphological features, material-and-chemical composition and properties, as well as trends of current evolutionary changes, using methodological principles of process-genetic paradigm and results of many-year soil genetic research carried out since 2003-2005. The data presented in this paper have been obtained from a considerable amount of field and laboratory studies and analytical research, as well as from mapping soils and soil landscapes. It includes studying of environmental and ecological conditions on Zmiiny Island, factors and processes of soil formation, geography of soils, in particular chernozems, their morphological and genetic peculiarities, material-and-chemical composition and properties. The research activities were performed using methods of the field, laboratory and analytical research, as well as mapping of soils involving aerial and space images of landscapes, generally accepted in soil-geographic practice. The main methods of soil genetic studies on the island were comparative-geographical, profile-morphological and comparative morphostructural-analytical.It should be only noted that the survey of the environmental and ecological conditions of the island landscape and chernozems covered nine key localities and six landscape transect profiles (including soil-vegetation-orological ones) on different geomorphologic-gypsometric and exposure-slope levels of the surface.

Results and their analysis. Zmiiny Island is the only dome-shaped remnant of a plate of rocks of Paleozoic age in the Black Sea, a plot of natural preserved land for hundreds of thousands of migrating and local birds. The island is formed by dense siliceous (acid) rocks of marked hardness (conglomerates and breccias, quarzites made of metamorphosed quartz arenite, etc.), which crop up widely and cover from

5-10 to 35-50% of the territory area, and even more in sloping areas(Manyuk, 2004). The weathering crust of dense rocks tends to be thin (not thicker than 25-40 cm) and it is very stony. The island is located in the region experiencing moderate continental climate with long hot summer and short mild winter. The annual precipitation is about 300-350 mm while evaporation reaches 800-1.000 mm. The east- and south-facing slopes receive 5-10% to 15-20% more solar radiation. Hence, the moisture supply in the north- and west-facing hillsides on the island is higher than in the south- and east-facing ones. Almost all year round, mineral salts – mainly, sodium chlorides and sulphates - biophile elements, nitrogen and phosphorus compounds are delivered to the island surface in atmospheric precipitation, as well as harvested from either rock deposits or directly from the sea (Bilanchyn et al., 2013).

Substantially intact steppe vegetation of mixed herbs and grasses covers the surface areas between juts of dense rocks over 75.5% of the total island area. The total biomass of herbaceous phytocoenosis in the areas of better moisture supply in the west- and north-facing areas of the territory, at flattened bottoms of hills and bottomlands reaches 70-85 t/ha, up to 110 t/ha. However, within the boundaries of xeromorphic east- and south-facing areas of the territory, it is 3-4 (5) times smaller (Leonidova, 2013). About 60-70% of the grass biomass is concentrated in the soil turf horizon Hd and the ground layer of the steppe litter mat Hc.

The bulk mass of grass roots is concentrated in regularly moistened to a mean depth of 15-25 cm and less stony upper humus accumulation horizon of the Hq or H profile. We have established an extremely high ability of the island steppe herbaceous phytocoenosis, in particular their surface organogenic horizon Hc + Hd and upper humus-rich horizons of soils, to accumulate an atmospheric moisture which plants use exclusively for the biomass production. The surface runoff, and especially the sub-surface runoff, in the areas with herbaceous vegetation cover is reduced and short-lived, hence the soil erosion processes are less likely to occur here (Leonidova, 2013; Leonidova and Bilanchyn, 2017).

Based on the groundwork laid by V.V. Dokuchaev (1948) onthe chernozem formation theory, as well as on the materials of studyingthe environmental conditions as the factors of soil formation conducted by us, it becomes clear that environmental and ecological conditions of the island are favourable for the formation of soils of this particular chernozemic type. First of all, this means fairly luxuriant steppe herbaceous vegetation beneath which the soil turf horizon Hd and the ground layer of the steppe litter mat Hc are formed and wherein 60-70% of the total biomass is concentrated. After vegetation die-off, considerable amount of its biomass is transformed into humic substances. Every-year seasonal variability in the spring and early-summer period of optimal moisture supply, mineralisation and humification of organic residues; duration of summer and autumn drying-out of soil and diapauses in grass development; coagulation, conservation and accumulation of newly formed humic substances – they all contribute to the humus formation and thickening, as well as formation of chernozems. And as a result of gradually increasing thickness of the surface organogenic horizon Hd+Hc beneath substantially intact steppe herbaceous vegetation of the island, the newly formed chernozems also enhance with time (Bilanchyn, 2011; Leonidova, 2017).

At the same time, the results of our investigations indicate a number of specific features of the chernozem formation on the island, primarily associated with peculiarities of the environmental factors of soil formation. The morphology, substance-and-chemical composition and properties of the island soils were defined and are still governed by rather thin stony weathering crust of dense acid rocks. Shallow thickness of the soil-forming substrate is a natural obstacle for the formation of extensive plant root system, and hence soils with thick profiles. Therefore, immature and shallow chernozems with a thickness of humus horizon up to 25 cm and 25-45 cm, respectively, have been formed on this island (Fig. 1). Such features as gravelly-and-stony profile and acidity which increase towards the lower layers, normally sandy-loam and sandy-granulometric texture of fine-grained soil, the absence of carbonates and base depletion were inherited by the island soils from parental rocks.

The island chernozems are characterised by a quasiuniform-dynamic salinity regime which depends on the weather and climate conditions, as well as on the atmospheric-chemical processes occurring throughout a year. The fraction of readily soluble salts in the surface soil turf horizon Hd is the most abundant (in average 0.3-0.4%) in the soil profile. Apparently, it is not just atmospheric moisture that is accumulated here, but also salts delivered in atmospheric precipitation and directly from the sea. The salinity over the soil profile is quite non-uniform either within the island territory or geomorphic-hypsometric levels of the surface; the most frequently it equals 0.15-0.20 to 0.30-0.40%.

Unlike chernozems spread over loess in the Southern Ukraine, the island chernozems are poorly

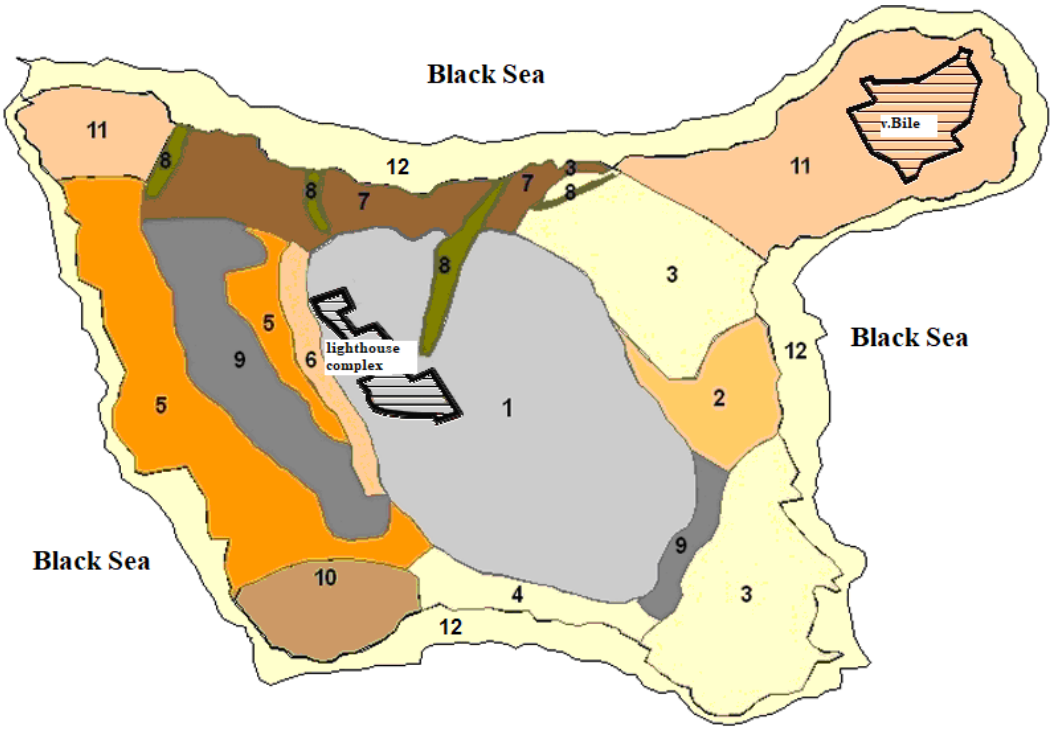

Fig. 1. Diagram map of the Zmiiny island soils
(*compliers – Y. M. Bilanchyn, P. I. Zhalatntai, M. I. Tortyk, A. O. Buianovskii, I. V. Leonidova)*

Legend

The level (zone) of the vertex-watershed comb-shaped plateau and near-watershed declivous slopes

1 - Short-profile chornozems in combination with non-fully developed chornozems 30-50%, and juts of dense rocks and their coarse-grained placers up to 10-20%

The level (zone) of the slopes

The slopes of the eastern, north-eastern and south-eastern expositions

2 - Non-fully developed chornozems in combination with short-profile chornozems up to 30%, slightly eroded*, with juts of dense rocks and their coarse-grained placers 20-30%

3 - Non-fully developed chornozems with juts of dense rocks and their coarse-grained placers exceeding 50%

The slopes of the southern exposition

4 - Non-fully developed chornozems, slightly eroded*, with juts of dense rocks and their coarse-grained placers 10-20%

The slopes of the western exposition

5 - Non-fully developed chornozems in combination with short-profile chornozems up to 20%, slightly eroded*, with juts of dense rocks and their coarse-grained placers 10-20%

6 - Non-fully developed chornozems, slightly eroded*, with juts of dense rocks and their coarse-grained placers up to 20-30%

The slopes of the northern exposition

7 - Short-profile chornozems in combination with non-fully developed chornozems 30-50%, slightly eroded*, with juts of dense rocks and their coarse-grained placers 20%

8 - Alluvial meadow chornozems on the bottom of the basins

The level (zone) of deluvial and accumulative areas in the elevation of slopes

9 - Short-profile chornozems in combination with non-fully developed chornozems 10%, and juts of dense rocks and their coarse-grained placers around 10%

The level (zone) of the ancient sea terraces

10 - Short-profile chornozems in combination with non-fully developed chornozems 30-50%, and juts of dense rocks and their coarse-grained placers around 10%

11 - Non-fully developed chornozems with locally weak erosion* and juts of dense rocks and their coarse-grained placers around 30-50%

The level (zone) of coastal steep slopes and gorges

12 - Exits of dense rocks and their coarse-grained placers with fragments of primitive soils on rocky-gravel substrate

** NB: Manifestation of erosion is likely in case of disturbance or erection of the cover of steppe grass vegetation.*

micro-aggregated and practically unstructured. It is likely due to the alkalinity of chernozems and low level of coagulating agents in structural "glues", in particular Ca humate (HA-2 fraction), which plays a critical role in the formation of soil structure and its water-holding capacity (Ponomariova and Plotnikova, 1980).

A specific feature of the physical and chemical characteristics of the island soils is their (high) acidity, which increases downwards in the soil profile. For instance, pH_{SOL} of lower horizons of almost all examined cross-sections of the island chernozems is below 4, while hydrolytic acidity reaches 20-30 (and even 35) mmol·eq/100 g that is only consistent with the relevant values of very acid brownified soils of the Carpathians. The base (alkali) saturation percentage in the lower horizons of the soil profile is just 30-40% while it is above 50% in the upper horizons, which can be due to the maximum abundance of the absorbed bases, including calcium which is the most likely of a biogenic origin, in the upper (root-containing) horizons.

The results of the examination of the humus status of the island soils are noteworthy indeed (see the Table below). These results show very high humus content in the upper humus-accumulative horizons (from 10-12 to 15-18%) and downwards in the soil profile (5-8 to 11%). The total nitrogen level features ubiquitously above 1% of the total fine-grained soil mass; the humus carbon to nitrogen ratio C:N is 7-8 which is indicative of high humus enrichment with nitrogen. Such unusually high total nitrogen content in the investigated soils is likely to result from advancing accumulation of this element in the biological cycle processes and also from its delivery in the litter of numerous species of the local ornithofauna to the island surface under conditions of low rate of its bioconsumption (Bilanchyn et al., 2008). The humic to fulvic acid ratio C_{HA}/C_{FA} tends to range within 2.5-3.3 which is quite typical for the soils of chernozemic type.

Meanwhile, the fractional composition of humus in the specified soils differs markedly from the humus composition in the chernozems spread over loess. In particular, the HA-1 fraction, which consists of free (newly formed) and bound with one and a half oxides of Fe and Al brown humic acids, dominates distinctly in the humus composition, making 65-75% of the total humic acid content in the upper horizons and increasing to 80-84% downwards in the soil profile. Such abnormally high content of the HA-1 fraction in the island chernozems may be associated with active interaction between the newly-formed humic acids and young oxides of Fe and Al, which are products of the weathering of acid dense rocks of the soil mineral base (Bilanchyn et al.,2009). It is the most likely that the afore-described factors along with increased levels of the relevant fractions of fulvic acids (FA-1 and FA-2; Leonidova and Bilanchyn, 2017, pp. 116 and 119) are responsible for such a high acidity of the island soils.

Another specific feature of the studied soils is unordinary law content or an absence of humus level of dark-brown humic acids bound with calcium (the HA-2 fraction), which are typical for chernozems. A very low concentration of this fraction (usually 1-2 to 3-4%) has been only found in the upper humus accumulation horizons while it is absent in the layers downwards in the soil profile. In our opinion, it can be due to insignificant amount of calcium involved in the biochemical cycle on the island as this element is virtually absent in the rocks forming its surface. With increasing rate of the biological cycling of chemical elements and chernozem formation, the upper soil horizons are enriched with calcium of biogenic origin; the amount of calcium adsorbed to the soil colloidal complex increases considerably, which is a prerequisite for the formation of the HA-Ca fraction in humus.

The results obtained in the study of optical properties of humic substances indicate relatively high optical density of humic acids which is typical for the soils of chernozemic type. As reported by M. Kononova (1963), high optical density of humic acids in chernozems is an indicator of high condensation of aromatic nuclei and low levels of side radicals carrying hydrophilic groups in their molecules. It is clear that the conditions of soil formation on the island, in particular alternation of spring and early-summer moistening and summer-autumn dry weather, favour the formation of humic acids of fairly complex structure and composition in chernozems. The optical density factor for humic acids in soils with relatively higher water availability in the western and northern parts of the island is slightly higher as compared to relatively more xeromorphic chernozems in the eastern part of the island. The optical density factors of humic acids decrease downwards in the profiles of almost all examined chernozems. Absorption spectral curves also become steeper with increasing depth; that indicates to the increase in the abundance of brown humic acids which is the most likely associated with the acid paternal rocks or simplification of their molecules under conditions of alkalinity and salinity of soils. The value $E^{0.001}_{4}$ in the upper horizons of the studied soils is 0.091-0.100, which gives grounds for their classification as southern chernozems with the signs of impact of acid soil-forming rocks, as well as alkalinity and salinity of soils (Kononova, 1963). This parameter of

Table. Morphology, chemical composition and properties of the Zmiiny Island chernozems

Profile, soil*	Horizon	Depth, cm	Skeletic content, % of mass	Physical clay	Total salts	Humus status indicators		$\frac{pH_{wat}}{pH_{sol}}$	Hydrol. acidity	Total absorbed base cations	Base saturation, %	Exchange Na^+, %
				% of the fine-grained soil mass		Humus	C_{HA}/C_{FA}		mmol·eq/100 g			
Geomorphic-hypsometric level (zone) of inland high plateau and close slopes												
O3-19, Ci	Hq	5-15	61.5	25.1	0.22	14.6	3.2	5.40 / 4.95	13.13	35.50	73.0	3.38
	Hpq	16-24	73.6	28.3	0.39	14.6	3.3	4.95 / 4.30	18.81	30.37	61.8	6.28
	Phq	24-34	76.9	32.2	0.72	10.9	3.5	4.30 / 3.70	22.75	24.63	52.0	10.96
Geomorphic-hypsometric level (zone) of slopes with an angle up to 3-5°												
O3-13, east-facing slope, Ci	Hq	4-14	70.1	25.2	0.15	17.9	2.4	4.75 / 3.80	24.06	23.30	49.2	3.56
	Hpq	14-23	85.8	25.1	0.15	15.1	2.5	4.15 / 3.28	35.00	19.10	35.3	8.48
	Phq	23-32	81.0	26.7	0.14	8.5	2.5	4.26 / 3.15	25.38	9.78	27.8	12.68
O3-16, south-facing slope, Ci	Hq	5-15	61.8	23.0	0.15	13.4	n/d	4.93 / 4.00	18.81	20.44	52.1	6.95
	Hpq	17-24	60.3	24.0	0.30	7.7		4.13 / 3.43	22.75	11.34	33.3	7.76
O3-20, north-facing slope, Cs	Hq	9-19	70.0	27.1	0.16	18.2	3.3	4.65 / 3.72	28.44	21.12	42.6	7.95
	Hpq	27-37	58.0	28.5	0.13	14.7	2.7	4.56 / 3.40	29.31	14.73	33.5	8.69
Geomorphic-hypsometric level (zone) of the diluvium-accumulative bottoms of the hillsides and bottomlands												
O3-15, bottom of slope, Cs	Htq	7-17	40.2	19.9	0.19	14.8	2.5	5.70 / 4.75	11.81	27.20	69.7	7.32
	Hq	20-30	46.6	28.2	0.41	14.0	2.9	4.55 / 3.85	22.31	20.77	48.2	5.58
	Hpq	33-44	52.5	19.2	0.50	12.8	3.0	4.40 / 3.75	23.19	20.87	48.4	5.17
	Phq	44-52	34.0	38.1	0.53	5.0	n/d	4.26 / 3.65	14.88	15.02	50.2	6.33
O3-17, bottom of slope, Cs	Hq	6-16	39.5	22.5	0.09	10.5		5.35 / 4.25	15.75	19.08	54.8	3.51
	Hpq	20-30	47.6	26.3	0.15	7.0		4.90 / 3.95	15.75	16.29	50.8	7.12
	Phq	40-50	44.0	35.5	0.14	4.1		4.98 / 4.03	10.06	14.80	46.2	6.28
O3-21, bottomland, Cm	H	6-15	38.1	38.1	0.16	12.3	1.7	5.78 / 4.85	10.94	34.41	75.9	4.74
	[H]	20-30	56.1	35.2	0.11	13.4	2.2	5.50 / 4.20	17.50	23.82	57.7	8.06
	[H]	40-50	56.0	35.7	0.15	13.5	3.6	5.25 / 3.86	24.94	22.92	47.9	13.66
	Hpqgl	60-70	65.0	40.9	0.09	5.9	n/d	5.30 / 3.85	13.13	15.46	54.1	13.78

* Soil type indices: Ci – chernozemic immature soil; Cs – chernozemic shallow soil; Cm - meadow-southern-chernozemic warp soil.

humus status of the island chernozems shows moderate to high values (Grishina and Orlov, 1978). The estimated values of the parameter are slightly higher for better moistened soils in the western and northern parts of the island with more favourable humus-formation conditions. The values of the parameter are lower for the soils of more xeromorphic east-facing slopes; this indicates not only to just worse conditions for the humus formation, but also to the higher level of brown humic acids in humus. The highest values of $E_4^{0.001}$(0.10-0.11) have been detected in the buried humus horizon H of the meadow-southern-chernozem warp soil at the bottom of the depression wherein under conditions of optimal moistening the conditions of humus formation and formation of humic substances typical for chernozems are also optimal. All cross-sections show this parameter decreasing with the profile depth, which is likely due to increasing content of brown humic acids associated with either growing impact of acid soil-forming rocks or simplification of humic acid molecules under conditions of alkalinity and salinity of soils.

The results of the investigation of the conditions of chernozem formation on Zmiiny island, their quite specific material-and-chemical composition and properties, enables us to present some considerations with regard to the nature and specificity of the genesis of these soils and criteria for their diagnostics and classification. Extensive root system of the steppe herbaceous vegetation, and hence thick chernozems, can hardly be formed here over thin stony non-carbonate weathering crust. Under such conditions, gradual accumulation of organics on the surface occurs, which results in gradual thickening of the soil profile, increasing granulometric composition and water-holding capacity, as well as higher content of humus and biophile elements in the surface horizons.

While the lower part ofthe island chernozem profile inherits to a certain extent the properties of parental rocks, the impact of these rocks gradually decreases upwards in the profile with increasing influence of soil turf and humus accumulation processes. The properties of chernozems gradually enhance in the island soils: the content of absorbed bases increases markedly; the HA-2 fraction is formed in humus; the stoniness and acidity decrease, and water-physical properties enhance. According to V.V. Ponomariova and T.O. Plotnikova (1980), it is the soil turf and humus accumulation process under conditions of the steppe biome that is responsible for the formation of carbonate horizon in the soil profile and that ensures the stability of the soils of chernozemic type. In our opinion, the soil formation on Zmiiny Island is an irreversible and continuous process which leads to the enhancement of the chernozem properties and characteristics, and the existing cover of the steppe herbaceous vegetation facilitates this process to a great extent.

The afore-mentioned results of our many-year study of the Zmiiny Island chernozems and specificity of their genetic origin, in particular their morphology, material-and-chemical composition and especially their properties, enable us to draw some conclusions about justification of diagnostics and classification of these soils as chernozems. First of all, it should be noted that diagnostics and classification of soils are two main lines of activities of the soil science and they are usually conducted simultaneously when studying soils. The profile method is mainly used to perform soil diagnostics; it implies examination of features and properties of the soil profile directly related to the processes of its genesis, further evolution and economic development. In particular, these are such features (parameters) as stage of maturity and degree of differentiation of the soil profile; accumulation or depletion of certain compounds and elements; the extent of transformation or alteration of soil-forming rock – they all serve as grounds for assumptions with regard to genesis and evolutionary processes, their tendencies and soil-genetic effects. Upon the results of diagnostics, soils can be assigned to one or another classification taxonomic unit, which is grouping soils by the conditions and genesis processes, profile configuration, key properties, thickness and specific features of fertility.

As diagnostics of any soil, as noted above, involves predominantly the analyses of characteristics, features and properties of its profile, the classification of the island soils as chernozems can be considered as fair lawful. The island soil exhibits a profile of typical chernozem humus accumulation type with characteristic genetic horizons, which is shallow yet very gravelly and non-carbonate within the entire bulk. However, as early as in 1948 in the classic monograph “Russian Chernozem”, V.V. Dokuchaev wrote about the possibility of formation of gravelly chernozems with shallow profile over dense rocks. He found out that chernozems were formed on the rocks of various types – loess, loess-like and light-clay loams, glacial and non-glacial clays, sandy- and clay-loam, limestone and marlstone, clay slates and other dense rocks. However, the structure, composition and properties of chernozems differ significantly depending on the rock on which they were formed. The classification of the island soils as chernozems within the national system of soil classification as of 2005 (Polupan et al., 2005), which is based on the

factor-genetic approach for the study and diagnostics of soils, is also justified.

Note that when classifying soils in accordance with the national classification system, it is necessary to specify additionally the lithological series assigned by the type and specific properties of the relevant soil-forming rock. In this case, the classification definition of chernozem should be extended with additional description "over alluvia or alluvium-deluvium of dense siliceous rocks".

At the same time, it should be noted that one of the objectives of this study is to determine a niche for classification of the Zmiiny Island chernozems within the World Reference Base for Soil Resources (WRB) which is the current international standard of soil classification. WRB is a reference database with elements of the hierarchy with certain formal boundaries (Polchina and Nichorich, 2006; World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps, 2014). The WRB classification is based on the substantive-genetic approach which employs a set of diagnostic horizons, properties and features of soils with clearly determined quantitative limits of the relevant parameters. The structure of WRB is two-level and non-hierarchical. The first level refers to reference groups of soils. The groups are clearly and formally separated from each other. At the second level of classification, the soil name is revised by adding the so-called qualifiers and specifiers for further extension of specification (Ivanyuk, 2017).

Thus, let us try to determine the position of the Zmiiny Island chernozems formed on dense acid rocks beneath the steppe herbaceous vegetation in the WRB classification system. According to the WRB classification, these are only soils that are formed on high-porous rocks (usually loess) beneath vegetation rich in grasses in the areas experiencing continental climate with cold winter and hot summer that can be classified as chernozems. Such soils are characterised by high humus content, neutral or nearly neutral reaction, and a carbonate (carbonate-accumulative) horizon which can be easily distinguished in their profile. Apparently, the island soils have specific genetic origin and differ distinctly from the classical chernozems as specified in the WRB system. These soils are shallow, gravelly-and-stony, not-carbonate throughout the entire bulk, acid, rich in humus of specific composition. Thus, it would be justified to assign these soils to the reference group of *Phaeozem* soils in the WRB system. According to Polchina and Nichorich (2006), phaeosems are soils of tall-grass steppe with moderate continental climate; they tend to be not-carbonate in their top layer of one-metre depth. Their profile is characterised by the presence of the surface mollic horizon of dark-brown to black colour, enriched with humus.

At the second level, qualifiers can be highlighted. The following qualifiers are characteristic for the island soil: *Leptic* as there are solid rocks within 100 cm from the soil surface; and Skeletic as it contains more than 40% (within the bulk) of coarse-grained fragments to a depth of more than 100 cm from the mineral surface of the soil. To revise the qualifier name, a specifier should be used. In this case, the specifiers Epi and Endo, which indicate the depth of the bedrock, are used to specify the Leptic qualifier. Therefore, we suggest classifying immature and shallow chernozemic soils of Zmiiny Island as Epileptic Phaeozem (Skeletic) and Endoleptic Phaeozem (Skeletic), respectively.

Conclusions

1. The Zmiiny Island chernozems have a specific genetic origin and are formed over shallow (usually 25-40 cm, up to 50 cm of depth) rocky-gravel weathering crust of dense acid rocks beneath the cover of substantially intact steppe herbaceous vegetation given the all year round supply of mineral salts, mainly sodium chlorides and sulphates. About 60-70% of the grass biomass is concentrated in the soil turf horizon Hd and the ground layer of the steppe litter mat Hc, which are able to retain moisture and, to a certain extent, readily soluble salts from atmospheric precipitation.

2. The morphology, material-and-chemical composition and some other properties of the island chernozems can be characterised by a number of distinctive features. These chernozems are shallow, gravelly and stony, not-carbonate, practically unstructured, acid, salinized to a different extent (from 0.15-0.20 to 0.30-0.40%), alkali (with Na content from 4-8 to 11-13%) yet without solonets-illuvial differentiated profile. The humus content in the upper soil horizons is very high (10-12 to 15-18%) with the humic to fulvic acid ratio C_{HA}/C_{FA} = 2.5-3.3 which is typical for chernozems. However, the HA-1 fraction dominates in the humus (65-75% in the upper horizons and 80-84% in the lower ones) while the level of typical chernozem fraction HA-2 is very low (1-2 to 3-4%) or is absent.

3. It has been suggested classifying immature and shallow chernozems of Zmiiny Island in accordance with the World Reference Base for Soil Resources (WRB) as Epileptic Phaeozem (Skeletic) and Endoleptic Phaeozem (Skeletic), respectively.

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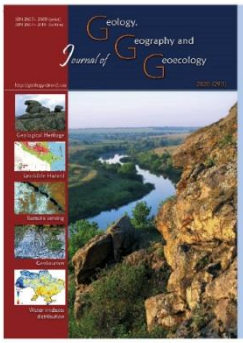

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Geoecological analysis of the impact of anthropogenic factors on outbreak of emergencies and their prediction

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Abstract.The purpose of this study is geoecological analysis of the risk of natural fires and other emergencies of an ecological nature based on the location of high-risk objects in the territory of the Kharkiv region. The following tasks were solved in the work: calculation of the risk of an ecologically dangerous event depending on the density of placement of objects of high danger in the region; Creation of a chart-map on the level of danger of environmental threat in the districts of the region; the search for the dependence of the area of forest fires on the density of the population, the number of high risk facilities, etc. An analysis of the influence of anthropogenic factors on the occurrence of natural fires on the example of the Kharkiv region was carried out. Distribution of potential risk and population density in the studied area allows us to obtain quantitative estimation of social risk for the population. Excessive population density in some areas of the region is one of the factors that increase the material and social risk of the territory and population of the region from natural disasters and man-made disasters. We created mapping zoning of multi-level districts of the region, the risk of an emergency reflects the patterns of spatial structure of potential sources of emergency situations and allows to increase the readiness of the executive and authorized services to act in the event of sudden emergencies and to act for their prevention. Available data allowed us to estimate the density of the placement of potential sources of man-made emergency situations for all districts of the region, which gives us the right, with a certain degree of conditionality, to speak about the extent of the technogenic danger of the territory of the studied areas of the Kharkiv region. We propose to apply a complex factor taking into account the population density, density of placement of objects of high danger and the proportion of high risk objects in the area of the forestry organization in comparison with the total number of objects in the region. For the simultaneous evaluation of both natural and anthropogenic conditions of forest fires in the region, we propose to use the methodology of scoring on which they are evaluated in a four-point system, taking into account the five main characterizing indicators : population density; forest area; the density of high risk facilities; climatic and weather conditions; the share of high risk facilities. Comparison of information on the average number of fires on the lands of the forest fund of Kharkiv region over the past ten years with the results of our typology of the areas shows some correlation. The results of studies on the assessment of the risks of the occurrence of fires depending on natural and anthropogenic factors can be used for zoning similar areas and forecasting the fire situation.

Key words: geoecological analysis, natural fires, risk of occurrence, man-caused loading, high-risk objects.

Геоекологічний аналіз впливу антропогенних чинників на виникнення надзвичайних ситуацій та їх прогноз

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Анотація. Мета даного дослідження – геоекологічний аналіз ризику виникнення природних пожеж та інших надзвичайних ситуацій (НС) екологічного характеру на основі розміщення об'єктів підвищеної небезпеки на території Харківській області. У роботі були вирішені наступні завдання: розрахунок ризику виникнення екологічно небезпечної події у залежності від щільності розміщення об'єктів підвищеної небезпеки (ОПН) у регіону; створення картосхеми за рівнем небезпеки екологічної загрози за районами області; пошук залежності площі лісових пожеж від щільності населення, кількості об'єктів підвищеної небезпеки та ін. Проведений аналіз впливу антропогенних факторів на виникнення природних пожеж на прикладі Харківського регіону. Розподіл потенційного ризику і щільності населення в досліджуваному районі дозволяє отримати кількісну оцінку соціального ризику для населення. Надмірна щільність населення в окремих районах області є одним з чинників, що підвищують матеріальний і соціальний ризик території і населення регіону від стихійних лих і техногенних аварій. Створено картосхему районування різнорівневих районів регіону, ризик надзвичайної ситуації відображає закономірності просторової структури потенційних джерел НС і дозволяє підвищити готовність виконавчої влади і уповноважених служб до дій при раптовому виникненні НС і до їх попередження. Наявні дані дозволили нам оцінити щільність розміщення потенційних джерел техногенних НС для всіх районів області, що дає право з відомою долею умовності говорити про міру техногенної небезпеки території вивчених районів Харківського регіону. Нами запропоновано застосовувати комплексний коефіцієнт, що враховує щільність населення, щільність розміщення ОПН та долю об'єктів підвищеної небезпеки у районі розташування лісгоспу у порівнянні із загальною кількістю даних об'єктів у регіоні. Для одночасної оцінки і природних, і антропогенних умов виникнення лісових пожеж в регіоні нами пропонується використовувати методику бальної оцінки, по якій вони оцінюються за чотирибальною системою з урахуванням п'яти основних показників, що характеризують: щільність населення; лісистість території; щільність ОПН; кліматичні і погодні умови; частка ОПН. Зіставлення інформації про середню кількість пожеж на землях лісового фонду Харківської області за останні десять років з результатами проведеної нами типізації районів показує певну їх кореляцію. Результати досліджень з оцінки ризиків виникнення пожеж в залежності від природних і антропогенних факторів можуть бути використані при зонуванні аналогічних територій і прогнозування пожежної обстановки.

Ключові слова: геоекологічний аналіз, природні пожежі, ризик виникнення, техногенне навантаження, об'єкт підвищеної небезпеки.

Introduction. Currently very few studies focus on geoecological analysis of the impact of antropogenic factors on occurrence of emergencies. One of them is the study by Y.A. Andreev (Andreev, 2003), which contains results of study of patterns of ignition of technogenic and naturally-driven wildfires. Modeling and assessment of factors, both technogenic and natural character, are essential for development of methods for preventing emergencies of pyrogenic character (Vacchiano, Foderi, Berretti, Marchi, 2018).

Among the anthropogenic factors, we should note technogenic and social (Fig. 1). Social risk and danger of fires was assessed in a study (Borisova, 2017) on the example of Buryatia.

In one study (Andreev, 2003), the author attributes ignition of wildfires to weather conditions, the population and number of inhabited localities per unit area. We think that such an approach is worthy of attention, but more effective would be the study of the number of fires relative to density of the population rather than the absolute number of inhabitants. Furthermore, values and functions of inhabited settlements can significantly vary. The most probable occurrence is the ignition of fires on the high-risk facilities or potentially dangerous objects. In particular their number should be taken into consideration for assessment of risk of emergency, including of pyrogenic character.

The objective of this study was geoecological analysis of risk of ignition of wildfires and other emergencies of ecological character on the basis of location of high-risk facilities in the territory of Kharkiv Oblast.

For achieving the goal, the following tasks were solved: assessment of risk of ecologically dangerous events depending on the density of location of high-

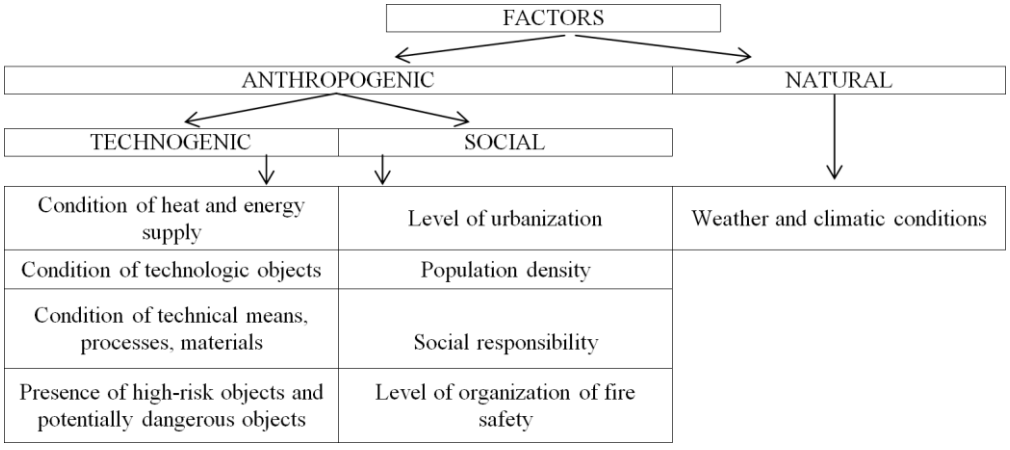

Fig. 1 Factors of ignition of wildfires

risk facilities (HRF) in the region; developing a map-scheme by the level of danger of ecological threat by the districts of the Oblast; search for dependence of the area of wildfires on density of population, number of high-risk facilities, etc.

Materials and methods. The authors conducted a geoecological analysis of the impact of anthropogenic factors on ignition of wildfires on the example of Kharkiv region. Distribution of potential risk and density of population in the studied district allows one to obtain quantitative assessment of social risk for the population. Excessive density of population in certain districts of the Oblast is one of the factors which increase the material and social risk of natural disasters and technogenic catastrophes for the territories and the population of the region (Buts, Asotskyi, Kraynyuk, Ponomarenko, 2018; Buts, 2018, Krainiuk, Buts, 2018, Buts, Asotskyi, Kraynyuk, Ponomarenko, 2019). We developed a map-scheme of zoning of different-level districts of the region, risk of emergency reflects the patterns of spatial structure of potential sources of emergencies and allows one to increase the readiness of the executive power to counter and prevent sudden emergencies.

Because wildfires are the leader among the emergencies, we performed a geoecological analysis of risk of potential emergency of ecological character on the basis of location of high-risk objects in the territory of Kharkiv Oblast and compared the obtained results with possible dangerous events of a pyrogenic character. In total, according to the state register of HRF, 381objects are located in the territory of the region, and 9,382 in Ukraine.

The risk of an ecologically dangerous event occurring depends on the density of locations of HRF in region. For all the districts of the Oblast, coefficient *f* (density of threat objects in the territory) was calculated, indicating the area for each HRF (Tables 1, 2).

Density of hazardous objects in the territory was calculated for point objects per unit area (km^2). By the density of hazardous objects in the territory, with a certain degree of accuracy, one can state the probability of emergency of technogenic character. The greater the density, the higher is the likelihood of emergency.

Results and their analysis. On the basis of the analyzed parameters, we performed grouping of the districts of the Kharkiv region according to the level of geoecological safety (Fig. 2). According to the calculations, the most dangerous districts were Kharkivsky district with a high-risk object every 11.3 km^2. In Derhachi and Chuhuiv districts one high-risk object is located per each 25.7 and 33.7 km^2 respectively. Using the provided data the authors produced a map-scheme of Kharkiv Oblast (Fig. 2), where this group of districts was coloured with red.

Pink colour-filled districts have HRF located every 70-83 km^2. This category includes Bohodukhiv and Zmiiv, Izium, Krasnohrad, Kupianskyi and Pervomaiskyi districts. Zolochiv, Balakliia, Lozova, Nova Vodolaha and Sakhnovshchyna districts are coloured in light green, having HRF located every 130-200 km^2. Other districts have the lowest density of HRF, i.e. one HRF per over 200 km^2. On average, one high-risk object is located in each 81.2 km^2 of the region.

For geoecological analysis of ecological danger, it is also expedient to take into account number of inhabitants in each district. For this purpose coefficient *d* was calculated (Table 1). The highest coefficient was determined for Iziumsky district with one HRF per every 935 people. Coefficients were also high for Kharkivsky, Chuhuiv and Kupianskyi districts with one HRF per every 1,379-1526 people. These districts have the largest circle chart on the map-scheme.

One HRF is located per 2,000 to 3,000 people in Sakhnovshchyna, Pervomaiskyi, Lozova, Derhachi and Bohodukhiv districts, indicated with smaller charts. Even smaller charts mark Velykyi Burluk, Dvorichna, Zachepylivka, Zmiiv, Zolochiv, Krasnohrad, Nova Vodolaha, Sakhnovshchyna districts, in which one HRF is located per every 3,000-6,000 inhabitants. Other districts are marked by the smallest chart, because there one HRF is located for each 7,000 inhabitants. In general, across the region, one high-risk object for 2,811 people is located.

Risk of emergency in one of the considered objects was estimated as ratio of number of HRF in the district to the total number of similar objects in the territory of the entire country (Table 1). The highest risk was determined for Kharkivsky district – $1.2 \cdot 10^{-2}$, the lowest in Kolomak district – $1.0 \cdot 10^{-4}$. In general, risk of technogenic emergency in Kharkiv region is high, equaling $4.0 \cdot 10^{-2}$.

The present data allowed us to estimate the density of location of potential sources of technogenic emergencies for all districts of the oblast, therefore, with a certain degree of conditionality indicate the level of technogenic threat in the territory of the studied districts of the Kharkiv region.

Let us compare the obtained results with territorial structure of the Kharkiv Oblast Management of Forestry and Hunting Grounds) with division into forestries and area of forest fires (Table 2). We assessed the average area affected by fire for each forestry according to the statistics of the fires over

Табл. 1. Number of population and HRF in Kharkiv Oblast (distribution by districts)

District	Number of inhabitants, M Thou people	Number of high risk objects, n	Area S, km^2	Coefficient which indicates the are for each HRF, f=S/n, km^2	Coefficient which includes the number of population for each HRF, d=M/n	Risk of outbreak of emergency R=n/9382
Zachepylivka District	16.1	3	794	264.6	5.366	$3.2 \cdot 10^{-4}$
Kehychivka District	21.8	3	782.5	260.8	7.266	$3.2 \cdot 10^{-4}$
Nova Vodolaha District	34.9	9	1,182.7	131.4	3.877	$9.6 \cdot 10^{-4}$
Krasnohrad District	45.8	14	985.1	70.3	3.271	$1.5 \cdot 10^{-3}$
Sakhnovshchyna District	22.5	7	1,169.9	167.1	3.214	$7.5 \cdot 10^{-4}$
Vovchansk District	48.7	6	1,888.6	314.7	8.116	$6.4 \cdot 10^{-4}$
Balakliia District	84.6	13	1,986.5	152.8	6.507	$1.4 \cdot 10^{-3}$
Kupianskyi District	26	17	1,280.3	75.3	1.529	$1.8 \cdot 10^{-3}$
Borova District	17.8	3	875.3	291.7	5.933	$3.2 \cdot 10^{-4}$
Velykyi Burluk District	23.7	5	1,220.8	244.1	4.740	$5.3 \cdot 10^{-4}$
Zmiiv District	73	18	1,364.7	75.8	4.055	$1.9 \cdot 10^{-3}$
Zolochiv District	27.8	5	968.6	193.7	5.560	$5.3 \cdot 10^{-4}$
Valky District	32.6	2	1,010.5	505.2	16.300	$2.1 \cdot 10^{-4}$
Kolomak District	7.7	1	329.5	329.5	7.700	$1.0 \cdot 10^{-4}$
Derhachi District	94.9	35	900.1	25.7	2.711	$3.7 \cdot 10^{-3}$
Kharkivsky District	183	124	1,403.4	11.3	1.475	$1.2 \cdot 10^{-2}$
Chuhuiv District	46.9	34	1,148.6	33.7	1.379	$3.6 \cdot 10^{-3}$
Pechenihy District	10.5	2	467.5	233.7	5.250	$2.0 \cdot 10^{-4}$
Shevchenkove District	21.2	4	977.4	244.3	5.300	$4.2 \cdot 10^{-4}$
Bohodukhiv District	40.4	14	1,160.3	82.8	2.885	$1.5 \cdot 10^{-3}$
Krasnokutsk District	29.3	5	1,040.8	208.1	5.860	$5.3 \cdot 10^{-4}$
Izium District	18.7	20	1,553.5	77.6	0.935	$2.1 \cdot 10^{-3}$
Barvinkove District	24.7	3	1,364.5	454.8	8.233	$3.2 \cdot 10^{-4}$
Blyzniuky District	20.7	3	1,380	460	6.900	$3.2 \cdot 10^{-4}$
Lozova District	30.7	10	1,403.5	140.3	3.070	$1.8 \cdot 10^{-3}$
Pervomaiskyi District	48.2	17	1,194.5	70.2	2.835	$1.8 \cdot 10^{-3}$
Dvorichna District	18.8	4	1,112.4	278.1	4.700	$4.3 \cdot 10^{-4}$
Total	1071	381	3,0945.5	81.2	2.811	$4.0 \cdot 10^{-2}$

10 years (2008-2017). This value was compared with the number of inhabitants in the districts of forestry location (Fig. 3).

Also, we consider it practical to compare the data on density of the high-risk objects with images of forest fires, obtained using satellite monitoring (Krainiuk, Buts, Nekos, 2019).

Earlier, it was already noted that it would be possibly more expedient to study the number or area of fires not with respect to] the total population, but rather from the density of population, as we did. As shown in the chart 4, stronger correlation is seen between the area of fires and density of the population of a given district.

Technogenic load in the region was assessed on the basis of number of HRF in such way that impact of the technogenic constituent on ignition of forest fires was assessed according to this indicator (number of HRF). The obtained dependence of the area of forest fires on the number of HRF in the district is shown in Fig. 5.

The dependence between the area of forest fires

Table 2. Number of population and HRF in Kharkiv Oblast (distribution by districts)

Forestry	Average area of forest fires according to the data of 10 years (2008-2017) ha	Number of inhabitants, M Thou people	Number of high risk objects, n	Area of districts S, km^2	Area of forestry, thou ha	Density of population, people/km^2	Coefficient which indicates area for each HRF, f=S/n, km^2	Coefficient which indicates the number of population for each HRF, d=M/n	Share of HRF in district regarding their total number in the region D
Krasnohradsky (Zachepylivka, Kehychivka, Nova Vodolaha, Krasnohrad, Sakhnovshchyna districts)	22.22	141	36	4914.3	14.6	28.71	136.51	3.92	0.095
Vovchansky	1.72	48.7	6	1888.6	27.9	25.78	314.7	8.11	0.015
Balakliisky	7.50	84.6	13	1986.5	28.3	42.58	152.8	6.50	0.034
Kupianskyi (Kupianskyi, Borova, Velykyi Burluk districts)	37.70	67.5	25	3376.4	37.4	19.99	135.0	2.7	0.066
Zmiivsky	2.60	73	18	1364.7	32.3	5.35	75.8	4.05	0.047
Zhovtnevy (Zolochiv, Valky, Kolomak, Derhachi, Kharkivsky districts)	10.65	318.2	162	3643.5	48.4	87.33	22.4	1.96	0.429
Chuhuievo-Babchansky (Chuhuiv, Pechenihy, Shevchenkove districts)	7.84	78.6	40	2593.5	22.6	30.30	64.8	1.96	0.106
Hutiansky (Bohodukhiv, Krasnokutsk districts)	3.87	69.7	19	2201.1	31.1	31.66	115.8	3.66	0.050
Iziumsky (Izium, Barvinkove)	8.44	43.4	23	2918	53.0	14.87	126.8	1.88	0.061

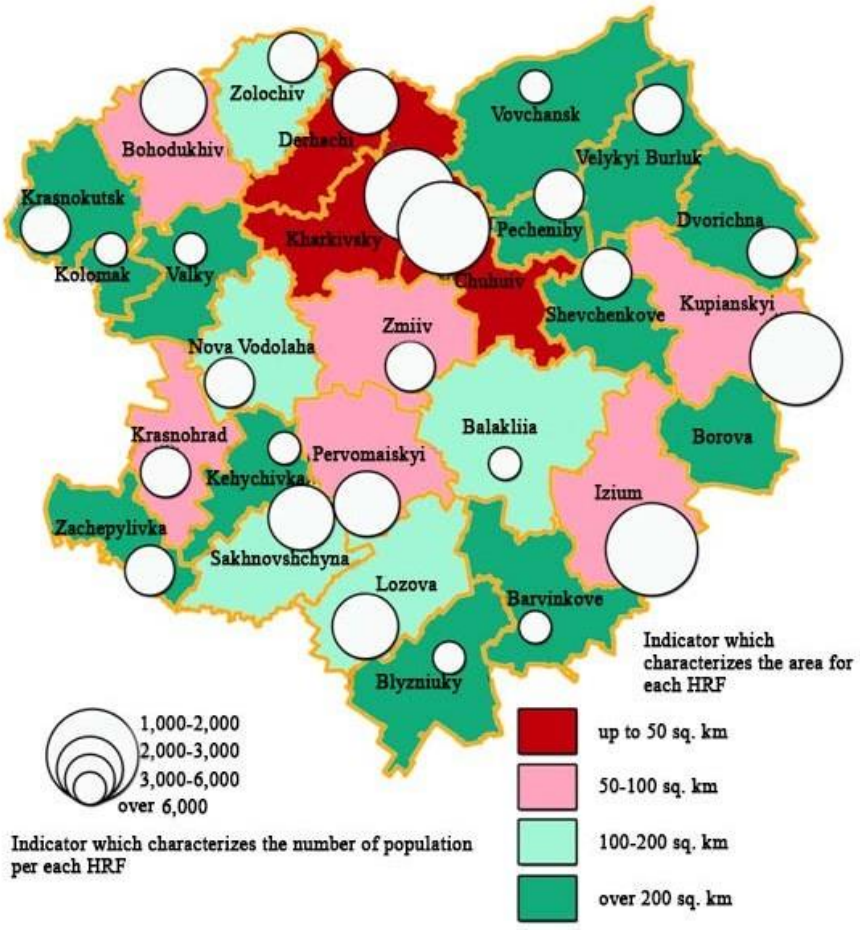

Fig. 2. Geoecological analysis of the level of ecological threat by regions of the Oblast

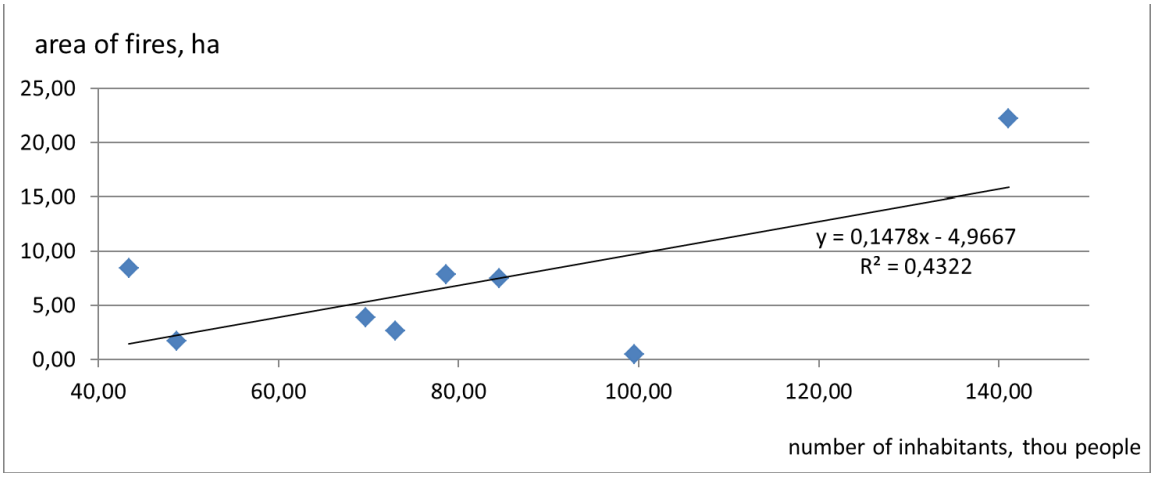

Fig. 3. Dependence of forest fires on the number of inhabitants

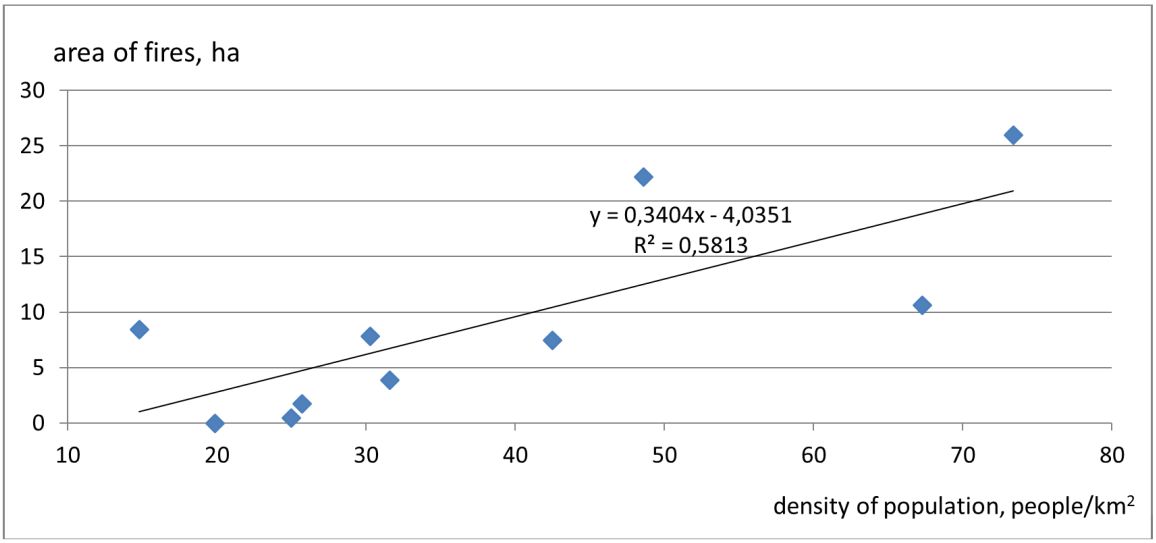

Fig. 4. Dependence of area of forest fires (ha) on the density of population

and density of HRF in district is shown in the same way (Fig. 6). Similarly to density of population, we observe stronger correlation.

We suggest using a complex coefficient which takes into consideration the density of population, density of HRF and share of HRF in the district of forestry compared to the total number of these objects in the region.

$$\mu = d \cdot f \cdot D, \quad (1)$$

Where μ – total coefficient which takes into consideration the technogenic load, d – density of population (people/km^2), f – density of HRF (objects/km^2), D – share of HRF in the total number of HRFs in the region.

Assessment of dependence of area of forest fires on this coefficient is shown in Fig. 7.

According to the presented calculations, quite good correlation is observed. Correlation coefficient equals 0.9.

Thus, the area of forest fires can be predicted using the formula:

$$A = 2.54 \cdot \mu + 2.12 \quad (2)$$

or

$$A = 2.54 \cdot d \cdot f \cdot D + 2.12 \quad (3)$$

where A – average area of forest fires in a forestry over a year.

Of course, the record of anthropogeic factors of forest fires is obligatory. According to Nikischenko N.G. (Nikischenko, 2007), the cause of 96.9% of forest fires is anthropogenic (i.e. social) factor, 2.1% – technogenic, and only 0.8% – natural. According to the statistics provided by Sobolev S.A. (Sobolev, 2006), 69% of forest fires are related to negligence with fires in places of the population`s recreation.

For simultaneous evaluation of both natural and anthropogenic conditions of ignition of forest fires in the region, we suggest using methods of point assessment, according to which, using a 5-point scale sys-

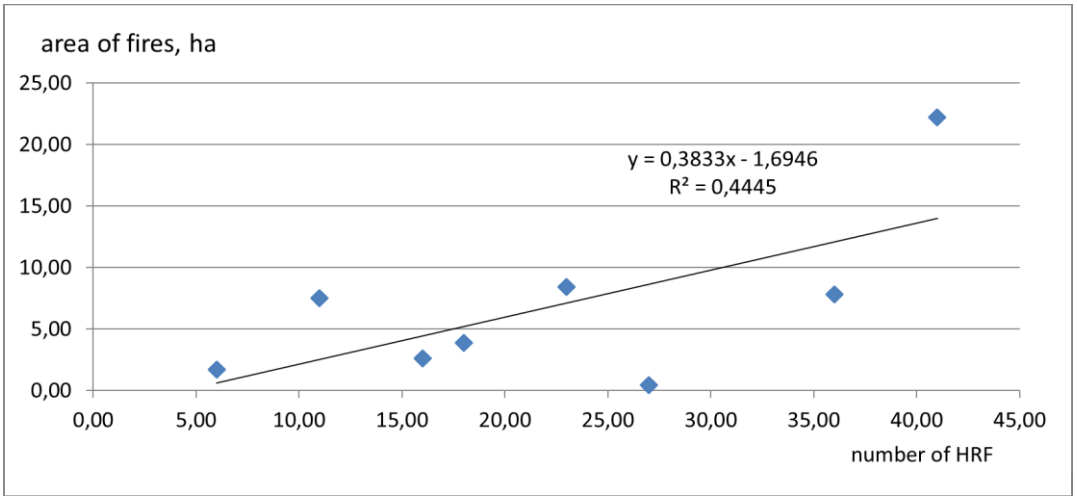

Fig. 5. Dependence of the area of forest fires (ha) on the number of HRF

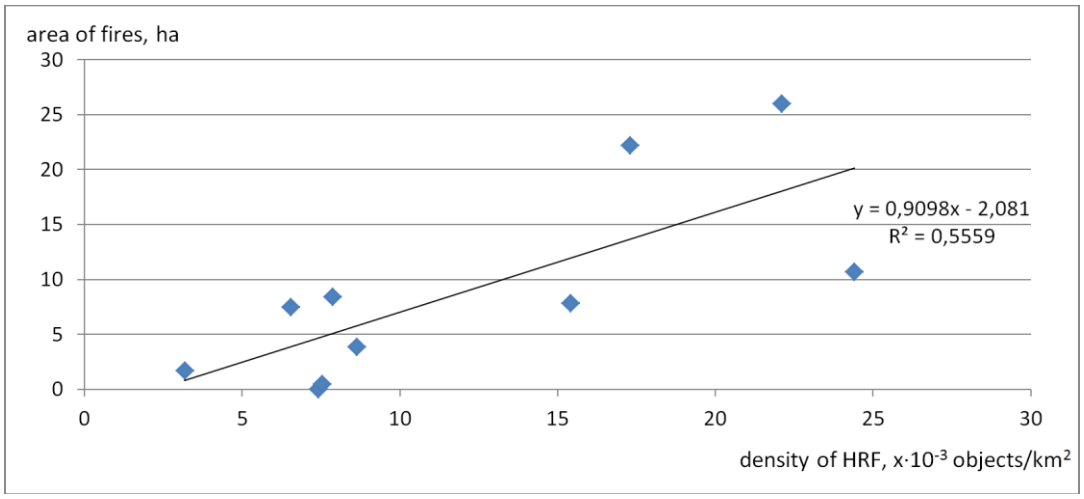

Fig. 6. Dependence of the area of forest fires (ha) on the density of HRF

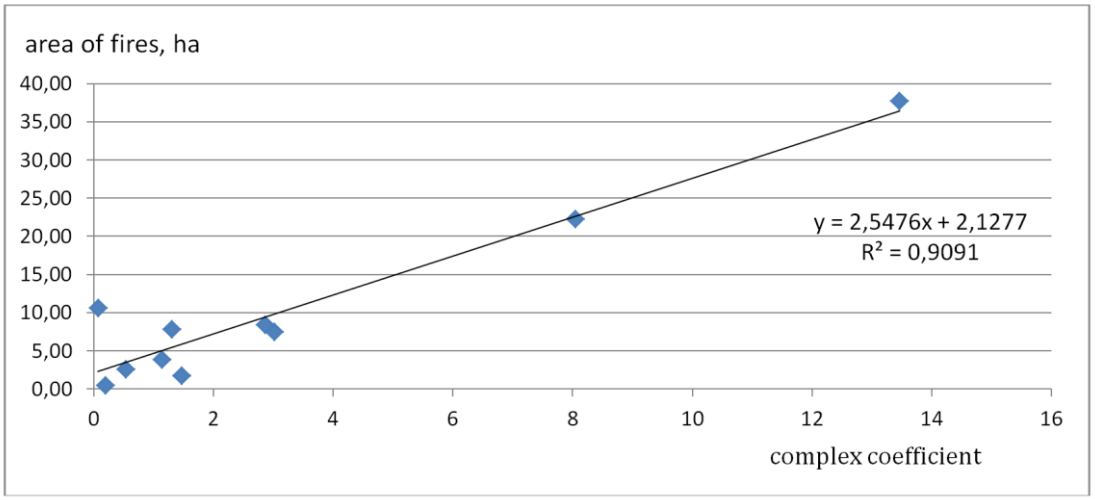

Fig. 7. Dependence of area of forest fires (ha) on the complex coefficient

tem, the five main parameters are taken into account. The five factors characterize:

Density of population;

Forest-cover of the territory;

Density of HRFs;

Climatic and weather conditions;

Share of HRFs.

As a result of studying the conditions of ignitions of forest fires in Kharkiv Oblast, we determined that the most significant are forest cover of the territories

Table 3. Assessment of the level of threat of ignition of forest fires

Level of threat	Points	Main factors				
		X_1	X_2	X_3	X_4	X_5
Extremely high	4	>41	>15	< 10	< 100	< 2,5
high	3	26–40	11–15	8–9	100–150	2,5–2,7
Moderate	2	11–25	5–10	4–7	150–200	2,6–3,0
insignificant	1	< 10	<5	> 4	>200	>3

Where X_1 – density of population, people/km^2; X_2 – forest area, %; X_3 – share of HRF,%; X_4 – area for each HRF; km^2; X_5 – ratio of amount of precipitations to the average air temperature in June-August.

Table 4. Determining integral indicator of forest fires and anthropogenic ignition of forest fires

Forestry	X_1	X_2	X_3	X_4	X_5	Integral parameter
Zhovtnevy	4	3	4	4	3	3.7
Chuhuievo-Babchansky	3	2	4	4	3	3.1
Kupiansky	3	4	2	3	4	3.2
Krasnohradsky	3	2	3	3	4	3.1
Balakliisky	4	3	1	2	3	2.95
Iziumsky	2	4	2	3	4	2.8
Hutiansky	3	3	2	3	3	2.5
Zmiivsky	1	4	2	4	3	2.4
Vovchansky	2	3	1	1	3	1.8

(λ = 0.3), and density of the population (λ = 0.3). To a less extent, the intensity of the fires depends on the share of HRF (λ = 0.15), area per one HRF (λ = 0.15), and also climatic factors (λ = 0.10). For each of the factors, we developed an assessment scale (Table 3).

As a result of summing up the points for the main factors, with consideration of the coefficients of their significance, for each administrative district, we determined an average value, an integral indicator of natural-anthropogenic condition of ignition of forest fires (Table 4).

These parameters allowed us to construct a geoecological typology of the administrative districts of Kharkiv Oblast distinguishing the areas with extremely high, high, moderate and low threats of ignition of forest fires in the lands of the forest fund.

As we determined, the highest such threat exists in the central part of the Oblast – in Zhovtnevy and Chuhuievo-Babchansky forestries, for they are located in the administrative districts with the highest density of the population and a high number of HRF. These territories are near the center of the region the city of Kharkiv and are characterized by dominance of pines, the most flammable trees, in the forest fund. Also, the highest threat was determined for Kupianskyi and Krasnohrad districts, in which over the last 10 years the largest area was damaged by fire (over 10% of the forest territory). A high threat of forest fires was determined also in Balakliisky, Iziumsky forestries. In those territories, the density of the population which uses the forest for recreation is also high. In the rest of the territories of the Oblast the threat of forest fires is much lower (Table 4).

Comparing of the data on the average num- ber of the fires in the lands of the forest fund of Kharkiv Oblast over the last ten years with the results of the typologisation of the districts, which we made, shows their certain correlation. Thus, for the districts with quite a high threat of ignition of forest fires and integral indicator higher than 3, the average area of forests damaged by the fires over the last 10 years is over 7%; with high threat (2.6–3.0

Table 5. Results of geoecological typologisation of lands by the conditions of ignition of forest fires and their factual number in Kharkiv Oblast (2008-2017)

Types of administrative districts by threat of ignition of forest fires	Integral indicator	Area, %	Integral parameter of threat	Area of forests damaged by forest fires over the 10 recent years, %
1. Very high threat	> 3	58.37	3.3	7.7
2. High threat	2.6– 3.0	19.70	2.9	2.1
3. Moderate threat	2.0– 2.5	14.32	2.5	1.0
4. Relatively low threat	<2	7.58	1.8	0.6

points), the area of the territories damaged by the fires - 2.1%; with moderate threat (2.0–2.5 points) – 1% of the territory damaged, low (below 2 points) – 0.6% (Table 5).

Conclusions. Geoecological analysis of the risk of ignition of forest fires and other emergencies of ecological character on the basis of location of the high-threat objects in the territory of Kharkiv oblast and depending on the ecological and anthropogenic factors can be used in geoecological zoning of similar territories and predicting emergencies.

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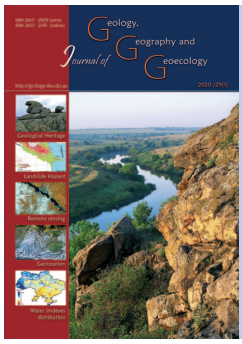

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Heritage objects as a resource for the development of tourism within the states and territories of Australia

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Abstract. The article discusses the Australian heritage sites as a resource base for the introduction of new tourist destinations. The relevance of the study of Australian tourism resources related to the increase in tourist flow, the prospects for the development of various types of tourism and the growing interest Ukrainian tourists are taking in this country is substantiated. The significant tourist potential of the country, the uniqueness and specificity of its components are highlighted: natural (primarily, vegetation and wildlife, as well as relief and climate), historical and cultural objects.It is noted the historical and cultural potential deserves to be in greater demand, because a large number of objects of historical and cultural heritage retain and disseminate authentic information about the historical past of the country, its ethnic, cultural characteristics and traditions. The purpose of the work is to explore the distribution of various heritage objects within the states and territories of Australia as an important resource for the development of various types of tourism. The database of the research is the information from the Australian Bureau of Statistics and the website of the Ministry of Environment and Energy. The paper analyses and assesses the number, composition, and degree of diversity of heritage sites and theirlocations on the territory of administrative units. The study was completed using methods of mapping, geographical analysis, information analysis techniques, namely the calculation of the entropy index. It was found that the regions of Australia provide outstanding diverse and unique resources, which creates preconditions for the development of new tourist destinations and the further growth of the tourism industry. The states and territories with the largest number and diverse composition of heritage sites and significant potential opportunities for the development of various types of tourism are identified. It was noted that Australia is a new active tourist destination for Ukrainian tourists that has significant prospects. Inaddition to the classic excursion routes and visits to wildlife parks, there are popular combined routes such as: excursion program with a beach holiday; combination of excursions with active tourism; professional training programs for agricultural workers combined with visiting heritage sites and beach recreation.New tourist routes are associated with the development of author's tours with a unique program in accordance with the features of the country and the wishes of tourists and the wider use of the country's historical and cultural heritage.

Key words:New tourist destinations, Australia, natural and historical-cultural heritage sites, tourist resources, entropy index, assessment of availability.

Об'єкти спадщини як ресурс розвитку туризму штатів та територій Австралії

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Анотація. В статті розглянуто об'єкти спадщини Австралії як ресурсної бази для запровадження нових туристичних напрямків. Обґрунтовано актуальність дослідження туристичних ресурсів Австралії, пов'язану зі збільшенням туристичного потоку, перспективами розвитку різних видів туризму та зростанням зацікавленості українських туристів до цієї країни. Підкреслено наявність значного туристичного потенціалу країни, унікальність і специфічність його складових - природних (насамперед, рослинності і тваринного світу, а також рельєфу та клімату) та історико-культурних об'єктів. Наголошено, що натепер історико-культурний потенціал затребуваний значно менше, ніж він на те заслуговує. Адже велика кількість об'єктів історико-культурної спадщини зберігають і поширюють автентичні відомості про історичне минуле країни, її етнічні, культурні особливості та традиції. Мета роботи - дослідження поширення різноманітних об›єктів спадщини в межах штатів і територій Австралії як важливого ресурсу розвитку різних видів туризму. Інформаційною базою дослідження є дані австралійського бюро статистики та сайту міністерства навколишнього середовища та енергетики. В роботі виконано аналіз та оцінку кількості, складу, ступеню різноманітності об'єктів спадщини та їх розміщення на території адміністративних одиниць. Дослідження здійснено з використанням прийомів інформаційного аналізу та методу картографування. З'ясовано, що регіони Австралії забезпечені видатними різноманітними й унікальними ресурсами, що створює передумови подальшого

розвитку туристичної індустрії, розробок нових туристичних напрямків. Визначені штати і території з найбільшою кількістю та найрізноманітнішим складом об›єктів спадщини та, відповідно, значними потенціальними можливостями для розвитку різноманітних видів туризму. Наголошено, що Австралія – це новий туристичний напрямок для українських туристів, який активізується і має значні перспективи. Окрім класичних екскурсійних маршрутів з відвідуванням парків диких тварин, популярними є комбіновані маршрути: з екскурсійною програмою та пляжним відпочинком, поєднанням екскурсій з активним туризмом, професійні навчальні програми для працівників сільського господарства поєднані з відвідуванням об'єктів спадщини та пляжним відпочинком. Нові туристичні маршрути пов'язані з розробкою авторських мандрівок з унікальною програмою відповідно особливостей країни та побажань туристів і більш широким використання історико-культурної спадщини країни.

Ключові слова:нові туристичні напрямки, Австралія, природні та історико-культурні об'єкти спадщини, туристичні ресурси, показник ентропії, оцінка забезпеченості.

Relevance of research. According to one of the most popular tourist resources "Lonely Planet" Australia has become one of the top tourist destinations in the world in 2019 (Best in travel. Lonely Planet, 2019). Tourists from around the world are strongly attracted by this exotic country. The more experienced among Ukrainian tourists have traveled sufficiently around Europe, Africa, Asia and are paying more and more attention the rather remote, but exotic and interesting destination Australia. The Ukrainian tourist market offers new tourist destinations in Australia, which requires a detailed study of tourism development resources.

Millions of tourists come to Australia, including Ukrainian ones, who are attracted mostly by a unique animal and plant world, which they have learnt about at school. Historical and cultural potential is much less in demand, although the list of heritage objects is dominated by historical and cultural objects(Department of the Environment and Energy. Australian Government, 2019). Therefore, the study of Australian states and territories is relevant especially in the aspect of the availability of heritage objects which is an important condition for the development of tourism. It is important to study not only the quantity but also the composition, the degree of heritance diversity.

Issues of international tourism are covered in works of O. O. Lubitseva, O. O. Beidyk, M. P. Malskaya, N. V. Antonyuk, Ye. V. Pankova, N. M. Ganich, and in works of foreign scientists like V.S. Senina, A. Yu. Alexandrov, V. Yu. Voskresensky, L. M. Gaudukevich, Godfrey Harris, Kenneth M. Kau and others. However, most of them cover the general issues of international tourism. More narrow topics, regarding the tourist potential of Australia, especially its historical and cultural achievements, have not been sufficiently studied.

The purpose of work is to study the distribution of various heritage objects within the states and territories of Australia as an important resource for the development of various types of tourism.

The material and methods of research. The Australian Bureau of Statistics and the website of the Ministry of Environment and Energy data was used as the information base to assess the state and territory ownership of the heritage objects as tourist resources (Australian Bureau of Statistics, 2019; Department of the Environment and Energy. Australian Government, 2019).

We have made a geographic analysis of the natural, historical and cultural objects in the national heritage list of Australia that are important for the nation and indigenous peoples. The register includes indigenous heritage sites, flora and fauna species, state-designated sites in certain states and regions, as well as valuable underwater objects and landscapes. The Indigenous State Agency or the Australian Environmental Agency are usually responsible for reservation of these objects. This data is open and available on the official site(Department of the Environment and Energy. Australian Government, 2019).

The registry contains detailed information about each object of national heritage, like geolocation, a short history of occurrence, a summary of the economic and social properties associated with the object, current and past use and areas for further research in order to preserve the object. When developing new tourist destinations, we have taken into account only those objects, which are nominated for including in the list of national heritage.

In our work, we studied the legal prerequisites for the reservation and usage of valuable national heritage sites, international environmental protection documents, the Australian Environmental Protection and Conservation Act (EPBC) , other federal laws and regulations , Australian National Long-Term Tourism Strategy (Australia's National Landscapes Program, 2019; Parliament of Australia, 2019; Tourism 2020. The National Long-Term Tourism Strategy, 2019). These documents contain the basic principles of conservation, tools for the management of national heritage and create the legal and scientific basis for scientific research.

In the research we used methods of mapping, geographic analysis, methods of information analysis, particularly the entropy index calculation.

Presentation of the main research material. Australia records the growth of the tourist flow. Accord-

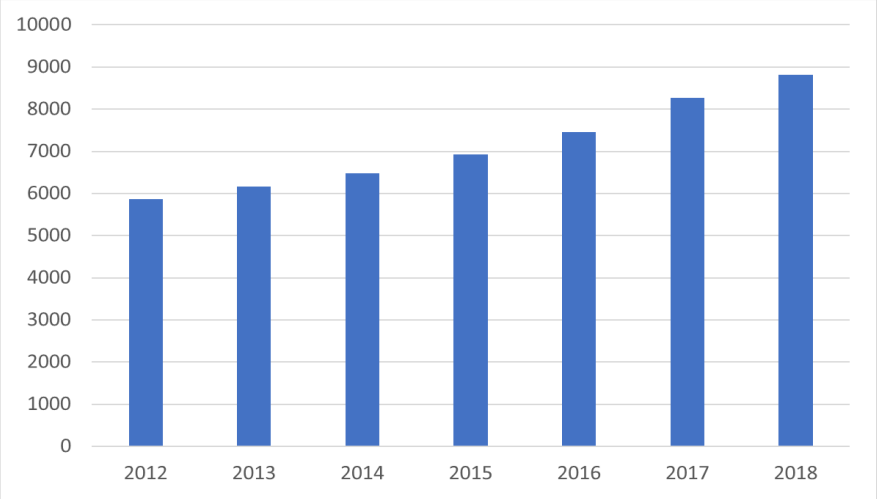

Fig. 1. Number of foreign tourists visiting Australia for the year, th.
Source: the data retrieved from the official websiteAustralian Bureau of Statistics

ing to the Australian Bureau of Statistics (Australian Bureau of Statistics., 2019) the number of arrivals on the continent increased from 5.1 million in 2006 to 8.8 million in 2018. The vast majority of tourists visit the eastern territories and most income from tourists is spent there. Australian Bureau of Statistics, 2019; Tourism Australia Corporate Website.,2019; Tourism Research Australia, 2019) (Fig. 1, 2).

The effective study of various types of monuments and the definition of their possibilities of use is impossible without the development of appropriate classification systems, primarily those that reflect the fundamental specificity of the objects being studied.

For the development of the classification of historical, cultural and natural heritage sites in Australia, we took into account the provisions of the Ukrainian Law "On the Protection of Cultural Heritage", the methods of O. O. Beidyk, O. Lyubitseva, P.O. Maslyak, V.I. Stafiychuk, E. F. Pankova, N. V. Fomenko, L. P. Tsaryk, G. V. Chernyuk, etc., certainly taking into account the peculiarities of the Australian approach to the counting and classification of objects of the inheritance (Department of the Environment and Energy. Australian Government, 2019; Ljubiceva O.O. 2002; Gavryljuk L. O., Gorbyk V. O. (ker.), Denysenko G. G., Kot S. I., Piskova E. M.,

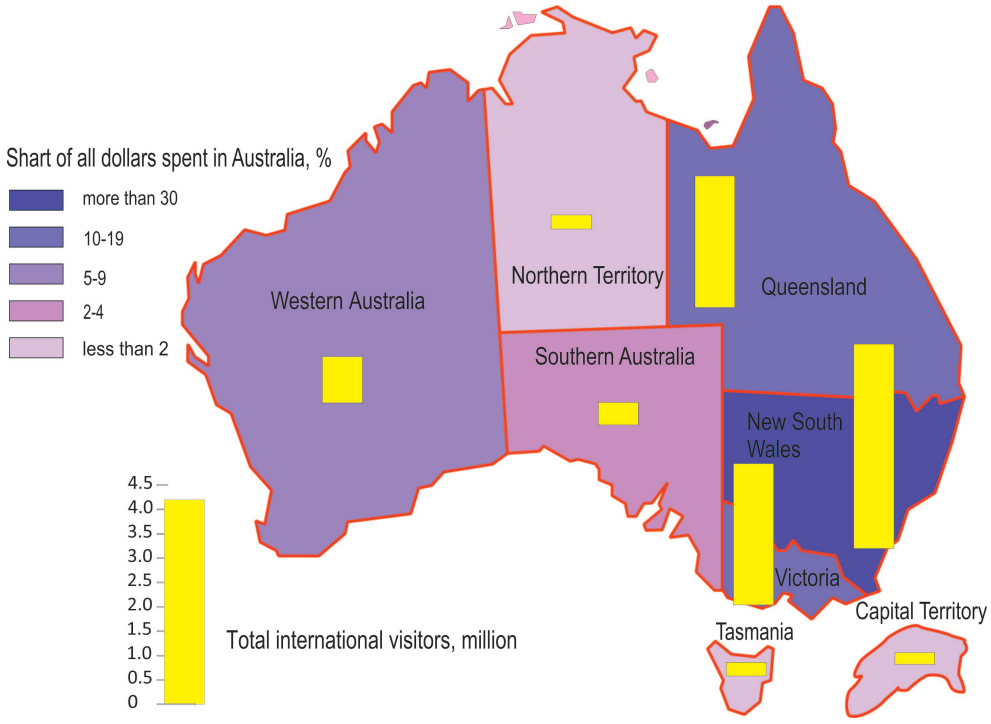

Fig. 2. Number of foreign tourists visiting states and territories of Australia for the year, ths.
Source:the data retrieved from the official websiteTourism Research Australia and Tourism Australia Corporate Website

Table 1. Classification of Heritage Objects in Australia: types and kinds of objects. Source: the data retrieved from the official website Department of the Environment and Energy

Types of Heritage Objects	Kinds of Heritage Objects	Total Objects
Natural objects	nature reserves, national parks, coastal, reefs, marine regions, islands, archipelagos, lakes	64
Garden and park complexes	botanical gardens, national rose gardens and park complexes near parliament and palaces	8
Art objects	galleries, opera houses, exhibition centers	8
Administrative objects	post offices, houses of parliament, courts, residences of ambassadors, headquarters, mint, universities, colleges	230
Infrastructure objects	bridges, lighthouses, roads, airports, offshore fuel stations, dams	60
Religious objects	monasteries, cathedrals, chapels	5
Military objects	military training zones, defense areas, barracks, prison barracks, millitary complexes, military training zones	41
Economic and public objects	regional radio stations, shops, mines, underground industrial facilities	23
Memorial objects	memorials to the victims of wars	6
Archeological objects	artistic aboriginal landscapes, mammal fossils, national dinosaur monument	8

Skrypnyk P. I., Fedorova L. D. 2011; Zakon Ukrai'ny «Pro ohoronu kul'turnoi' spadshhyny», 2019).

As a result, categories of heritage objects (UNESCO heritage objects, heritage objects of the Commonwealth, objects of national heritage), as well as types of objects were identified (Table 1, Fig. 3, 4).

In general, there are 452 UNESCO, the Commonwealth and National Heritage sites in all states and territories of Australia (Table 2). Note that historical and cultural objects predominate in the category of the Commonwealth and National Heritage, while there are 16 natural objects out of 19 objects in the UNESCO heritage list.

Many natural objects make up the resource base for classic excursion routes throughout the country. These are nature reserves and national packs with unique flora and fauna, oceanic coasts, coral reefs, sea zones, picturesque islands and archipelagoes, lakes. Also included in the tourist routes are landscape gardens - botanical gardens, national rose gardens and park complexes near the parliament and palaces.

Among the historical and cultural heritage sites, tourist attractions are predominantly artistic - galleries, opera house, exhibition centers. In addition, the aboriginal art landscapes, fossil sites of mammals, the national dinosaur monument are included in the

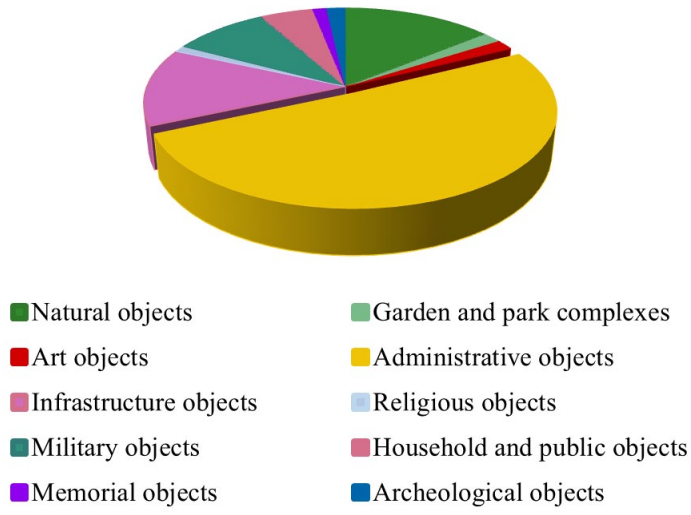

Fig. 3. Composition of heritage objects of Australian. Source: the data retrieved from the official website of the Department of the Environment and Energy

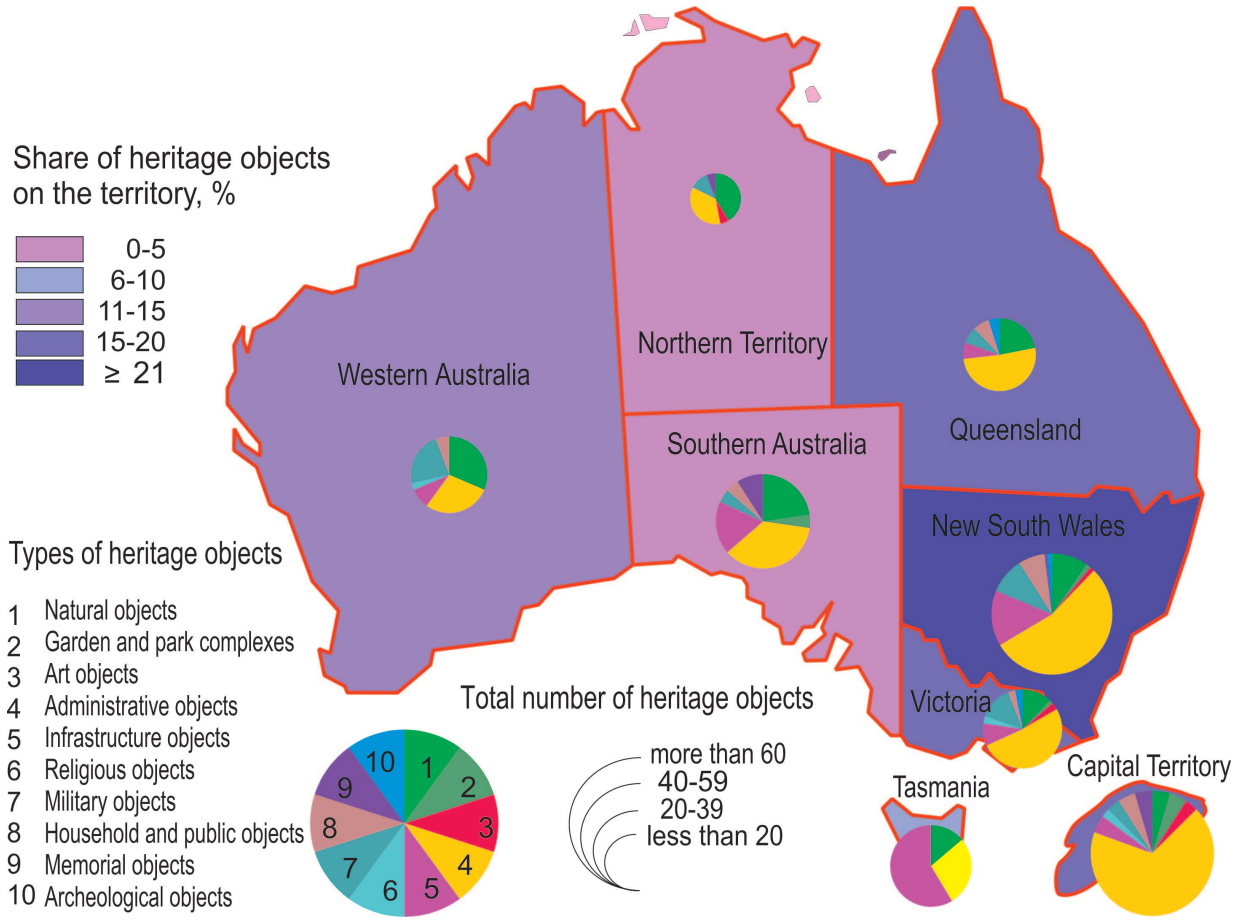

Fig. 4. Composition of Australian State and Territory heritage objects.
Source: the data retrieved from the official website of the Department of the Environment and Energy

tourist routes. However, the largest group consists of objects which we classified under the administrative type.

For tourism development, not only the quantity but also the variety of objects visited by tourists is of great importance. To assess the degree of diversity of heritage objects, which also affects the tourism potential of the territory in general, we used methods of information analysis, the indicator of entropy in particular, calculated by the formula:

$$E(A) = -\sum_{1}^{n} \omega_l \log_2 \omega_l,$$

where ω_l - the proportion of objects of a certain kind, and n - the number of kinds.

The function of mass entropy has the following properties. For n = 1, that is, the phenomenon is homogeneous. In our case, only one type of object is present, so it is converted to zero. E (A) increases with the increase in the number of types and has the maximum value E (A) max in case of equality of probabilities that is the equality of the particles of all types of objects.

The results of the performed calculations are represented in Table 2.

Australia's overall entropy index is 1.88, which indicates a significant diversity of objects on its territory.

According to the calculations, the states and territories were grouped into 3 groups according to the entropy index. The first group includes areas with low entropy (1.61-1.76) - Capital Territory, Western Australia, Northern territory, Tasmania. The territories included in the second group are those with with the average entropy (1.80-1.83): Queensland and New South Wales. The third group includes only one region Southern Australia, which has the highest entropy index (1.88-2.18).

There is an interesting feature: those states which have the largest number of objects have entropy rates below average. This is due to the geographical features and to the historical past of the states. Understandably most of the old buildings and other historical and cultural objects have remained on the territories where cities began to be built earlier and where the capital was. As a result, there is a significant predominance of administrative objects (Fig. 4), which reduces

Table 2. Indicators of entropy and the number of heritage objects in Australian states and territories. Source:the data retrieved from the official website of the Department of the Environment and Energy and author's calculations

Name of state (territory)	Indicator of entropy	Number of objects
New South Wales	1.83	155
Capital Territory	1.61	87
Victoria	1.82	66
Queensland	1.80	41
Western Australia	1.75	35
Tasmania	1.75	29
Southern Australia	2.18	22
Northern territory	1.76	17
Australia	**1.88**	**452**

the entropy. Most of the natural objects were assigned to different categories of heritage during the period from 1983 until now until now which led to a lower number of them being indicated and an increased rate of entropy as a result. Natural objects are mostly preserved their pristine condition, for example, the rainforest of Tasmania and the natural complexes of the modern Blue Mountains National Park.

The maps we have created (Fig.4, 5) also show a certain discrepancy between the indicator of entropy and the number of heritage objects in the administrative units of Australia. Thus, states with a large number of heritage objects, such as New South Wales (155) and Metropolitan Area (87), have an average and low entropy index due to the significant dominance of administrative objects in them. It should be noted that, in spite of the significant number of one of the heritage types, there are almost all the types of objects in these states and territories and the overall diversity is higher than in South Australia which has the highest index of entropy with the smallest number of heritage objects. However, because the number of different types of objects in the state is approximately the same, the rate of entropy here has been high. A similar situation is observed in other states and territories of Australia and the country as a whole (Table 2, Fig.4, 5).

The most popular Australian regions among foreign visitors are New South Wales, Victoria and Queensland. At the same time, New South Wales got most of costs, received most of the tourist income, which increased by 11% to 10 billion dollars during five years, of which 9 billion dollars were spent in Sydney(Australia: Tourism and Travel.,2019; Australia: Tourism and Travel, 2019;Tourism Research Australia, 2019).

An analysis of the content of the sites of Ukrainian tour operators and airlines operating in the Ukrainian market (Bodotravel, Yana Luxury Travel, Voyage De Luxe Club, Mansana, Saga and other) was conducted, which allowed us to identify the main tourist destinations for tourists from Ukraine.

A variety of products that are in great demand are offered for Ukrainians by tour operators. The cost of such products is becoming more affordable for the domestic consumer and ranges from $ 2,790 to $ 6,500 and more. Group, corporate, individual and author's tours luxury category are organized with visits to natural, historical and cultural objects. The most popular trails include routes in which a beach holiday is combined with active and sightseeing tourism. Extreme recreational activities such as snorkeling on the Great Barrier Reef, a walk along the river of jumping crocodiles, hiking, diving with whales and others make it possible to experience new emotions and pleasure and at the same time explore the unique nature environment of Australia. Particularly attractive are safaris (more precisely, photo safari) in the Red Center, the tropical forest, the coral reef.

The classic destinations include excursions to wildlife parks, where you can feed the kangaroos and Tasmanian devils or enjoy the parade of penguins on Philippe island. Traditionally, tourists visit Tjapukai Aboriginal villages, feel the spirit of the gold miner's era at the Sovereign Hill open-air museum.

Professional tours are also popular among Ukrainians. For example, agrotours, in which professional training programs for agricultural specialists and farmers are combined with tourism programs. In addition to agricultural reviews of all the interesting segments of agriculture, adjacent industries, modern ecological farming enterprises, tourists have an opportunity to get acquainted with

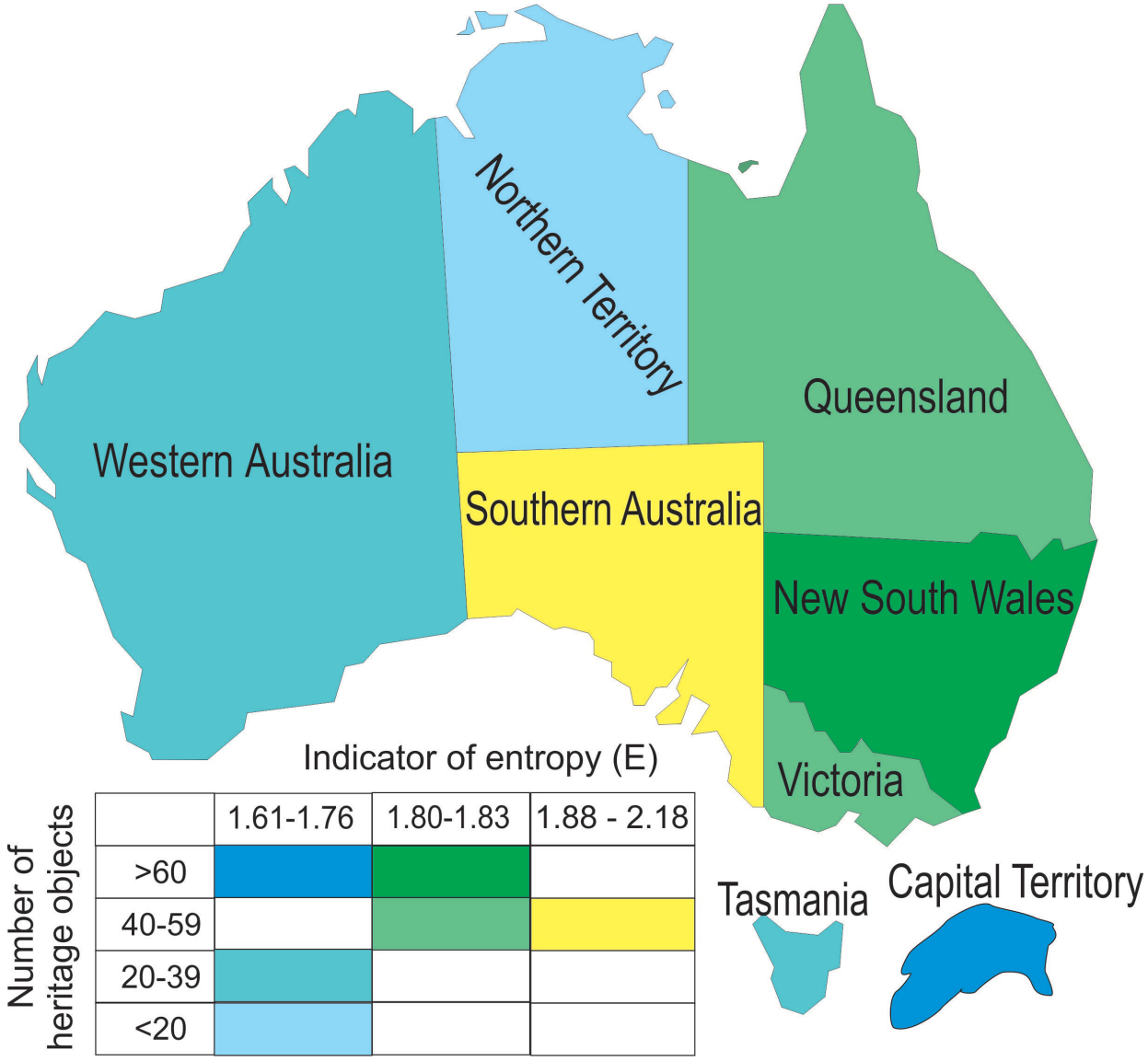

Fig. 5. Interrelation of number and variety of heritage objects. Source: the data retrieved from the official website of the Department of the Environment and Energy and author's calculations

heritage objects. The most popular among them are the Winery, Manjie and Hunter Winery in South Wales, the Royal Canyon in the Red Center with its unique scenery, as well as the Australian city-building traditions of Sydney and Melbourne (the Queen Victoria Building, Sydney Opera, Sydney TV Tower and many others).

It should be noted that new historical and cultural objects are more and more included in Australian touristic routes, which have natural objects predominating. We paid the most attention to their assessment in our study. In our opinion, they can be a resource base for expanding the range of tours.

Conclusions. Australia's tourist resources are diverse and unique, which creates a base for further development of the tourism industry. Australia is a new tourist destination for Ukrainian tourists, which has significant prospects. The routes that are particularly popular are combined ones with sightseeing programs and beach holidays, combination of excursions and active tourism, professional training programs for agricultural workers combined with visiting heritage sites and beach holidays. New tourist routes are connected with the development of author's trips with a unique program in accordance with the country's characteristics and the wishes of tourists and wider use of the country's historical and cultural heritage.

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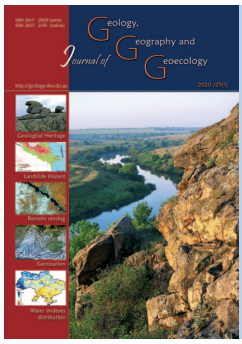

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Human-induced load on the environment when using geothermal heat pump wells

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Abstract. The research is aimed to study the process of change in temperature mode dynamics for the Earth subsurface layer when heat is extracted with geothermal heat pump systems, reveal and disclose specifics of effect on the ecology caused by technologies using geothermal resources and give practical recommendations regarding further development of methods for designing heat pumps using low potential heat energy of soil based on the long-term forecast and efficacy assessment. Mathematical statistics and mathematical model methods were applied for assessment of economic and environmental effects. Methods based on principles of the theory of thermal conductivity, hydromechanics, theory of differential equations and mathematical analysis were applied for calculation of proposed systems and review of field observation findings. The authors had developed for research purposes an experimental geothermal heat pump system consisting of four structurally connected geothermal wells, each with installed U-shaped twin collectors of 200 m overall length, and a heat pump of 14 kW capacity with a heat energy battery for 300 L connected to the building heat-supply system. They also created a computer data archivation and visualisation system and devised a research procedure. The paper provides assessment of the effect caused by changes in the process operation mode of the heat pump system on the soil temperature near the geothermal well. As a result, the authors have found that the higher the intensity of heat energy extraction, the lower the soil temperature near the geothermal heat exchanger, in proportion to the load on the system. Moreover, it has been determined by experimental means that at critical loads on the geothermal heat exchanger the soil temperature is unable to keep up with regeneration and may reach negative values. The research also determined relation between in-service time and season of the system operation and temperature fluctuations of geothermal field. For example, it has been found by experimental means that the heat flow from the well is spread radially, from the well axis to its borders. Additionally, it has been proved that depending on the heat load value, the bed temperature is changed after the time of the first launch. For example, the geothermal field temperature has changed from the time of the first launch during 1-year operation by 0.5 °C in average. The research has proved that depending on the heat load value, under seasonal operation (heating only or cooling only) of the system, the soil temperature has decreased for five years by 2.5 °C and switched to quasi-steady state, meanwhile, stabilisation of the geothermal field in the state under 1-year operation (heating and cooling) occurred yet in the 2nd year of operation. In conclusion, the paper reasonably states that geothermal heat pump systems using vertical heat exchangers installed into the wells put no significant human-induced load on the environment. At the same time, still relevant are issues of scientific approach to development of the required configuration of the geothermal collector, methodology for its optimal placement and determination of efficacy depending on operation conditions.

Key words: human-induced load, geothermal well, heat pump.

Техногенне навантаження на довкілля при використанні теплонасосних геотермальних свердловин

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Анотація. Відомо, що геотермальні джерела енергії поділяються на петротермальні та гідротермальні. Геотермальні свердловини до 400 м використовуються в теплонасосних системах для забору теплової енергії з приповерхневих шарів Землі. У роботі виконано теоретичний аналіз впливу технологій використання геотермальних ресурсів на навколишнє середовище. Розроблено та сконструйовано експериментальну геотермальну теплонасосну систему. Проведені експериментальні дослідження із використанням геотермальних свердловин, та наведені практичні результати впливу відбору теплової енергії з приповерхневих шарів Землі на тепловий режим геотермального поля. Описані теплофізичні особливості притоку геотермальної енергії, яку генерують гірські породи до внутрішнього простору свердловин за відсутності процесу циркуляції в ній теплоносія на довгостроковому інтервалі часу. Виявлено та оцінено вплив зміни технологічного режиму роботи теплонасосної системи на температуру ґрунту навколо геотермальної свердловини та встановлено залежність тривалості та

сезонності експлуатації системи на температурні коливання геотермального поля. З'ясована залежність інтенсивності відбору теплової енергії геотермальними теплонасосними системами на регенераційні властивості геотермального поля. Доведено, що актуальним є питання наукового підходу до розробки необхідної конфігурації геотермального колектора, методології оптимального його розміщення й визначення ефективності в залежності від умов експлуатації. Обгрунтовано висновок, щодо екологічної безпечності використання геотермальних теплонасосних систем. З'ясовано, що актуальними залишаються дослідження температурного режиму навколо свердловинного простору при вилученні теплоти геотермальним теплонасосними системами з урахуванням літологічних особливостей робочого розрізу при збільшенні глибини свердловини. Отримані в ході дослідження дані мають важливе наукове і прикладне значення для подальшої розробки методики проектування теплонасосних геотермальних свердловин на основі довгострокового прогнозу й оцінки їх екологічної та економічної ефективності.

Ключові слова: техногенне навантаження, геотермальна свердловина, тепловий насос.

Introduction. One of the nowadays problems that are highly relevant for the world's society is need to determine the balance between satisfaction of current human demands and protection of interests of future generations. In Ukraine, as well as in many other countries of the world the impact of the power generation industry on the environment is associated with considerable emissions of pollutants from the companies of fuel and energy complex. One of the ways to ensure environmental security for the state may be the transfer to environmentally friendly technologies which is impossible without broad use of renewable energy sources. In climatic and geographical conditions of Ukraine, one of the promising areas of use of renewable energy, both for ecology and economy is application of heat pump geothermal systems (GTS) that use low-potential energy of subsurface layers of the Earth as a renewable energy source (Goshovskyi, Zurian, 2013).

To obtain primary energy, GTSs are equipped with heat exchangers installed in geothermal wells that all together set up an integrated system for extraction of low-potential renewable energy from soil.

Operational experience with geothermal wells shows that continuous extraction or discharge of heat energy causes considerable change in the soil heat balance. Change in the temperature background that is formed under long operation (GTSs) may result in significant change of the soil mass temperature (geothermal field) which is not immediately compensated by the background heat flows and has negative consequences for human-induced load on the environment (Saprykina, Yakovlev, 2016).

Review of recent researches and publications. The practical issue of using heat pump systems in Ukraine and worldwide where low-potential energy of subsurface layers of the Earth is used as a primary energy source is studied in a lot of research works. (Boyle, 2014; Tidwell, Weir, 2016; Morozov, 2017; Limarenko, Taranenko, 2015). The works of Shubenko, Kuharec, 2014; Morrison and others, 2004; Hepbasli, Kalinci, 2009 have proved scientifically that a heat pump itself as a component part of the heat pump system is an environmentally clear appliance with the principal function of transferring low-temperature energy from a renewable source to the building heat-supply system with the consumption-grounded values of temperature and capacity. The studies by Gao and others, 2008; Li et al., 2009; Nikitin et al., 2015 assumed that human-induced load on the environment and environmental hazard may be induced by thermalphysic processes that occur in the geothermal heat exchanger – soil system. The work by Chao et al., 2016 shows mathematical analysis of the soil heat balance. Based on digital-analytical simulation of the system, the study by Kordas, Nikoforovich, 2014 has revealed the interconnection of energy exchange processes between soil and heat-carrying agent of the geothermal heat exchanger under stable conditions. Besides, analytical calculations based on the mathematical model aimed to devise methods for forecasting the temperature field under operation of the geothermal well in various processing conditions were made in the studies by Saprykina, Yakovlev, 2017; Nakorchevsky, Basok, 2005; Filatov, Volodin, 2012. Krylov et al., 2015 have designed a laboratory bench and researched temperature changes near the well area using the experimental model. Review of the references showed lack of attention given to the experimental investigation of the environmental effect made by the geothermal well on the geothermal field under field operation of the GTS in terms of particular lithologic and geographical conditions. Research of the thermal field change dynamics is largely focused on mathematical calculations and experimental investigations with laboratory models which may not always give unbiased scientific information and requires for experimental confirmation in field conditions. In consideration of the above, it is required to find out the dynamics of changes in the temperature mode of the Earth subsurface layer under extraction of heat with geothermal heat pump systems under field operation of the heat pump unit, namely: describe specifics of energy in-flow from rocks to the inner space of the well without circulation of heat-carrying agent therein over the long time interval;

find out the impact of change in process operation mode of the heat pump system on the soil temperature near the geothermal well and describe deviations of temperature fluctuations of the geothermal field in connection to duration and seasonality of the system operation; determine the impact made by intensive extraction of heat energy with geothermal heat pump systems on regeneration abilities of the geothermal field; give practical recommendations regarding further development of methods for designing heat pumps using low potential heat energy of soil based on the long-term forecast and assessment of environmental impact and efficacy.

Research data and methods. Mathematical statistics and mathematical model methods were applied for assessment of economic and environmental effects. Measurements were made by means of temperature sensors, pressure sensors and amount of heat-carrying agent flow with direct readings and DC sensors with electrical data transfer.

Digital data were processed with MAXYCON FLEXY controller and the software using FDB open configurator by RAUT AUTOMATIK. Methods based on principles of the theory of thermal conductivity, hydromechanics, theory of differential equations and mathematical analysis were applied for calculation of proposed systems and review of field observation findings.

Findings and review. Geothermal resources are considered to included, first of all, thermal fluid and warmth of heated dry rocks.

Geological regions of Ukraine differ in geothermal conditions. For example, the Ukrainian Shield, the Southern slope of Voronezh mountain group (the Northern side of Dnipro-Donetsk cavity), Volyn-Podillia basin have very low geothermal gradients. The Black Sea cavity, Plain Crimea, Transcarpathian inner bay have higher gradients and are promising in the view of using the Earth warmth.

The Ukrainian Shield in whole is featured with the lowest geothermal gradients compared to other territory of Ukraine. From the geothermal point, it is studied almost exclusively in the areas of iron-ore deposits of Kryvyi Rig and Bilozerka. Average value of the geothermal depth for Kryvyi Rig which represents the area of the lowest geothermal gradients is 116.3 m per grad. Generally, geothermal depth indicators within the Ukrainian Schield vary from 90 to 185 m per grad rising, mainly, in the areas of large tectonic breaks (Fig. 1).

The Earth heat energy is a power resource. Geothermal resources of Ukraine at developed depths are described with thermalphysic properties of the Earth, namely, temperature and density of heat flow.

The geothermal energy source has diversified impact on the environment. Since geothermal resources are a renewable energy source, environmental sustainability must be their principal advantage. So that, firstly, geothermal power stations do not require for large land space; secondly, discharge waters are pumped out back to the well which allows to maintain environmental security of the region and stable production process; thirdly, geothermal power stations release much smaller amount of toxic substances into the atmosphere, for example, a geothermal station releases 0.45 kg of CO2 emissions per 1 mW□hour of produced power, while a thermoelectric power station that runs on natural gas releases 464 kg, 720 kg on fuel oil, and 819 kg on coal (Limarenko, Taranenko, 2015).

At the same time, geothermal power industry has its own disadvantages that can be summarised as follows: Firstly, action of mineralised geothermal waters and vapours; secondly, sinking of the earth surface located over the mined geothermal layer; thirdly, change of the underground water level, formation of sinkholes in soil, swamping; fourthly, gas emissions (methane, hydrogen, nitrogen, ammonia, hydrogen sulphide) and heat emissions into the atmosphere or surface waters; fifthly, contamination of underground waters and water-bearing layers, soil salting; sixthly, change of temperature fields of underground levels (Degtyarev, 2013).

Thus, in spite of allegedly simple and accessible use of geothermal energy, technical and environmental implementation of this method of power generation is a complex scientific technical issue.

Also, there has been particularly strong interest today in possible use of energy of subsurface layers of the Earth (at the depths up to 400 m) for heating systems both for residential buildings and industrial facilities using heat pumps (Limarenko, Taranenko, 2015).

Over 90% of the areas of Ukraine at the industrially accessible depths of 50 to 100 m below the Earth's surface level always maintain temperatures of 14 to 18 °C which can be classified as low-potential heat sources. This temperature range can not be utilised in the most production processes including the heating systems. In this connection, extraction of low-potential energy with heat pumps that allow with relatively low cost to obtain the required heat-carrying agent temperatures seems to be the most promising (Saprykina, Yakovlev, 2017).

Heat pumps with vertical soil heat exchangers (VSHE) that are PE pipes placed in the wells at the

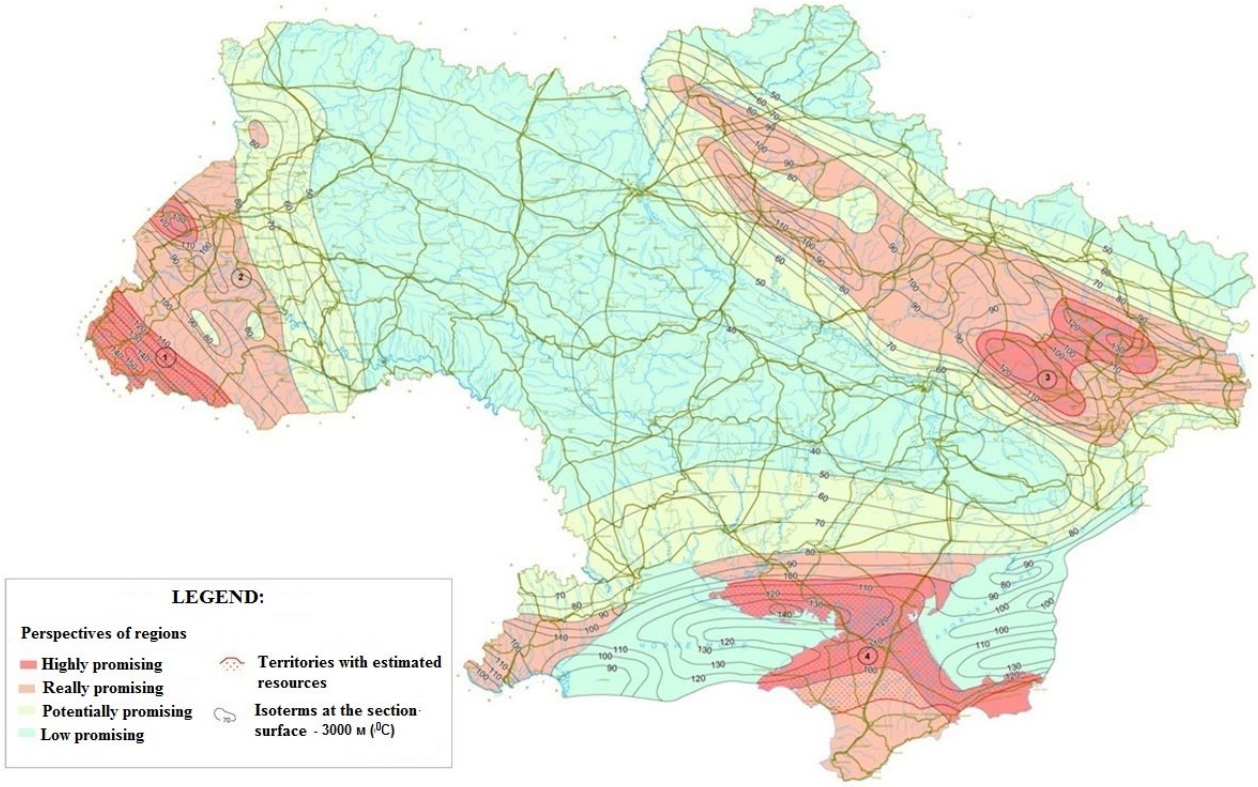

Fig. 1. Geothermal zoning of geostructures of Ukraine (made by the Ukrainian State Geological Research Institute, 2008)

depth of up to 400 m have been widely used. The space around them is filled in with special heat-conducting solution. The heat-carrying agent is heated in a VSHE and transfers its heat energy to an evaporator of a heat pump (HP), the vapour of which is condensed after compression in a compressor condenser. This process goes together with supply of extracted heat energy to consumers (Filatov, Volodin, 2012).

The principal advantage of a geothermal heat pump is its high performance which is achieved in result of a high energy conversion factor (ECF) for the heat pump (400% to 500%) which ensures that 4–5 kW of heat energy will be obtained for each 1 kW of consumed electrical power and thus allows for lower operational cost (Filatov, Volodin, 2012).

Introduction of heat pump technologies for heat production in Ukraine is one of the effective energy saving measures that allow to save fossil fuel and reduce pollution of the environment. Harmful emissions during heat pump operation are the ones generated where electrical power is produced. No harmful emission is produced right in the place of heat pump installation. Heat pumps with ECF equal to 3.0 compared with traditional boiler houses produce almost twice less emissions of nitrogen, sulphur, and carbon oxides than under operation on coal; more than 1.5 times less than under operation on fuel oil; and by 30% less than under operation on natural gas. (Goshovsky, S.V., Zuryan, A.V. 2017).

Operational experience of existing GTSs shows that we have no enough information regarding: a) impact made by extraction of heat energy from subsurface layers of the Earth with the geothermal well on regeneration processes near the well area over the long time interval (5-7 years); b) relation between in-service time and season of the system operation and temperature fluctuations of geothermal field; c) connection of unstable operation of GTS with termination of heat exchange between the well and geothermal field; d) impact made by intensive extraction of heat energy with geothermal heat pump systems on regeneration abilities of the geothermal field.

The temperature field is a complicated object both for a natural (experimental) and mathematical study and is regulated by variable limit conditions that depend on climate of the region, operation mode of the object, season, change of thermalphysic properties of soil, etc.

For the purpose of investigation of the temperature field around the vertical well, the **Ukrainian State Geological Research Institute** developed and installed an experimental geothemal heat pump system to extract heat energy. Principal diagram of the geothermal experimental heat pump system is shown in Fig. 2. The land-located part of the experimental power system consists of a heat power battery and heat pump elements with automation system.

The geothermal collector for collection of low-temperature heat energy is made of plastic pipe of 32 mm in diameter and consists of four heat exchangers coupled in parallel. The pipe length in each heat exchanger is 200 m. Total length of the collector is 800 m. Aqueous propylene glycol solution 25% ($C_3H_8O_2$) was used as a heat-carrying agent.

For the purpose of study, the complex included measurement equipment and management information system.

Measuring devices that include temperature probes and heat-carrying agent flow-rate sensors are installed both in land-based and underground parts of the complex.

The temperature sensors (resistance thermal converters) TSP-204 were used for temperature measurements in the check points. Resistance thermal converters TSP-204 are included into the State Register of Measuring Devices of Ukraine under number U246-07. The working range of measured temperatures is -40 °C to +270 °C, thermal response indicator does not exceed 6-8 sec.

The temperature sensors in the land-based part of the power system are installed in supply and exhaust pipelines of all loops, on the heat battery and at input and output of heat-carrying agent flow-rate sensors. The sensor readings were taken automatically with a time interval of five seconds.

The water meter by SENSUS was used for measuring flow-rate of the heat-carrying agent. The rated flow is 10 m^3per hour and withstands the working pressure of 16 bar.

Six heat-carrying agent flow-rate sensors are connected to the system: four at each line of heat-carrying agent supply to the probes (geothermal) and two at common lines for heat-carrying agent flow over low-temperature and high-temperature loops of the land-based part of the system.

The temperature sensors installed in the underground part of the geothermal power system allow for discrete measurements of soil temperature at depths of 0.02 to 50.0 m and heat-carrying agent temperature both in vertical and horizontal parts of the soil collector at the site between the geothermal well and entrance to the building (Goshovskyi, Zurian, 2015).

The MAXYCON FLEXY controller and special software using FDB open configurator by RAUT AUTOMATIK in the geothermal system allowed for data collection from the measuring devices to be further processed and recorded into the archive, interpreted and shown on the computer monitor by means of visualisation software in real time (Fig. 3). MAXYCON FLEXY controller allows to take readings from more than 36 data channels and operate the system remotely both offline and manually.

The research was carried out in three stages:

Description of thermalphysic specifics of geothermal energy in-flow generated by rocks to the inner space of the well without circulation of heat-carrying agent therein over the long time interval.

Investigation of the impact made by intensive extraction of heat energy with geothermal heat pump systems on regeneration abilities of the geothermal field.

Investigation of the impact of change in process operation mode of the heat pump system on the soil temperature near the geothermal well and determination of the extent of deviation of temperature fluctuations of the geothermal field in connection to duration of the system operation.

1. With the purpose of determination of regularities in seasonal temperature changes in the upper layers of the Earth and depth of annual temperature changes in soil, investigators applied the experimental research method which allowed for temperature measurements of intact soil during twelve months, from October 2018 to September 2019.

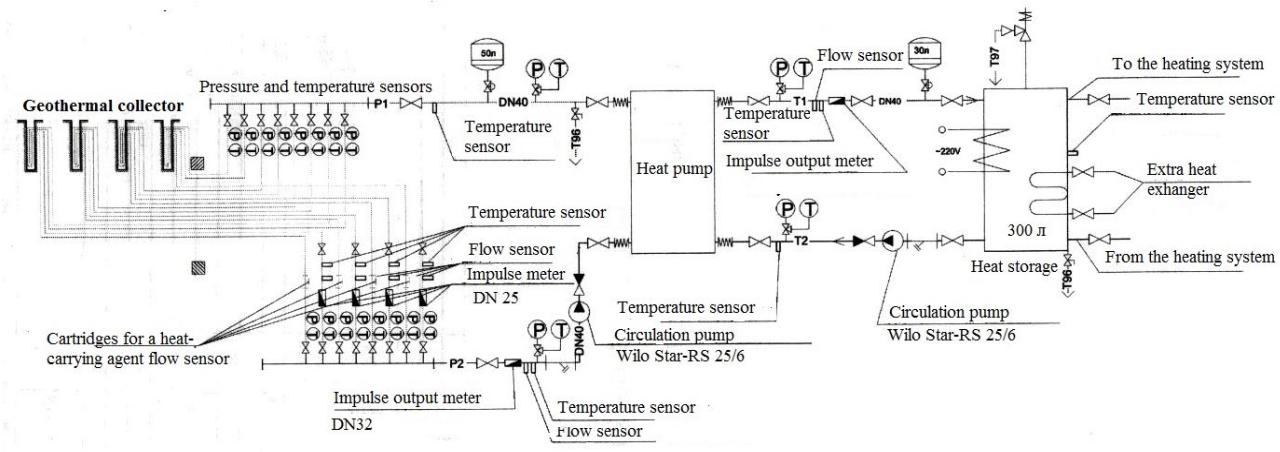

Fig. 2. Principal diagram of the geothermal experimental system

Fig. 3. Main measuring devices used for testing at the geothermal heat pump system:
1 – temperature sensors (resistance thermal converters) TSP-204; 2 – MAXYCON FLEXY controller; 3 – special software using FDB open configurator by RAUT AUTOMATIK

The temperature sensors installed in the well allowed to measure the soil temperature at standard depths during the experiment: 0.02; 0.30; 0.70; 1.2; 2.0; 5.0; 15.0; 35.0; 50.0 m. The sensor readings were taken automatically with a time interval of five seconds. Measurements of soil temperature were made at the geothermal landfill of the **Ukrainian State Geological Research Institute**. In order to maintain the experimental integrity, no heat extraction was effected from the geothermal field where the research was carried out both before and during the experiment.

Findings that allowed to make an analysis of relation between the soil temperature change and depth at various time intervals, from a day to a year, and to determine the relation of average monthly temperatures T and depth h for soil mass in the place where geothermal probes were installed (geothermal field), were obtained in the course of research.

It was found out by experiment that daily fluctuations of ambient air temperature caused by change of sunlight intensity had significant impact on the soil temperature at depth of up to 0.30 m. Starting from depth of 0.70 m and more, daily fluctuation of air temperature has no impact on change of the soil temperature. It is grounded scientifically that the soil temperature at depth of up to 2 m during the month tends to decrease continuously under general dynamics of decrease in the air temperature. Moreover, it is essential that change in the soil temperature at depth of up to 0.70 m depends on the air temperature, while the air temperature has no impact on the soil temperature at depth of over 5 m during the month. We can see the moment when the soil temperature at depth of 2 meters decreasing from 18 °C at the beginning of the month to 15 °C at the end of the month crosses the soil temperature isotherm at depth of 5 m (Fig. 4)

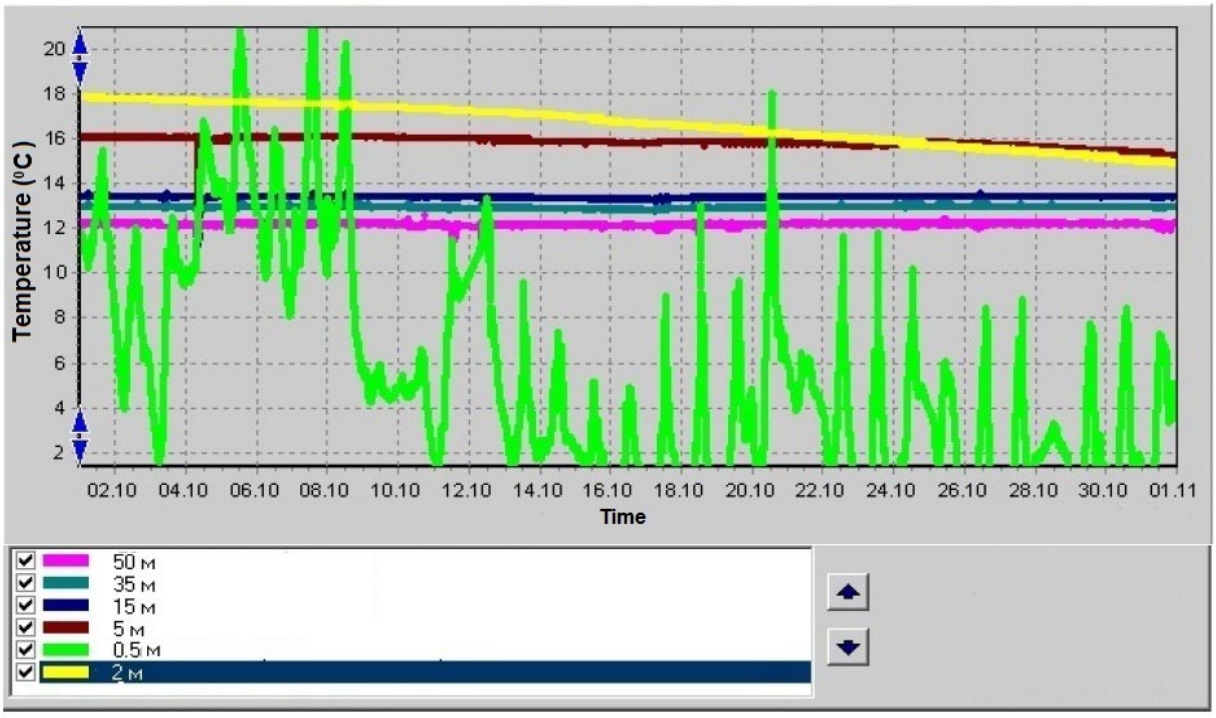

Fig. 4. Curve of soil temperature versus operation time of the geothermal system during October at depths of 50.00, 35.00, 15.00, 5, 0.5, 2 m

Table 1. Change in soil temperatures versus depth during the year without load on the geothermal filed*

Month	Depth (h, м)								
	0.02	0.30	0.75	1.20	2.00	5.00	15.00	35.00	50.00
October	8.0	13.0	15.0	16.5	17.0	16.8	13.2	12.8	12.0
November	5.0	9.0	11.0	12.5	13.8	14.2	13.2	13.0	12.0
December	4.5	8.0	9.0	10.5	11.8	13.0	13.2	13.0	12.0
January	3.0	5.5	7.0	8.0	9.8	11.8	13.2	13.0	12.0
February	2.0	3.5	5.5	6.5	8.0	10.0	13.0	12.8	12.0
March	5.0	4.0	4.0	6.0	7.0	6.5	13.0	12.8	12.0
April	14.0	11.5	9.5	8.0	7.0	7.4	13.0	12.8	12.0
May	19.0	16.0	15.0	14.5	13.0	11.0	13.2	13.0	12.2
June	21.0	18.0	17.0	16.0	13.8	11.0	13.2	13.0	12.2
July	24.0	22.0	21.0	19.0	17.0	13.0	13.8	13.2	12.3
August	23.0	23.0	22.0	20.0	18.0	16.0	13.9	13.3	12.4
September	20.0	18.0	19.0	19.0	18.0	17.0	13.2	13.0	12.2
T (°C)	12.37	12.63	12.92	13.04	12.85	12.31	13.26	12.98	12.11
ΔT (°C)	22.0	19.5	18.0	14.0	11.0	10.5	0.9	0.5	0.4

*Note: T is the average soil temperature during the year; ΔT is the difference in extreme temperature values (the highest and the lowest temperatures) during the year

With experimental findings obtained during the year we can make conclusion as to existent tendency for the difference in extreme temperature values ΔT to decrease as the depth h increases (Table 1).

Besides the above stable tendency of 'compression' of temperature line bundle, the review of data given in Table 1 allowed to make conclusion as to independence of average annual temperature (T) from depth h for each measurement mass data. So, for the temperature change data in Table 1 we obtained, to the extent of acceptable to us increase in depth, the following values (T) (in °C): 12.37; 12.63; 12.92; 13.04; 12.85; 12.31; 13.26; 12.98; 12.11. Consequently, if we put h_r to be the depth where no seasonal temperature fluctuations are found, then temperature $T(h_r)$ can be determined as the arithmetic mean value for the average annual temperatures (T). In addition, considering that h_r value fulfils condition (T) $(h_r) = 0$, then we can see from the experimental findings given in Table 1 that h_r value fulfilling condition (T) $(h_r) = 0$ is within 15 m.

2. The impact made by intensive extraction of heat energy with geothermal heat pump systems on temperature fluctuations of the geothermal field has been investigated. The intensity of heat energy extraction from the geothermal field changed, according to the investigation procedure, with change in both number of wells with geothermal heat exchangers involved to extraction of the Earth's warmth and number of geothermal heat exchangers installed into the wells (Zurian, 2019). Technical capabilities of the experimental system allowed to carry out the experiment in the configurations of the geothermal heat exchanger as follows: 1) 4×2: four wells, each with two U-shaped geothermal heat exchangers installed; 2) 4×1: four wells, each with one U-shaped geothermal heat exchanger installed; 3) 2×1: two wells, each with one U-shaped geothermal heat exchanger installed. Meanwhile, heat load on the system over the condenser loop was unchanged. Amount of flow-rate of the heat-carrying agent through the building heat supply system kept the same.

The investigation procedure and capabilities of the software developed by the **Ukrainian State Geological Research Institute** allowed to discrete time intervals required for research which enabled to obtain necessary findings and make conclusions regarding certain dependencies: 1 – heat-carrying agent temperature at the output of the geothermal system condenser decreases with reduction in number of geothermal heat exchangers, however not significantly depends on their configuration; 2 – temperature hysteresis for heat-carrying agent in the condenser loop decreases both in case of reduction in number of geothermal heat exchangers and when configuration of the heat exchanger is changed from U×2 to U×1; 4 – heating capacity of the geothermal system decreases when the number of geothermal heat exchangers is reduced and slightly lowers when configuration of the heat exchanger is changed from U×2 to U×1; 5 – heat-carrying agent temperature at the input and output of the geothermal system evaporator decreases with reduction in number of and depends on configuration of geothermal heat exchangers; 6 – heat-carrying agent temperature at the input and output of the geothermal system evaporator decreases

when configuration of the heat exchanger is changed from U×2 to U×1; 5 – difference between the ambient medium and working body temperatures at the evaporator output is uniformly increasing both with reduction in number of geothermal heat exchangers and when configuration of the heat exchanger is changed from U×1 to U×2 (Table 2).

the experiment. The temperature increasing dynamics for the heat-carrying agent in the heat supply system slowed down. The system was operated in such mode for short time period (Fig. 5).

At the time point of 6:33 pm, the output temperature of the low-temperature loop evaporator reached the extreme of 2 °C. This triggered the safety auto-

Table 2. Summary of experimental and calculated data obtained during operation of the geothermal system under changed load*

Parameter	Operation mode of a geothermal heat exchanger					
	4x2	4x1	2x2	2x1	1x2	1x1
t_1 (°C)	45.00	43.85	43.5	43.00	42.98	37.90
t_2 (°C)	37.1	36.05	36.29	36.30	36.41	32.10
Δt_k (°C)	7.90	7.80	7.70	6.70	6.57	5.80
V_k (м^3·h)	1.42	1.42	1.42	1.42	1.42	1.42
W_k (kW)	12.46	12.30	12.10	10.57	10.36	9.15
t_3 (°C)	12.70	11.20	11.00	9.00	8.10	7.40
t_4 (°C)	9.90	8.40	8.10	5.90	5.00	3.00
Δt_e (°C)	2.80	2.80	2.90	3.10	3.10	4.40
V_e (м^3·h)	3.00	2.85	2.87	2.36	2.40	1.62
W_e (kW)	9.34	8.86	9.26	8.14	8.27	7.91

*Note: t_1 is the temperature at the condenser output; t_2 is the temperature at the condenser input; Δt_k is the temperature hysteresis at the condenser; V_k is the heat-carrying agent flow rate over the condenser loop; W_k is the heating capacity of the geothermal system; t_3 is the temperature at the output of the geothermal collector (ambient); t_4 is the temperature of the working body at the evaporator output; Δt_e is the difference between the ambient medium and working body temperatures at the evaporator output; V_e is the heat-carrying agent flow rate over the evaporator loop; W_e is the cooling capacity of the geothermal system.

Accordingly, the experimental findings of temperature settings near the well area during heat energy extraction for operation of the collector heat pump prove that with increased intensity of heat energy extraction the soil temperature near the geothermal heat exchanger decreases in proportion to the increase in the system load.

In addition, in accordance with the tasks set, the GTS operation under extreme loads on the geothermal heat exchanger were studied.

As with previous experiments, the initial temperature of the heat-carrying agent in the heat supply system was 28 °C and that equal to 15 °C for propylene glycol in the soil heat exchanger loop under continuous circulation. At the beginning of the experiment, from 6:12 pm till 6:25 pm under 1×1 mode, the temperature changing dynamics both for high-temperature and low-temperature loops matched the processes that took place under the experiment conditions of 4×2, 4×1, 2×2, 2×1, 1×2; however, the experiment proved operation of the system under such mode conditions to be unstable. For example, propylene glycol temperature started to drop at the very beginning of

mation signal. Further recurrent unstable operation of the geothermal system after 6:33 pm time point was associated with failure of 1×1 configuration soil heat exchanger in the geothermal system to restore the required evaporator input temperature under set options of 12 kW for heating capacity at the geothermal system output. Up to the moment the system switched to the emergency operation, the readings for temperature, flow rates of heat-carrying agents in low-temperature and high-temperature loops and calculated data for the system capacities under operation in 1x1 mode were: – temperature hysteresis at the input and output of the heating system at 6:30 pm time point was 5.8 °C; – difference between the ambient medium and working body temperatures at the evaporator output at 6:30 pm time point was 4.4 °C. In consideration of meter readings for heat-carrying agent flow rate of 1.419 m^3 over the evaporator loop and 1.618 m^3 over the condenser loop, we can conclude that the system is trying to maintain the required cooling and heating capacities but because of drop in evaporator input temperature which is the result of failure of the renewable energy source to maintain regeneration

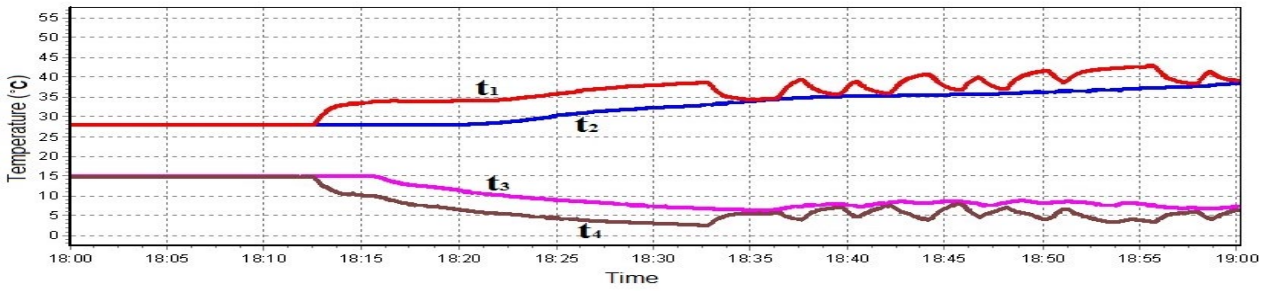

Fig. 5. Curve of temperature versus system operation time when one geothermal heat exchanger installed into the well is connected to the geothermal system (1×1 mode): t_1 is the temperature at the condenser output; t_2 is the temperature at the condenser input; t_3 is the temperature at the output of the geothermal collector; t_4 is the temperature of the working body at the evaporator output

processes under routine operation, switches to the emergency operation. In other words, the soil heat exchanger of 1×1 configuration has capacity insufficient to ensure stable operation of the geothermal system even for short time.

Such operation of the geothermal system we believe to be the emergency mode. This is because further operation under such conditions without safety automation devices may result in ice formation on the heat exchanger and freezing of the well which makes regeneration of soil in the place of freezing impossible and the well may be exposed to thermal heating (freeze-over).

3. Relation between in-service time of the system operation and temperature fluctuations of the geothermal field was investigated by experiment. It was found out that with temperature setting of 40 °C at the condenser input on the geothermal heat pump system which, with hysteresis of 8 °C, allows to supply heat-carrying agent to consumers at 48 °C, the soil temperature near the well area during short-term operation (to one point) may decrease from 3 °C to 12 °C (Fig. 6). At the same time, regeneration of the soil heat balance at the place of heat energy extraction may take 20 minutes to 1 hour.

Moreover, review of findings obtained in the short run (during one day) showed that at the depth of 50 m, temperature deviations in the place of heat energy extraction exceed 3 °C and tend to decrease in absolute values. Also, the ratio of charge duration till discharge of the soil battery was determined. The factors for fast discharge and slow charge of the thermal field were found out, as well determined that with given time interval of operation for the particular soil

Fig. 6. Curve for input and output temperatures on the condenser and evaporator of the heat pump geothermal system versus the load on the soil collector

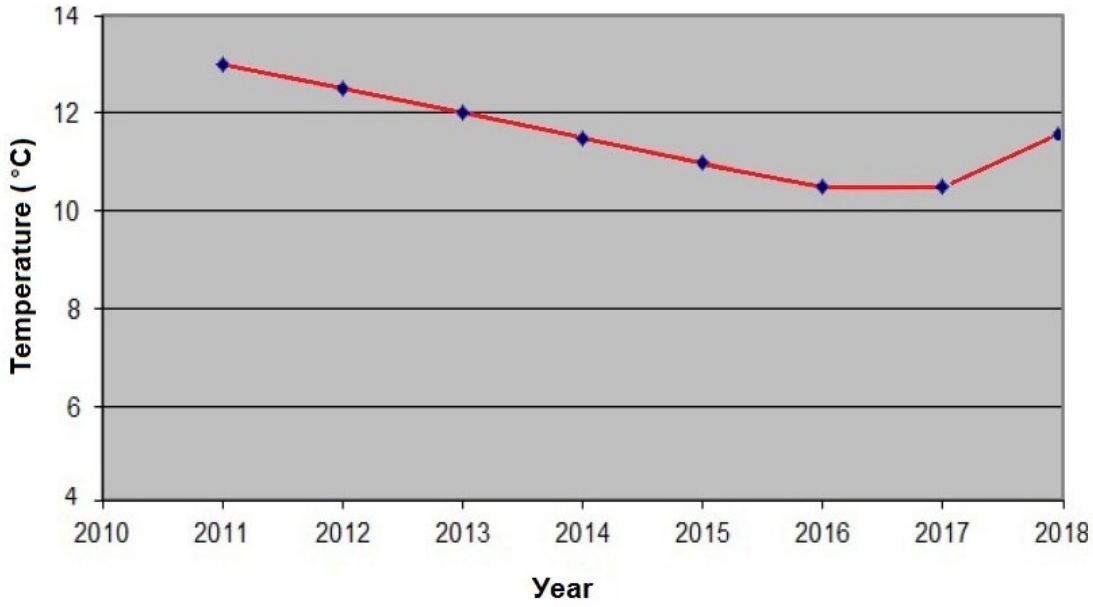

Fig. 7. Curve of the geothermal field temperature change versus the year of operation plotted by experiment

battery the thermal field charge last five times longer than the discharge. At the same time it is relevant to carry out certain investigations to review how fast the temperate mode of the rock mass can be restored due to its thermalphysic properties and what changes in the temperature mode of the near the well area considering lithologic specifics of the working section may take place with the well depth increased.

We also determined that the soil temperature in the place of heat energy extraction regardless of the depth is to some extent influenced by intensity of sun insolation at the surface of the geothermal field. This influence has certain delay by time. This is connected with circulation of the heat-carrying agent in the geothermal heat exchanger over entire space of the geothermal well from top downward generating heat exchange between various soil layers adjacent to the well.

It has been proved by experiment that in the long run, namely during five years of the system operation, the soil temperature near the well area decreased by 2.5 °C (in average, by 0.5 °C each year). Measurements were taken during September at the beginning of heating season prior to the well operation at the depths of 15, 35, and 30 m with year-round thermal loading on the geothermal field. We have proved by experiment that the soil temperature in the sixth year of the system operation had stabilised and stopped at 10.5 °C. And at the beginning of the seventh year of operation it increased by 1.2 °C, i.e. Resulted in the effect of heat in-flow to the near the well area of the geothermal field (Fig. 7).

The findings obtained by experiment fully correlate with mathematical calculations made when modelling the temperature field in conditions of multiple cyclic turn-ons and turn-offs of the heating system [2]. The numeric model is based on discrete presentation of the energy equation, extreme and initial conditions, with various densities of the heat flow and implemented by means of MathLab application software package. Main found factors present (Fig. 8) changes of the temperature field under conditions of cyclic heat supply to the well of 100 Wt per m^2

With pre-set values for the thermal load, well and bed, the well cut-off temperature after seasonal operation in conditions of heat supply has increased by more than 20 °C. The bed temperature evened up under downtime of half a year, and temperature deviations at the moment of well cut-off from the background one were maintained within 2 °C. Cyclical alterations of heat supply modes and downtimes (i.e. when a heat pump is idle) cause heat accumulation effect that is compensated with background heat flows. Quazi-steady condition that constitutes cyclic mode without further temperature rise is assumed to occur in 2.5 years and in 3 years under downtime.

Conclusions.

Continuous heat energy extraction from or discharge into soil causes change in the heat balance of the geothermal field at locations of heat pump geothermal wells. The above changes depend on h=geological and hydrogeological specifics of the mined bed, background heat flows, climate conditions and operation parameters of the geothermal systems.

Long-term operation of heat pump geothermal wells has its specifics: – firstly, it has been found by experiment that under seasonal operation of the geothermal heat pump system during the first 5 years of

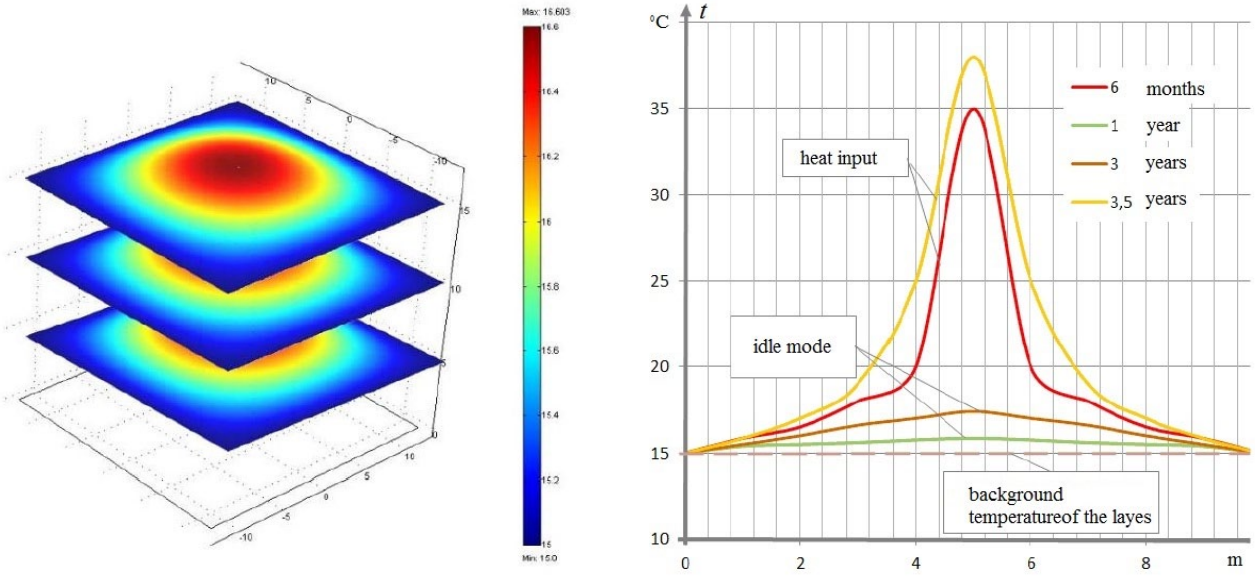

Fig. 8. Changes of the bed temperature obtained under modelling the temperature field [2]:
a – temperature pattern of the geothermal field by depth; b – change in the bed temperature under unsteady heat supply starting from the first turn-on till quazi-steady operation

heat energy extraction, the soil mass temperature decreases in average by 0.5 °C each year of the system operation, and starting from the fifth year, operation of the geothermal heat pump system is stabilised and switched to the quazi-steady mode; – secondly, stabilisation of the geothermal field under year-round operation is achieved in the second year of operation; – thirdly, freezing of the geothermal well is possible, however, only under operation of the heat pump system in contingency and emergency.

It has been proved necessary to study the dynamics of changes in the temperature mode of the Earth subsurface layer under extraction of heat with geothermal heat pump systems under field operation of the heat pump unit in consideration of stratigraphical specifics of the working section with increased depth of the geothermal well.

Human-induced load of geothermal power industry on the environment and humans is insignificant, and use of geothermal heat pump systems for heat supply of residential and industrial facilities seems to be promising and environmentally friendly courses of renewable power industry.

The research findings have scientific and applied significance for future studies in the field of design and development of geothermal heat pump wells based on long-term forecast and assessment of their environmental and economic efficacy.

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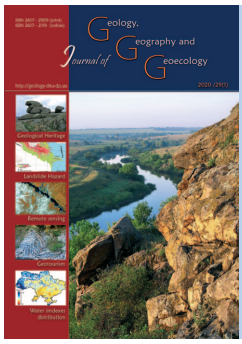

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The State Service of Geology and Subsoil of Ukraine (Geonadra) as a legal subject exercising the right of geological control

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Abstract. The article analyzes the scientific and legislative provisions related to the legal status of the State Service of Geology and Subsoil of Ukraine as a subject of geological control. The external and internal structural peculiarities and normative bases of exercising the control and supervisory functions of the State Geonadra are investigated. The external aspect is the subordination of the organization to the Ministry of the Environment, which determines the priority areas of work of the State Geonadra, approves its work plans and harmonizes the structure of the apparatus. The internal aspect is that it exercises its powers directly both through established territorial bodies (Department of State Geological Control, inter-regional territorial departments and through territorial inspectorates, which are within the sphere of management of the State Geonadra) created within the established order. The normative grounds for exercising control and supervisory functions by the State Geonadra at the present stage are analyzed: the law on state surveillance; government regulations; orders of the State Regulatory Service of Ukraine, the Ministry of Environment and the State Geonadra; annual and monthly inspection plans; document forms and reporting forms. The authors propose a classification of subjects of geological control rights, which includes the following types: general, generic and direct (primary and secondary). The classification of scheduled and unscheduled inspections as measures of state supervision (control) was made according to the following criteria: patrimonial subject of control; the object of control over the use of mineral resources; the subject of the initiation and the reason for unscheduled inspections; the object of control over the destination of minerals; the object of control over the type of natural mineral substance. The beginning of the reform of the state supervision (control) system in the field of environmental protection is characterized. Its purpose is to create an effective state system for the prevention of environmental offences and for environmental monitoring, reduce the pressure on the business environment, encourage broad involvement of the public in the supervision (control), formation of a single integrated state body of environmental monitoring and control (D) – State Environmental Protection Service.

Keywords: State geological control, State Geonadra, geological study of mineral resources, subjects of control.

Держгеонадра як суб'єкт права геологічного контролю

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Анотація. У статті проаналізовано наукові та законодавчі положення, пов'язані з правовим статусом Державної служби геології та надр України як суб'єкта геологічного контролю. Досліджено зовнішні та внутрішні структурні особливості та нормативні підстави здійснення контрольно-наглядових функцій Держгеонадрами. Зовнішні є підвідомчою організацією Мінприроди, яке визначає пріоритетні напрямки роботи Держгеонадр, затверджу плани роботи і узгоджує структуру апарату. Внутрішні – здійснює свої повноваження безпосередньо і через утворені в установленому порядку територіальні органи (департамент Державного геологічного контролю, міжрегіональні територіальні відділи і територіальні інспекції, які належать до сфери управління Держгеонадр). Проаналізовано нормативні підстави здійснення контрольно-наглядових функцій Держгеонадрами на сучасному етапі: закон про держнагляд; постанови уряду; накази Державної регуляторної служби України, Мінприроди і Держгеонадр; річні і місячні плани проведення перевірок; форми документів і форми звітності. Авторами запропоновано класифікацію суб'єктів права геологічного контролю, яка включає такі його види: загальний, родовий і безпосередній (основний і додатковий). Класифікацію планових та позапланових перевірок як заходів державного нагляду (контролю) здійснено

за такими критеріями: родовий суб'єкт контролю; об'єкт контролю за видом користуванням надрами; суб'єкт ініціювання і підстави позапланових перевірок; об'єкт контролю за призначенням корисних копалин; об'єкт контролю за видом природної мінеральної речовини. Охарактеризовано початок реформи системи державного нагляду (контролю) у сфері охорони навколишнього природного середовища. Її метою є створення ефективної державної системи запобігання екологічним правопорушенням і моніторингу стану навколишнього природного середовища, зниження тиску на бізнес-середовище, широке залучення громадськості до здійснення нагляду (контролю), утворення єдиного інтегрованого державного органу природоохоронного моніторингу та нагляду (контролю) – Державної природоохоронної служби.

Ключові слова: державний геологічний контроль, Держгеонадра, геологічне вивчення надр, суб'єкти контролю.

Introduction. In the current conditions the control function of the state has, apart from regulative, preventive value, since the subject of the control performs the assessment on and inspections of how the object of the control performs and follows the legally-imposed requirements in order to prevent deviations from legitimate activity in its work, and in case of discovery of a violation – bringing the controlled objects to a condition of allowable safety level using the generally-binding, formally defined, state-guaranteed rules of behaviour which regulate public relations.

The problem of state control on study, use and protection of the mineral resources is closely related to the processes characteristic for the modern stage of the development of relations between the state and the subjects of the economy in general and a new understanding of the role of state monitoring (control) (hereinafter – SM (C)) in particular.

Materials and methods of research. The SM (C) in the environmental sphere was examined in numerous scientific works, orientations of which could be divided into the following groups: 1) ecological control and monitoring; 2) SM (C) in the sphere of use of natural resources; 3) ecological control and monitoring of use and protection of mineral resources.

Therefore, O.V. Holovkin, in his study on the conceptual and legal-regulatory provisions of the formation and development of the system of state control and monitoring in the sphere of protection of the environment in Ukraine, also analyzed the system of the bodies of the state control and specifics of their legal status in this sphere (Holovkin, 2012). At the same time, according to the author, such means of the corresponding improvement of the legislation, particularly the adoption of the Law "On State Monitoring" or improvement of these provisions in the Law "On Ecological Control", from the perspective of the modern approaches to the systematization of legislation as the most promising form of improvement, must be considered sub-optimum (Holovkin, 2013).

In his dissertation, O.B. Fedorovska suggested providing civic organizations with the right to have a within their composition a subdivision of public inspectorate in the sphere of environment protection and determining the norm according to which an organization or community that recommends a person for performing duties of a public inspector would bear costs associated with the public control (Fedorovska, 2007).

While developing the characteristic of the current condition of public management in the sphere of use of the natural resources, Y.O. Leheza, among the problems of its execution, distinguished the following: low efficiency of performing the functions of state control and monitoring; absence of legally-defined administrative permission-license procedures for obtaining special rights; necessity of development and implementation of state programme of ecologization of production, etc (Leheza, 2018).

O.A. Hrytsan substantiated for the first time the expedience of re-distribution of the responsibilities in the sphere of use and protection of the mineral resources between the bodies of power of special competence in order to eliminate parallelism and duplication of the functions (Hrytsan, 2009).

A.S. Yevstihnieiev provided arguments that undertaking measures of SM (C) for enforcing compliance with the rules of ecological safety during special use of mineral resources is one of the main legal means of ensuring ecological safety (Yevstihnieiev, 2014).

As a possible solution of the problem of re-distribution of the functions of management, control and monitoring on use and protection of mineral resources, V.L. Bredihina considers proposes making a clear designation of the responsibilities of the bodies which perform mining monitoring and bodies which perform control in the sphere of use of mineral resources and control-implementing organs according to the objects of control (Bredikhina, 2016).

O.O. Surilova, in her conclusions, on the one hand supports the well-known principle of necessity of designating the permissive and control functions in one management body, and on the other hand, as a supporter of the integral control function, rather illogically suggests differentiating it according to the

type of natural resource by establishing a specialized control organ – State Service for Protection of Mineral Resources (Surilova, 2016). It seems more expedient to have an internal specialization of control in an integrated control body, for example as suggested by the government – State Environmental Protection Service (Pro zatverdzhennia Polozhennia pro Ministerstvo ekolohii ta pryrodnykh resursiv Ukrainy, 2015).

According to V.V. Strelnyk, who determined identical and special features of the state geological control (hereinafter – SGC) and mining monitoring in the considered sphere in terms of their content, SGC is orientated at inspection of the results of geological survey of mineral resources (hereinafter – GSoMR), and mining monitoring – process of survey of the latter (Strelnyk, V.V., 2017). Similar conclusion seems discussible, since the analysis of the responsibilities of the subjects of control and monitoring as defined in the articles 62, 63 of the Code of Ukraine on Mineral Resources (hereinafter – CoMR) respectively, does not imply such interpretation.

Detailed comparison of the rights and duties of the subjects in the chain "use of mineral resources – control and monitoring – responsibility", and the conclusion that they were insufficiently correlated was made by R.S. Kirin (Kirin, 2019).

Therefore, the analysis of separate scientific developments of domestic scientists of ecological, nature-resource, mineral resource, mining and geological law in the sphere of implementation of SGC indicated the potential for further analytical work. Thus, the **objective of the article** was determining the peculiarities of the legal status of the State Service of Geology and Mineral Resources of Ukraine, or Geonadra, (hereinafter Geonadra) as a subject of state geological control.

Results and their analysis. The recent history of the establishment and reformation of the organs and order of carrying out SGC is equally dynamic and complex. Therefore, less than in a month after adoption of The "Act of Declaration of Independence of Ukraine**"** by the Verkhovna Rada of Ukrainian SSR, the Cabinet of Ministers of Ukraine (hereinafter – CMU) through the "Questions of the State Committee of Ukraine on Geology and Use of Mineral Resources" from 23th September of 1991 № 219 adopted the corresponding Provision, according to which the main duties of the State Committee of Geology of Ukraine are, among others, control and monitoring of protection of the mineral resources and geological environment.

After almost a year, by the order of the CMU from 12th August of 1992 № 467, a new provision with a similar name was adopted. However it lost is force as well due to regulation of the CMU from 1st of April of 1996 № 387. In the meantime, the provision on SGC was amended twice, particularly:

1) by the regulation of the CMU from 17th March 1993 № 200 "On the adoption of the Provision on the State Geological Control of works of geological studies on the Mineral Resources of Ukraine" (the provision identified the following bodies of the SGC:

The Main Office of the SGC of works on the GSoMR of the State Committee of Geology Ukraine;

Territorial inspections of the SGC of the works on GSoMR);

2) the regulation of the CMU from 30th November 1994 № 801 "On the adoption of provision on the state geological control of the works on geological surveys and use of the mineral resources of Ukraine" (SGC of the works on GSoMR was conducted by the Ministry of Nature and its local bodies). The latter regulation was developed due to adoption of the CoMR from 27.07.1994

However, that regulation lost its force as well due to the regulation of the CMU from 14th December 2011 № 1294 "On adoption of the order of conducting state geological control", according to which the SGC was carried out by the State Service of the Mineral Resources and its territorial bodies. Eventually, the same happened to the most recent government`s regulation which lost its force due to the regulation of the CMU from 10th March of 2017 № 239.

Thus, currently, the Geonadra executes its duties directly or through the territorial bodies created according to the established procedures (Pro zatverdzhennia Polozhennia pro Derzhavnu sluzhbu heolohii ta nadr Ukrainy, 2016), entirely corresponding to the provision of Article 5 of the Law of Ukraine "On the State Geological Service of Ukraine" (hereinafter – law on the State Geoservice) (Pro derzhavnu heolohichnu sluzhbu Ukrainy, 1999), because the State Geoservice includes: 1) State Geonadra; 2) State enterprises, institutions and organizations in the sphere of management of the State Geonadra. By contrast, according to Article 7-1 of the same law, SGC is performed by the State Geonadra, and the order of execution is adopted by the CMU. However, taking into consideration the discrete nature of the changes, in fact there is now practically no such control.

The abovementioned governmental regulation of 10th March 2017 № 239 mentions cancellation of some regulations of the CMU, the existence of which is not prescribed by the law of Ukraine "On the main provisions of the State Monitoring (Control) in the sphere of the economic activity" (hereinafter the State

Monitoring) and no other law which defines the order of conducting state monitoring (control) (SM (C)), and the goal of adoption of this regulation was elimination of the reasons for conducting excessive (doubled) control in the sphere of the economic activity, decrease in the regulatory pressure on business, improvement of investment climate. However, such argumentation obviously contradicts the abovementioned provisions of the law on the State Geoservice13, article 7-1.

Furthermore, the current CoMR contains a whole section (section VII "State Control and Monitoring of the Work on Geological Study of the Mineral Resources, their Use and Protection", articles 60-63), which defines the goals of the SGC, the body which performs its functions and responsibilities regarding the SGC. Also, article 62 of CoMR stipulates that the order of implementation of the SGC is determined by the CMU and should be orientated towards the ensuring the fulfillment of the established order of exploitation of mineral resources, fulfillment of the obligations regarding the protection of mineral resources by all state bodies, enterprises, institutions, organizations and citizens, according to the Legislation of Ukraine.

Therefore, a situation has developed, in which, first of all, according to part 4 of article 4 of the law on state monitoring , a body of the SM (C) cannot conduct state monitoring (control) in the sphere of economic activity, if the law does not directly impose SM (C) in a particular sphere of economic activity on such body and does not define the obligations of such body during SM(C).

Secondly, the abovementioned instructions of the Law on State Geoservice and CoMR do regulate the described relations regarding the State Geonadra and SGC, though both laws empower particularly the government to set out the order of SGC.

Thirdly, the law on the state monitoring sets out general requirements on SM (C) and special laws are adopted taking into account the peculiarities defined in the corresponding spheres, that is the law on the State Geoservice and CoMR.

Fourthly, at subsidiary level, according to the law on state monitoring, general instructions are defined regarding: a) requirements to design of the annual complex plans on measures of SM(C), making changes in them and reporting on their execution (Pro zatverdzhennia Vymoh do oformlennia richnykh ta kompleksnoho planiv zdiisnennia zakhodiv derzhavnoho nahliadu (kontroliu), unesennia zmin do nykh ta zvitu shchodo yikh vykonannia, 2017); b) methods of the development of the criteria which define the extent of risk caused by carrying out economic activity and the periodicity of planned measures of SM (C) is defined, as well as the unified forms of acts concluded based on the results of planned (exceptional) measures of SM(C) (Pro zatverdzhennia metodyk rozroblennia kryteriiv, za yakymy otsiniuietsia stupin ryzyku vid provadzhennia hospodarskoi diialnosti ta vyznachaietsia periodychnist provedennia planovykh zakhodiv derzhavnoho nahliadu (kontroliu), a takozh unifikovanykh form aktiv, shcho skladaiutsia za rezultatamy provedennia planovykh (pozaplanovykh) zakhodiv derzhavnoho nahliadu (kontroliu), 2018).

Fifthly, at the subsidiary level, according to the Law on State Monitoring, special instructions are made regarding: a) criteria defining the extent of risk from economic activity in the sphere of geological study and rational use of the mineral resources and the periodicity of the planned measures of SM(C) by the State Geonadra (Pro zatverdzhennia kryteriiv, za yakymy otsiniuietsia stupin ryzyku vid provadzhennia hospodarskoi diialnosti u sferi heolohichnoho vyvchennia ta ratsionalnoho vykorystannia nadr i vyznachaietsia periodychnist zdiisnennia planovykh zakhodiv derzhavnoho nahliadu (kontroliu) Derzhavnoiu sluzhboiu heolohii ta nadr, 2018); b) forms of documents in the sphere of SGC (Pro zatverdzhennia form dokumentiv u sferi zdiisnennia derzhavnoho heolohichnoho kontroliu, 2013) and reporting formats (Pro zatverdzhennia formy zvitnosti, 2013).

A complicated situation has developed in the legal status of territorial bodies of the State Geonadra. Therefore, for the execution of the provisions of the Law on the State Geoservice (Pro derzhavnu heolohichnu sluzhbu Ukrainy, 1999), the order of the Ministry of Ecology and Natural Resources of Ukraine from 26 January 2001 №12 "On establishment of territorial inspections of state geological control", 6 territorial inspections of SGC (hereinafter TIoSGC) were created for monitoring work on geological surveys and use of mineral resources (hereinafter – GSUoMR) in the form of property and legal status as a state organization: Donetsk, Southern, Central (Kirovsk), Western, North-Eastern (Poltava), Black Sea, which operate according to the order of the Ministry of Nature from 7th April 2008 № 174. According to the proposition of the Ministry of Nature and State Geonadra, entire property complexes of these State Organizations (SO) TIoSGC were given to the sphere of the management of the State Geonadra (Pro peredachu tsilisnykh mainovykh kompleksiv derzhavnykh pidpryiemstv, ustanov ta orhanizatsii do sfery upravlinnia Derzhavnoi sluzhby heolohii ta nadr, 2011). Directly after that, in the second half of 2011 another three notable events occurred:

1) adoption of the order which defines the organizational and procedural issues of the interaction between the Ministry of Nature and the State Geonadra (Pro zatverdzhennia Poriadku vzaiemodii Ministerstva ekolohii ta pryrodnykh resursiv Ukrainy z tsentralnymy orhanamy vykonavchoi vlady, diialnist yakykh spriamovuietsia i koordynuietsia Kabinetom Ministriv Ukrainy cherez Ministra ekolohii ta pryrodnykh resursiv Ukrainy, 2011);

2) establishment of interregional territorial bodies as structural units of the apparatus of the State Geonadra (Pro utvorennia mizhrehionalnykh terytorialnykh orhaniv Derzhavnoi sluzhby heolohii ta nadr, 2011);

3) adoption of new order of implementation of SGC – resolution of the CMU from 14th December 2011 № 1294 "On adoption of the order of implementation of state geological control" (lost its force according to the regulation of the CMU from 10th March 2017 № 239).

In early 2012 SGC was performed, according to the abovementioned order, by the Geonadra and its territorial bodies, which according to the government order (Pro utvorennia mizhrehionalnykh terytorialnykh orhaniv Derzhavnoi sluzhby heolohii ta nadr, 2011) comprised 6 inter-regional departments (hereinafter – IRD): Northern, Southern, Western, Eastern, Central, Azov-Black Sea. The IRD were included in the Department of SGC of the Geonadra, which, according to the set goals performed the following functions (Struktura Derzhavnoi sluzhby heolohii ta nadr Ukrainy, 2019): 1) ensuring compliance with the established order, norms and rules of geological-survey, search, survey and other works related to geological study of the mineral resources by all users of mineral resources, i.e. legal and normative-regulatory acts of Ukraine, state standards, normative-technical documents during the use of mineral resources and requirements regarding protection of mineral resources during their complete and complex studies; 2) organizing and carrying out planned and unscheduled inspections of users of mineral resources, according to the results of which (in case of finding violations of the legislation obligations) acts are concluded, it gives obligatory guidance (instructions) about eliminating the found defects and violations of the legislation; 3) preparing data on the basis of analysis and generalization of the initial materials for giving propositions to the management of the Geonadra regarding improvement of the effectiveness of works on GSUoMR; 4) developing data bases of the conducted inspections and collecting, analyzings and processing information on activity of users of mineral resources throughout Ukraine, its continental shelf and exceptional (marine) economic zone; 5) according to the established order preparing materials for action in cases of administrative violations. Apart from IRD, the Department of SGC has also the department of control on GSUoMR.

Therefore, all State Organizations (SO) TIoSGC, by remaining state organizations that belong to the sphere of management of the Geonadra, lost their functions of SGC. Instead, their goal was still activity related to collecting materials and assessment of results of activities of the resource users, which are necessary for control of compliance with the conditions of special permission for using the mineral resources or agreement about the conditions of using mineral resources.

Therefore, for example, SO Southern TIoSGC performs work with consideration of requirements of the CoMR, government resolutions, other normative documents in the sphere of geology, protection of mineral resources and mining, involving description of issues regarding:

Rationality of geo-surveys during GSUoMR;

Methodological compliance of works during GSUoMR;

Rationality of applying the methods and technologies, complexity, effectiveness of work on GSUoMR;

Full amount and probability of the initial data on the quantity and quality of the reserves of the main and together embedded fossil fuels and components in them;

Timely state registration of the works of GSoMR;

Timeliness and correctness of the reports of mineral resource users which carry out extraction of fossil fuels;

Compliance with the requirements, standards and other requirements to the GSUoMR by the users;

Correspondence of geosurveys performed by the users to the aim of GSoMR projects of such works;

Completeness of the extent of study of the geological structure of mineral resources, mining-technical, hydrogeological, engineering-geological, geological-ecological and other conditions of deposits of fossil fuels; - quality and efficiency of works on GSoMR;

Fulfillment of the technologies which would ensure the necessary study, while not reducing the industrial value, during survey-industrial mining;

Compliance with the stipulations of special permissions for using the resources;

Fulfillment of the agreement on using the resources;

Observance of the decisions and recommendations of the State Commission of Ukraine on the Mineral Resources (Derzhavna orhanizatsiia «Pivdenna terytorialna inspektsiia derzhavnoho heolohichnoho kontroliu za vedenniam robit po heolohichnomu vyvchenniu ta vykorystanniu nadr», 2018).

In these conditions, collaboration of the State Geonadra with SO TIoSGC in the sphere of SGC looks specific. According to the standard formula (about planned measures of SM (C) in a certain period) the head of the Geonadra orders the department of SGC to 1) carry out planned inspections on the activities of the resource users; 2) involves scientists and experts, workers, including ДО TIoSGC (with approval with their management) in participating in the inspections according to the established order. That is, while not being de jure a subject of SGC the workers of territorial inspections de facto can perform certain duties regarding the SGC, in the case of their involvement by the Department of SGC as a legal subject of SGC, because these SO TIoSGC are within the management sphere of the Geonadra.

To a great extent, this scheme of SGC was organised composed taking into account the staff deficiency during performance of the established plans of SM (C) by the departments of SGC, because, for example, in the report for 2016, this department had 37 officials who carried out the inspections of the highest level in all administrative-territorial units of Ukraine (except the temporarily occupied territory of Crimea and certain areas of Donetsk and Luhansk Oblasts). At the same time, 962 measures of SGC took place, including 907 planned and 55 exceptional measures of SGC. In 2017 and 2018 these indicators were respectively 62 (0 and 62) and 1045 (979 and 66). In 2017 the planned inspections of the resource users by the Department of SGC were not performed due to the established moratorium on their implementation.

Finally, we should note that during planning of the control-monitoring orientation of the work in 2018 by the Department of SGC, a risk-orientated approach was used, implying risk criteria defined by the resolution of the CMU from 5th November 2014 № 593, which in late 2018 was updated and currently the planned measures of SM (C) of the activities of subjects of economy in the sphere of GSUoMR in accordance with the special permission for using the resources are carried out by the Geonadra within their authority depending on the criteria defined in the appendices to the regulation (Pro zatverdzhennia kryteriiv, za yakymy otsiniuietsia stupin ryzyku vid provadzhennia hospodarskoi diialnosti u sferi heolohichnoho vyvchennia ta ratsionalnoho vykorystannia nadr i vyznachaietsia periodychnist zdiisnennia planovykh zakhodiv derzhavnoho nahliadu (kontroliu) Derzhavnoiu sluzhboiu heolohii ta nadr, 2018) with the following periodicity: 1) with high level of risk – no more than twice in two years; 2) with average level of risk – no more than once in 3 years; 3) with low level of risk – no more than once in 5 years.

At this stage the reform of the SM (C) in the sphere of the protection of the environment in general and mineral resources in particular has not stopped, because in Ukraine the corresponding Conception of Reformation of SM (C) system was adopted (Pro skhvalennia Kontseptsii reformuvannia systemy derzhavnoho nahliadu (kontroliu) u sferi okhorony navkolyshnoho pryrodnoho seredovyshcha, 2017). In this aspect, we suggest looking at some important issues, solving which and consideration of which in the future development of the subject of the SGC seem quite relevant.

1. *Duplication of control-monitoring functions*. According to articles 231 and 239 of the Code of Ukraine on administrative violations (Kodeks Ukrainy pro administratyvni pravoporushennia, 1984) (hereinafter – CoAV), the subjects of prosecution regarding administrative responsibility of violations of laws on mineral resources and geology are as follows:

1) central body of executive power which implements the state policy in the sphere of labour safety (now State Labour Service of Ukraine) which considers the violation of legislation on mineral resources (article 57 of CoAV);

2) central body of executive power which implements the state policy in the sphere of geological study and rational use of mineral resources (now – State Service of Geology and Mineral Resources) which deals with cases of administrative violations listed in article 57 of CoAV.

According to duties of the Labour Service, this subject implements state mining monitoring and in cases described in the legislation concludes protocols on administrative violations, considers cases on listed violations and prepares protocols on administrative fines (Pro zatverdzhennia Polozhennia pro Derzhavnu sluzhbu Ukrainy z pytan pratsi, 2015). The further subsidiary regulation of mentioned provisions of CoAV and articles 60-63 of CoMR was reflected in the government resolution on state mining monitoring (Pro zatverdzhennia Polozhennia pro poriadok zdiisnennia derzhavnoho hirnychoho nahliadu, 1995). At the same subsidiary level, the issues of drawing

up materials on administrative violations regarding mineral resources were detailed.

Currently, by clause 5 of the regulation of the CMU from 10th September 2014 № 442 "On optimization of the system of central bodies of the executive power" and regulation of the CMU from 30th September 2015 № 1021-p "Issues of the State Labour Service", Labour Service and its territorial bodies are the corresponding successors of the State Service of Mining Monitoring and Industrial Security of Ukraine and its territorial bodies which cease their activity. Instead, in the structure of the State Labour Service the control-monitoring functions will be implemented by the Management of Mining Control, including: 1) Department of Monitoring the Coal Industry; 2) Department of the Monitoring the Mining Industry, on Explosive Works and Utilization of Ordnance; 3) Department of Geological-Mine Surveys (Derzhavna sluzhba Ukrainy z pytan pratsi).

A situation has developed, in which the functions of protection of the mineral resources, and therefore control-monitoring ones are performed by two bodies of executive power – the Labour Service and Geonadra, which in the conditions of duplication of functions of SM (C) would obviously complicate both subjective execution and objective perception. Particularly this aspect – elimination of duplication of the functions in monitoring (control) of central bodies of executive power is emphasized in the Conception of Reformation of the SM (C) (Pro skhvalennia Kontseptsii reformuvannia systemy derzhavnoho nahliadu (kontroliu) u sferi okhorony navkolyshnoho pryrodnoho seredovyshcha, 2017). Furthermore, the framework of de-regulation implies transition from the system of total planned monitoring (control) to a service system which would orientate towards such measures as 1) nature protection monitoring; 2) prevention of violations of nature protection legislation; 3) performing control based on risk-orientated criteria.

2. The principle of management and structuring of the subject of SGC. Reformation of the system of monitoring (control), according to the Conception (Pro skhvalennia Kontseptsii reformuvannia systemy derzhavnoho nahliadu (kontroliu) u sferi okhorony navkolyshnoho pryrodnoho seredovyshcha, 2017), is performed by placing the authority of implementation of the state policy of monitoring and control in the sphere of protection of the environment, rational use and restoration and protection of the mineral resources on the State Environmental Protection Service (hereinafter – SEPS) which is planned to be established.

This decentralized approach includes redistribution of nature protection functions and authorities by forming the interregional territorial bodies of SEPS as one integral state body of nature protection monitoring and control. The basis of such structure should comprise of the principles of ecological-resource and ecological-technogenic peculiarities of the districts (Carpathian, Polisky, Prydniprovsky, North-West, Stolychny, Black Sea, Podilsky, Central and North-East). Besides, the latter are planned to include 27 special Oblast inspector managements.

A similar intention fully corresponds to the main purposes of collaboration of Ukraine with the EU regarding the development of an inclusive strategy in the environmental sphere, including: a) planned institutional reforms; b) distribution of the duties of nature protection bodies at national, regional and local levels; c) procedures of adoption of solutions and their execution; d) procedures of supporting the integration of nature protection policy into other spheres of state policy. The abovementioned measures, in turn, should ensure the execution of the tasks of reformation of the SM (C) system with the purpose of: - reducing the number of inspections and increasing their effectiveness; - implementation of the principle "polluter pays"; - creating an efficient system of prosecuting those responsible for harm to the environment and ensuring compensation.

Therefore, we should agree with the expert group of independent assessment of the Geonadra (Demikeli *et al.*, 2016) which suggests, based on the principle "first – functions, then – form": 1) forming a management team which would develop a conception of organization and strategy of management, reflecting the key functions, lines of subordination and priority goals; 2) develop such strategic component of staff provision which would avoid fragmentation of the resources for the support of numerous secondary programmes, and provide the resources for priority tasks; 3) stop non-priority works until the appearance of additional resources; 4) study initiatives of subjects of the economy in respect to the partnership between the state and private subjects, create quasi-state subjects, companies "on a turn-key basis", etc, devolving the transition of certain current state functions onto the private sector.

3. Legal strategy of nature protection function. The first stage of implementation of the Conception (2017-2020) was planned to include, among others, the formation of SEPS and adoption of provision for it. Instead, by the initiative of particular parliamentarians, two draft bills were proposed: 1) the main "On the

State Environmental Protection Service of Ukraine" (registry № 9336 from 23.11.2018) – defines the legal aspects of organization and work of SEPS, order of employing the staff, status of state inspectors on environmental protection and responsibility of legal persons and individual entrepreneurs for violation of the requirements of the nature protection legislation; 2) alternative one "On State Inspection on Protection of Environment of Ukraine" (register № 9336-1 from 07.12.2018) – defines the legal aspects of organization and work of the State Inspection on Protection of Environment of Ukraine, its structure and status of state inspectors of environmental protection.

According to the authors of the abovementioned draft bills, their adoption would allow improving the condition of the environment and the living conditions of the population, implementing a system of monitoring (control) and monitoring in accordance with international standards, avoiding duplication of the control-monitoring functions and ensuring efficient performance of the monitoring and control in the sphere of the environmental protection.

However, such initiative looks disputable, because according to the provisions of Article 116 of the Constitution of Ukraine, issues of orientating and coordinating the work of a ministry and other central bodies of the executive power, their formation, re-organization and closure (according to the law) is attributed to the competence of the CMU. Moreover, such proposition does not correlate with the tasks set by the government`s development of a draft bill on improvement of the system of state nature protection monitoring of the conditions of the environment, as defined by the President`s Decree (Pro dodatkovi zakhody shchodo rozvytku lisovoho hospodarstva, ratsionalnoho pryrodokorystuvannia ta zberezhennia obiektiv pryrodno-zapovidnoho fondu, 2017), for the law on the regime of the SM (C) and the law on the status of the body of SM (C) are obviously not equivalent. Therefore, naturally, both bills were rejected at the same time on 29.08.2019.

Thus, a legal strategy on the regime of nature protection control, as well as its subjects is desperately needed, for on the example of SGC, it is orientated towards fostering the changes necessary for the reformation of the State Geonadra regarding cessation of work or transfer of competence from/to ministries or agencies and modification of the internal procedures of executing the works of the service (exchange and management of the data, etc).

4. Content and procedure of prosecuting violation of nature protection. The European Parliament and the Council of the European Union in their recommendations indicate that existence of inspecting systems and effective performance of inspections is a tool of controlling ecological violations, because it allows the authorities to identify the violations and implement the ecological laws through sanctions or other means (Rekomendatsiia 2001/331/IeS Yevropeiskoho Parlamentu ta Rady «Shcho peredbachaie minimalni kryterii shchodo ekolohichnykh inspektsii u derzhavakh-chlenakh» vid 4 kvitnia 2001 roku, 2001). The Government of Ukraine, while developing the provisions of the Conception (Pro skhvalennia Kontseptsii reformuvannia systemy derzhavnoho nahliadu (kontroliu) u sferi okhorony navkolyshnoho pryrodnoho seredovyshcha, 2017), set the task of developing and submitting to the CMU in the established order draft bills of making amendments to the CoAV and the Criminal Code of Ukraine regarding increasing the responsibility for administrative violations and crimes against the environment, including use of natural resources. Also, the government plans to create a fund of financial guarantees of ecological responsibility (Pro zatverdzhennia planu zakhodiv shchodo realizatsii Kontseptsii reformuvannia systemy derzhavnoho nahliadu (kontroliu) u sferi okhorony navkolyshnoho pryrodnoho seredovyshcha, 2018).

Separate attention should be paid to the proposition of State Geological Service of Mineral Resources regarding the draft bill "On Changes to Article 65 of the Code of Ukraine on Mineral Resources" developed with consideration of Article 276 of the CoAV, according to which cases of administrative violations are considered at the place where they occurred, but at the same time the laws of Ukraine may permit another place for consideration of such cases. According to the existing staff of officials of the Geonadra who are responsible for the corresponding actions, this subject of SGC has no possibility of providing the needed consideration of cases on administrative violations at the place of their occurrence. For this purpose, the draft bill defines the place of considering cases on administrative violation, particularly at the location of the Geonadra, by its authorized officials. These changes, according to their developers, would ensure the fulfillment of the CoAV-defined terms of consideration of cases on administrative violations, as well as legislation-established procedure of consideration of such cases (Zvit pro rezultaty derzhavnoho heolohichnoho kontroliu za heolohichnym vyvchenniam nadr ta ratsionalnym i efektyvnym vykorystanniam nadr u 2018 rotsi, 2019). Such changes obviously would not be welcomed, first of all by the subjects of use

of mineral resources due to a number of objective concerns. At the same time, we should note the possibility of considering cases at the places of registration and record of certain types of violation recorded in automatic regime.

Thus, the institution of legal responsibility is an important connection between the regulatory link and effective instrument of contributing to more consistent implementation and use of ecological legislation of the European Union and avoiding unhealthy competition in this sphere.

Therefore, the conducted analysis of scientific developments, instructions to the legislation on mineral resources and administrative violations, defining the legal status of State Service of Mineral Resources as subject of law of geological control, allowed us to draw the following **conclusions**.

1. Structural peculiarities of the State Service of Mineral Resources can be divided as follows:

1.1) external:

1.1.1) among the main tasks of the Ministry of Nature is performing SGC (Pro zatverdzhennia Polozhennia pro Ministerstvo ekolohii ta pryrodnykh resursiv Ukrainy, 2015);

1.1.2) Geonadra is an organization of the Ministry of Nature (central body of the executive power, activity of which is orientated and coordinated by the CMU through the Minister of Ecology and Natural Resources);

1.1.3) The minister orientates and coordinates the work of the Geonadra, particularly: - ensures the formation of state policy in the corresponding sphere and controls its implementation by the Geonadra; - determines the priority directions of the work of the Geonadra and means of execution of the task placed before it, approves the plan of the Geonadra`s work; - agrees on the structure of the apparatus of the Geonadra;

1.2) internal:

1.2.1) the Geonadra implements the control on geological study of the mineral resources (SGC) and their rational and effective use (Pro zatverdzhennia Polozhennia pro Derzhavnu sluzhbu heolohii ta nadr Ukrainy, 2016);

1.2.2) the head of the Geonadra submits the plan of his organization's work to the Minister of Ecology and Natural Resources for approval, approves provisions on separate structural subunits of the apparatus of the Geonadra;

1.2.3) The Geonadra performs its duties directly and through the territorial bodies created according to the established order;

1.2.4) implementation of control-monitoring functions of the Geonadra is placed on the Department of SGC which includes 6 inter-regional territorial departments (IRD) as structural units of the Geonadra apparatus, and also the department of control of GSUoMR;

1.2.5) Department of SGC, during the implementations of SM (C), can involve 6 territorial inspectorates of SGC (SO TIoSGC) as state organizations which belong to the sphere of management of the Geonadra.

2. Control-monitoring orientation of the work of subjects of law of geological control is implemented at the current stage according to:

2.1) p.1 Article 5 of the law on State Monitoring;

2.2) subclauses 12, 14 of Clause 4 of the Resolution on Geonadra, adopted by the Regulation of the CMU from 30.12.2015 № 1174;

2.3) Plan of implementation of complex measures of SM (C) for 2019, adopted by the order of the State Regulatory Service of Ukraine from 15.11.2018 № 152;

2.4) order of the Geonadra from 28.11.2018 № 450 "On Adoption of the Annual Plan of Measures of State Monitoring (Control) by the State Service of Geology and Mineral Resources for 2019";

2.5) monthly plans of inspections of users of mineral resources, approved by the orders of the Geonadra;

2.6) requests for implementation of exceptional checks in accordance with the legislation;

2.7) criteria which define the extent of risk from the implementation of economic activity in the sphere of GSUoMR and the periodicity of planned measures of SM(C) by the Geonadra is determined (Pro zatverdzhennia kryteriiv, za yakymy otsiniuietsia stupin ryzyku vid provadzhennia hospodarskoi diialnosti u sferi heolohichnoho vyvchennia ta ratsionalnoho vykorystannia nadr i vyznachaietsia periodychnist zdiisnennia planovykh zakhodiv derzhavnoho nahliadu (kontroliu) Derzhavnoiu sluzhboiu heolohii ta nadr, 2018);

2.8) forms of documents in the sphere of implementing SGC (Pro zatverdzhennia form dokumentiv u sferi zdiisnennia derzhavnoho heolohichnoho kontroliu, 2013) and form of reporting (Pro zatverdzhennia formy zvitnosti, 2013).

3. The developed classification of the subjects of law of geological control looks as follows:

3.1) general subject – Ministry of Ecology and Natural Resources and its territorial organizations;

3.2) patrimonial subject – Geonadra and its territorial bodies formed in the established order;

3.3) the main particular subject - officials of the

units of the Geonadra with the duty of implementation of SGC (the responsible officials of the bodies of the SGC – Department of SGC (inter-regional departments (IRD), unit of control on GSUoMR));

3.4.1) additional obligatory subject – scientists, specialists, workers of SO TIoSGC belonging to the sphere of management of the Geonadra (approved with their management);

3.4.2) additional optional subject – scientists, specialists, workers of central and local bodies of the executive power, bodies of local management, enterprises, institutions and organizations not belonging to the sphere of management of Geonadra (approved with their management).

4. Planned and exceptional measures of SM (C) implemented by the Geonadra in the form of inspections are classified according to the following criteria:

4.1) by department (IRD) which implements inspection (subject of the control);

4.2) by types of use of mineral resources (article 14 CoMR) (mineral resources object of control);

4.3) by the reasons for implementation of exceptional inspections (article 6 of the law on state monitoring);

4.4) by the value of the fossil fuels (article 6 CoMR) (economic-resource object of the control);

4.5) by the level of the risk from implementation of economical activity by the object of control (Pro zatverdzhennia kryteriiv, za yakymy otsiniuietsia stupin ryzyku vid provadzhennia hospodarskoi diialnosti u sferi heolohichnoho vyvchennia ta ratsionalnoho vykorystannia nadr i vyznachaietsia periodychnist zdiisnennia planovykh zakhodiv derzhavnoho nahliadu (kontroliu) Derzhavnoiu sluzhboiu heolohii ta nadr, 2018) (ecological safety object of the control);

4.6) by the region of administrative-territorial structure of Ukraine where the inspection was conducted (regional object of control);

4.7) by type of fossil fuel (mineral-resource object of the control).

5. Ukraine has started the reform of the system of SM(C) in the sphere of the protection of the environment (Pro skhvalennia Kontseptsii reformuvannia systemy derzhavnoho nahliadu (kontroliu) u sferi okhorony navkolyshnoho pryrodnoho seredovyshcha, 2017) intended to, with consideration of the implementation of the obligations indicated in the Treaty on Association, create an efficient state system of preventing ecological violations and monitoring the condition of the environment, reducing the pressure on the business-environment, broadly involving the public in the monitoring (control), forming the integral state body of the environmental monitoring and control – the State Environmental Protection Service. Against the background of duplication by the central bodies of the executive power of monitoring (control) functions, the absence of an integral approach is seen, therefore the aims of the government to eliminate non-characteristic functions and authorities of the enterprises, institutions and organizations which belong to the sphere of the Geonadra, and improve the organizational structure of the Geonadra (Pro zatverdzhennia planu priorytetnykh dii Uriadu na 2019 rik, 2019) indicate the high probability of imminent reform of the system of SGC.

In the process of such reforms it is suggested to take into consideration the European experience in this sphere, because the EU has a great inconsistency in the various inspectional systems and mechanisms of its member states not only with respect to their ability to perform the inspection tasks, but also the sphere of action and content of the initial inspection tasks, and even in the existence of inspection tasks in several member states, and this situation cannot be considered satisfactory for the purpose of the efficient and more consistent implementation, practical use and application of legislation of the Community regarding the protection of the environment (Rekomendatsiia 2001/331/IeS Yevropeiskoho Parlamentu ta Rady «Shcho peredbachaie minimalni kryterii shchodo ekolohichnykh inspektsii u derzhavakh-chlenakh» vid 4 kvitnia 2001 roku, 2001).

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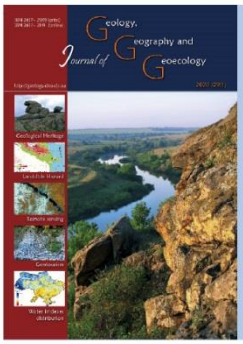

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The regional nosogeographical analysis and factors affecting population respiratory morbidity (on example of the Sumy region, Ukraine)

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Abstract. The article is devoted to consideration of the spatial-temporal structure of the primary morbidity and prevalence of the respiratory organs diseases among the population of the Sumy region. The article based on the data of annual statistical reports of medical institutions of Sumy region, which are subordinate to the Ministry of Public Health of Ukraine. The article used the methods of factor and correlation analysis, as well as methods of mathematical-statistical analysis, and ranking. The authors analyzed the spatial-temporal structure of respiratory organs pathology among the population and revealed the territorial differences and the dynamics of respiratory morbidity of the population. Nosogeographic assessment of territory of the Sumy region, which was carried out according to the integral respiratory diseases morbidity index (IMI), shows that today the highest values of IMI are obtained by analyzing the incidence rate in Putyvl' (1.01), Krasnopillia (1.02), Konotop (1.11), Buryn' (1.32) districts and in the city of Sumy (1.15). These are the districts where the incidence rate of respiratory diseases among the population has increased most of all during the study period. Low values of IMI are noted in Lypova Dolyna (0.63), Seredyna Buda (0.71), Velyka Pysarivka (0.72) and Nedryhailiv (0.79) districts. The higher is the IMI value, the worse the health level of the population. The average index storage respiratory diseases (ISD) in the Sumy region in 2017 was 1.27, with polarization ISD value in some areas from 1.19 in Shostka, 1.22 in Konotop, 1.23 in Yampil' and Trostianets regions to 1.39 in Lebedyn, 1.42 in Romny and 1.61 in the Seredyna Buda districts. This indicates the predomination of chronic forms of diseases over acute ones and can be explained by the influence of environmental and socio-economic factors. It also points to the need to increase of attention of both the regional and state components of the health care system. Besides that, the issues of providing financial and human resources for the health care system in districts with high incidence rates of respiratory pathology require attention. The study of the primary morbidity and the prevalence of respiratory diseases trends is a prerequisite for the development of preventive measures in the Sumy region. They are also needed to assess the quality of medical care for residents who have the pulmonary diseases. The factor analysis results are confirmed the importance of environmental and technogenic factors in formation of the indicators of primary morbidity and prevalence of respiratory diseases among the residents of the Sumy region.

Key words: respiratory diseases, primary morbidity, diseases prevalence, nosology, morbidity factors, nosogeographic assessment, medical and environmental research, Sumy region.

Регіональний нозогеографічний аналіз пульмонологічної захворюваності населення та пошук факторів, що її зумовлюють (на прикладі Сумської області, Україна)

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Анотація. Стаття присвячена розгляду просторово-часової структури первинної захворюваності та поширеності хвороб органів дихання серед населення Сумської області. Авторами виконана загальна нозогеографічна оцінка території регіону за цією групою нозологій й виділені фактори, що визначають рівень захворюваності на них. Отримані результати ґрунтуються на даних щорічних статистичних звітів медичних установ Сумської області, які підпорядковуються Міністерству охорони здоров'я України. У статті використано методи факторного і кореляційного аналізу, а також інші математико-статистичні методи і прийоми. У результаті аналізу просторово-часової структури поширення патологій органів дихання серед населення виявлено територіальні відмінності пульмонологічної захворюваності та з'ясовано динаміку рівнів захворюваності населення

на хвороби органів дихання. Проведена нозогеографічна оцінка території Сумської області, здійснена за показником інтегрального індексу захворюваності населення на хвороби органів дихання, свідчить, що сьогодні найвищі показники його показники отримані при аналізі захворюваності мешканців Путивльського (1,01), Краснопільського (1,02), Конотопського (1,11), Буринського (1,32) районів та м. Суми (1,15). Це ті райони, де показники захворюваності населення на хвороби органів дихання найбільше зросли за досліджуваний період. інтегрального індексу захворюваності відмічаються у Липоводолинському (0,63), Середино-Будському (0,71), Великописарівському (0,72) та Недригайлівському (0,79) районах. Чим вищий показник інтегрального індексу захворюваності населення на хвороби органів дихання, тим рівень здоров'я населення гірший. Середнє значення індексу накопичення пульмонологічних хвороб у Сумській області в 2017 р. становило 1,27 при поляризації цього показника в окремих районах від 1,19 у Шосткинському, 1,22 у Конотопському, 1,23 у Ямпільському та Тростянецькому районах до 1,39 у Лебединському, 1,42 у Роменському та 1,61 у Середино-Будському районах, що свідчить про переважання хронічних форм захворювань над гострими та може пояснюватися впливом екологічних та соціально-економічних чинників та рівнем медичного обслуговування.. Результати факторного аналізу підтверджують важливість екологічних і техногенних факторів у формуванні показників первинної захворюваності і поширеності хвороб органів дихання серед жителів Сумської області. Натомість показник забезпеченості населення регіону лікарями-пульмонологами характеризує розвиток системи охорони здоров'я, а не рівень здоров'я населення.

Ключові слова: хвороби органів дихання, первинна захворюваність, поширеність захворювань, нозологія, фактори захворюваності, нозогеографічна оцінка, медико-екологічне дослідження, Сумська область.

Introduction. Respiratory diseases are occupying a leading position among the diseases of the world's population in terms of prevalence as well as by percentage in the structure of death causes – through of them the 1/6 of all deaths in the world is occurring. Diseases of the respiratory system not only lead to premature death, but also often cause to disability of the able-bodied population, which is an additional social and financial burden for many countries. WHO estimates (Chronic, 2019) that 64 million people have chronic obstructive pulmonary diseases (COPD). In the European Union countries 600 thousand people die each year from pulmonary diseases only. Pathologies of this group are occupying the third place among the causes of death, after cardiovascular and oncological diseases.

According to modern interpretation, a respiratory pathology combines the diseases of infectious, allergic, immunological, and hereditary origin. In addition to these factors, some chronic diseases of respiratory organs as well as cancer pathologies of their, are associated with environmental, occupational and other harmful factors, and the etiology of some diseases has not yet been determined, therefore they are interpreted as idiopathic (Yakovenko, 2017).

In Ukraine, as in the world at large, respiratory diseases are also one of the most common pathologies of the population. According to the results of 2016, diseases of this nosological class in Ukraine were on second place in the structure of the prevalence of diseases (33952.9 cases per 100 thousand of people) after cardiovascular diseases, and in terms of primary incidence – on first place (28.445 case per 100 thousand people) (Dudina, 2015; Shevchenko, 1997). Residents of Sumy region, where respiratory diseases are very common and inferior only to diseases of the cardiovascular system (Kornus, 2018), are not an exception. This makes the study of regional disproportions of the pulmonary morbidity as important and relevant. The relevance of the study is also emphasized by the rapid rates of the respiratory diseases prevalence.

Review of previous researches. Regional differences in the incidence of the Ukrainian population by various diseases, including respiratory diseases, were considered in the works of various geographers. Most of them were relied on the classical works by V. Shevchenko about the medical-geographical analysis of the territory of Ukraine (the experience of foreign scientists is summarized in the monograph (Mayer, 2010), for example, (Shevchenko, 1997). Among the new ones, it is worth noting the scientific research by R. Molikevich, who investigated the peculiarities of population morbidity of the Kherson region for a wide range of nosologies (Molikevych, 2016). An analysis of the morbidity of population of the Chergihiv region is presented in the reaearch of T. Shovkun (Shovkun, 2012). Medical-geographical studies of the Ternopil region were conducted by I. Demianchuk (Demianchuk, 2017).

A certain part of the scientific works is devoted to clarifying the influence of environmental factors on the structure and level of morbidity formation (medical ecology). So, I. Mezentseva determined the coefficients of the relationship between the total chemical pollution of various components of the urban environment and the population morbidity of the Volyn region (Mezentseva, 2008). V. Gutsulyak & K. Nakonechnyi were engaged a medical and environmental analysis of Chernivtsi region's landscapes and medical-ecological assessment of the settlement geosystems of this region (Hutsuliak, 2010).

The third group of publications consists the works devoted to the geography of the medical

care sphere. Among of them are the studies of Kh. Podvirna, which examined the geospatial organization of the population health care of the Lviv region (Podvirna, 2010) and I. Martusenko, who studied the characteristics of the medical complex organization and the population health status of the Vinnitsa region (Martusenko, 2005).

Regarding the Sumy region, all of the above issues were considered in general form in numerous works by O. Kornus with co-authors, which found their generalization in the monograph (Kornus, 2015). However, diseases of the respiratory system, as such, which occupy the first place in the structure of the primary population morbidity, require more detailed study, as well as the search for the causes that cause of it. This is what determined the aim of our article. **The aim of the article** is to perform the nosogeographical assessment of the Sumy region's territory based on the analysis of the spatial and temporal structure of the respiratory diseases prevalence and the primary morbidity of inhabitants of the Sumy region, as well as to establish the factors defining the level of respiratory morbidity.

Material and research methods. The observation covers the period from 2005 to 2017. This study analyzed the data of annual statistical reports of medical institutions of the Sumy region, which are subordinate to the Ministry of Public Health of Ukraine. The structure of the following major respiratory diseases was investigated in the space-time aspect: 1) acute pharyngitis and acute tonsillitis; 2) acute laryngitis and tracheitis; 3) pneumonias); 4) allergic rhinitis; 5) chronic rhinitis, nasopharyngitis and pharyngitis; 6) chronic diseases of tonsils and adenoids; 7) chronic laryngitis and laryngotracheitis; 8) chronic obstructive pulmonary diseases; 9) bronchial asthma; 10) other respiratory diseases.

To establish the factors influencing on respiratory diseases prevalence, a methods of factor and correlation analysis were applied. The latter provided for the determination of the correlations between the prevalence of diseases and the environmental and socio-economic indicators, as well as the number of doctors providing specialized medical care. As a result of the analysis, 680 paired Pearson correlation coefficients were obtained between the socio-economic indicators and factors characterizing the environment quality, on the one hand, and the primary morbidity of Sumy region inhabitants and the respiratory diseases prevalence belonging to the above mentioned ten nosological groups, on the other hand. From the resulting correlation array, there are 37 pairs for which the correlation is significant at the level of ≤0.05 and 10 pairs for which the correlation is significant at the level of ≤0.01 were identified, that is; those where the connections between the correlated parameters are the closest and most reliable. Thus, out of all correlation array, only 47 (6.9 %) correlation coefficients are statistically significant.

To carry out a nosogeographic assessment of territory of the Sumy region, the indicators of the diseases prevalence and the population primary morbidity were used. Nosogeographical assessment we understanding as selection and systematization of administrative-territorial units, differing from each other by the structure of nosologies, prevalenting among inhabitants. This assessment was carried out in several stages. At the first stage, the average value of both estimated indicators for the period 2005-2017 was calculated for each respiratory disease by administrative units of the Sumy region. After that, the normalized health indicators *(HI)* of the population (Demianchuk, 2017) were calculated for all nosologies in the administrative districts by the formula

$$HI = \frac{\bar{x}}{P_n} \qquad (1),$$

where: $\bar{x}$ – average value of the nosology indicator (average value of the j-th indicator in the n-th administrative district); – the value of the normative nosology indicator (average regional value of the j-th indicator).

At the final stage, the calculation of the integral morbidity index *(IMI)* of the population by respiratory diseases for each of administrative districts of the region was carried out by formula:

$$IMI = \frac{1}{n}\sum_{i=1}^{n} HI \qquad (2),$$

where: n – the number of nosologies taken for analysis; *HI* – normalized health indicator of the n-th administrative district.

Many nosological forms are diagnosed in a launched state, therefore they are difficult to cure that quite often lead to mortality. Take into account this fact an important moment of the nosogeographical evaluation of territory is the determination of the level of diseases accumulation. It is believed (Demianchuk, 2017) that the indicator of diseases accumulation, in addition to assessing the actual morbidity, provides an opportunity to analyze the level of preventive work, to assess the quality of primary diseases diagnosis and the medical services availability. One such index is the index storage diseases *(ISD)* – the ratio between prevalence of diseases and primary morbidity. Higher values of this index indicating, first of all,

the predomination of chronic forms of diseases over acute ones in a some region, and also indicate a better level of medical care for the population as well as the favorable influence of other social factors on the diseases course (Demianchuk, 2017).

All calculations as well as the graphic images and figures were obtained using SPSS Statistic 17.0 computer software by SPSS Inc., Microsoft Excel 2010 and Statistica 10 by StatSoft Inc.

Results and discussion. As of January 1, 2018 in Sumy region the primary morbidity by respiratory diseases was 22,070.29 cases per 100 thousand people, and the prevalence of diseases was 28,054.31 cases per 100 thousand of inhabitants. During 2005-2017, there is an increase both primary morbidity (by 15.04 %) and the prevalence of respiratory diseases (by 14.42 %). The city of Sumy, Konotop and Bilopillia districts have the highest rates of both primary morbidity and prevalence of disease. The lowest prevalence of respiratory pathologies in 2017 was recorded in Lebedyn, Hlukhiv, Nedryhailiv and Lypova Dolyna districts, and the primary incidence – in the Lebedyn, Hlukhiv, Nedryhailiv and Seredyna Buda districts.

During the study period, the primary incidence and respiratory diseases prevalence among the population were decreased in three administrative units only – Krasnopillia (by 12.26 % and 7.99 %, respectively), Okhtyrka (by 7.61 and 3.08 %) districts and Sumy city (by 7.67 % and 3.94 %). And for most districts of Sumy region, the growth of primary incidence and prevalence of this group of nosologies was characteristic, which was most noticeable in four districts – Shostka (primary incidence increased by 66.06 % and prevalence by 52.04 %), Konotop (86.37 % and 56.96 %), Seredyna Buda (1.8 times and 68.36 %), Putyvl' (76.28 % and 69.42 % respectively).

According to medical statistics, chronic obstructive pulmonary diseases (COPD) were the most common pulmonary diseases in the Sumy region in 2017. According to WHO, (Chronic, 2019) COPD is a collective term, but not a single disease. It is used to describe all chronic respiratory diseases that limit airflow to lungs. Terms such as «chronic bronchitis» and «emphysema» are no longer used and are now included into the diagnosis COPD. Among administrative districts, the highest of this pathology prevalence are observed among the inhabitants of Velyka Pysarivka (1,842.93 cases per 100,000 people), Konotop (1,844.74), Lebedyn (1,979.03) and Putyvl' (3,228.39 cases per 100 thousand of people) districts. The inhabitants of Shostka (1,054.87) and Trostianets districts (1,158.53 cases per 100 thousand people) are suffer from COPD at least of all.

As for primary morbidity by COPD, according to the results of 2017, Buryn' (141.87 cases per 100 thousand people), Velyka Pysarivka (146.6), Okhtyrka (172.74) and Putyvl' (421.73 cases per 100 thousand people) districts are the leaders on this indicator. The number of cases of bronchitis, emphysema and other chronic obstructive pulmonary diseases, reported for the first time in 2017, was lowest among the inhabitants of Romny (35.71) and Seredyna Buda (36.45 cases per 100 thousand people) districts.

It is also worth noting a decrease of the prevalence of this group of pathologies among the inhabitants of all districts of the Sumy region, except Putyvl', where this indicator for 2005-2017 was grow by 18.35 %. In the six districts of the region, the prevalence of these diseases is reduced by more than 50 %; in Yampil' (by 66.21 %), Romny (by 60.42 %), Seredyna Buda (by 59.81 %), Konotop (by 58.03 %), Shostka (by 56.87 %) and Okhtyrka (on 51,82 %) districts. The primary respiratory nosologies are also decrease in most administrative-territorial units of the region (11 out of 19). Among the districts where there is an increase of the primary morbidity by COPD, Putyvl' district is again stands out. For the Putyvl' district inhabitants this indicator has more than doubled.

Acute pharyngitis and tonsillitis are in second place in the structure of respiratory diseases of the Sumy region residents. These are infectious diseases developing on the background of acute respiratory viral diseases. Complications from them can cause an acute rheumatic fever, which in 40-60 % of cases leads to irreversible autoimmune damage of heart valves and the development of chronic rheumatic heart disease (Masheiko, 2017). For the years 2005-2017 in the region only in four administrative-territorial units there was a decrease of the prevalence of acute pharyngitis and tonsillitis: in Buryn' (by 17.78 %), Bilopillia (by 16.64 %), Konotop (by 3.21 %) districts and in the city of Sumy (by 12.69 %).

However, in most areas there are an increase of prevalence of these nosologies. The prevalence of acute pharyngitis and tonsillitis among the inhabitants of Putyvl' district increased by 10 times (from 422.32 to 4,224.53 cases per 100 thousand people), and among residents of Seredyna Buda district – almost by 20 times (from 115.23 to 2,205.48 cases per 100 thousand inhabitants). For these two districts, there are also a high growth rate of primary morbidity, which in Putyvl' district during 2005-2017 has increased by 4 times. Therefore, here, as well as among the residents of Yampil' and Trostianets districts, the highest rates of primary morbidity and prevalence of this group of nosologies were observed.

The decrease of the population primary morbidity by acute pharyngitis and acute tonsillitis during the above mentioned observation period was recorded only in Buryn' (by 7.36 %), Bilopillia (by 13.7 %), Konotop (by 21.51 %), Lebedyn (by 16,01 %) districts and in the city of Sumy (by 22.1 %). In Sumy, as well as Lypova Dolyna, Romny and Shostka districts, the lowest indicators of the primary morbidity of their inhabitants were recorded.

Chronic diseases of the tonsils and adenoids are occupying the third place in the structure of respiratory diseases of the Sumy region population. Most often children are falling ill by these. The reasons that contribute to the development of this diseases group including inflammatory diseases of the upper respiratory tract, infectious diseases (measles, diphtheria, influenza, etc.). In this case, what happens is a lesion of the nasal mucosa and tonsils, which leads to a violation of nasal breathing. In 2017, the chronic diseases of the tonsils and adenoids were most common among the inhabitants of Bilopillia (1,034.75 cases per 100,000 people), Lypova Dolyna (1,039.11), Putyvl' (1,265.18) and Buryn' (2,245.55) districts, and the lowest prevalence rates were recorded in Velyka Pysarivka (387.43) and Hlukhiv (392.95 case per 100 thousand inhabitants) districts. During 2005–2017, in eight districts of the region there was a decrease of the prevalence of these diseases, especially noticeable among the residents of Krasnopillia (by 77.17 %) and Hlukhiv (by 55.10 %) districts. At the same time among the inhabitants of Putyvl' district the diseases of tonsils and adenoids were almost doubled, and in Lypova Dolyna district were increased almost by 8 times.

The highest rates of newly registered cases of chronic diseases of the tonsils and adenoids were observed in Shostka (400.58), Yampil' (436.42), Putyvl' (596.23) districts and in the city of Sumy (453.92 case per 100 thousand inhabitants). In 2017, least of all these nosologies were distributed among the residents of Nedryhailiv (12.33), Lebedyn (30.65) and Velyka Pysarivka (68.06 case per 100 thousand people) districts. According to the dynamics of primary population morbidity of the region by nosologies of this group, then in nine districts there are positive trends to its reduction. It was especially noticeable among the residents of Nedryhailiv (by 95.86 %), Krasnopillia (by 86.53 %), Lebedyn (by 79.85 %) and Velyka Pysarivka (by 68.74 %) districts. In other administrative units, on the contrary, an increase of primary morbidity is observed: Romny (2 times increase), Lypova Dolyna (almost 4 times increase), Seredyna Buda (6.5 times increase) and especially in Putyvl' (more than 12 times increase) districts.

Theoccurrenceofrespiratorydiseasesisassociated with many factors, including environmental, natural, genetic, socio-economic, and others. Environmental or technological factors (dustiness and gas pollution of atmospheric air, the excess of safe concentrations a chemical elements in the environment, water and food products pollution) cause mainly infectious-inflammatory diseases (bronchitis, pneumonia), as well as allergic reactions that can develop to bronchial asthma. For example, it is estimated that indoor air pollution is responsible for 2.7 % of diseases globally (the 8th most important risk factor for pathologies occurrence) and 1.5–2 million deaths annually. As separate factor is the effect of mold fungi, which is a source of allergens and may increase the risk of asthmatic problems by 30-50 % (Zdorove, 2014). The effect of suspended particles, gases, vapors or smoke in the workplace causes 15 % of all cases of the respiratory tract cancer in men and 5 % in women and 15-20 % of all asthma cases (are known about 350-400 different agents causing occupational bronchial asthma) and COPD among adults (Zdorove, 2014).

Atmospheric pollution in the Sumy region occurs because of emissions into the atmosphere from stationary and mobile sources of pollution, transboundary transfer of pollutants and the ability of atmosphere to self-purification. The presence and nature of stationary pollution sources are determined by the development in the region a mining and chemical industries, engineering, food industry and other sectors of the economy that emit the pollutants. At the end of 2015, there are 936 industrial enterprises that emitted the pollutants into the atmospheric air operated in the region (Kornus, 2017).

The results of many medical-ecological studies are show that there is close links between pollution of surface layer of the atmosphere and the population health in time and in space (Kornus, 2015). For example, in (Hutsuliak, 2010), which concerns to medical and ecological assessment of the Chernivtsi region was found that the most vulnerable human organs are organs of direct exposure (the respiratory organs). In the same paper was received extremely high correlation coefficients ($r = 0.9$) between air pollution and disease of children by bronchial asthma, as well as the dependence of mortality due to respiratory diseases from overall emissions of air pollutants. Our results partially confirm these conclusions (Fig. 1), although the correlation coefficients values that we obtained are significantly lower. As can be seen from Fig. 1, there is so close relationship between the prevalence of bronchial asthma ($r = 0.468$, $p < 0.038$)

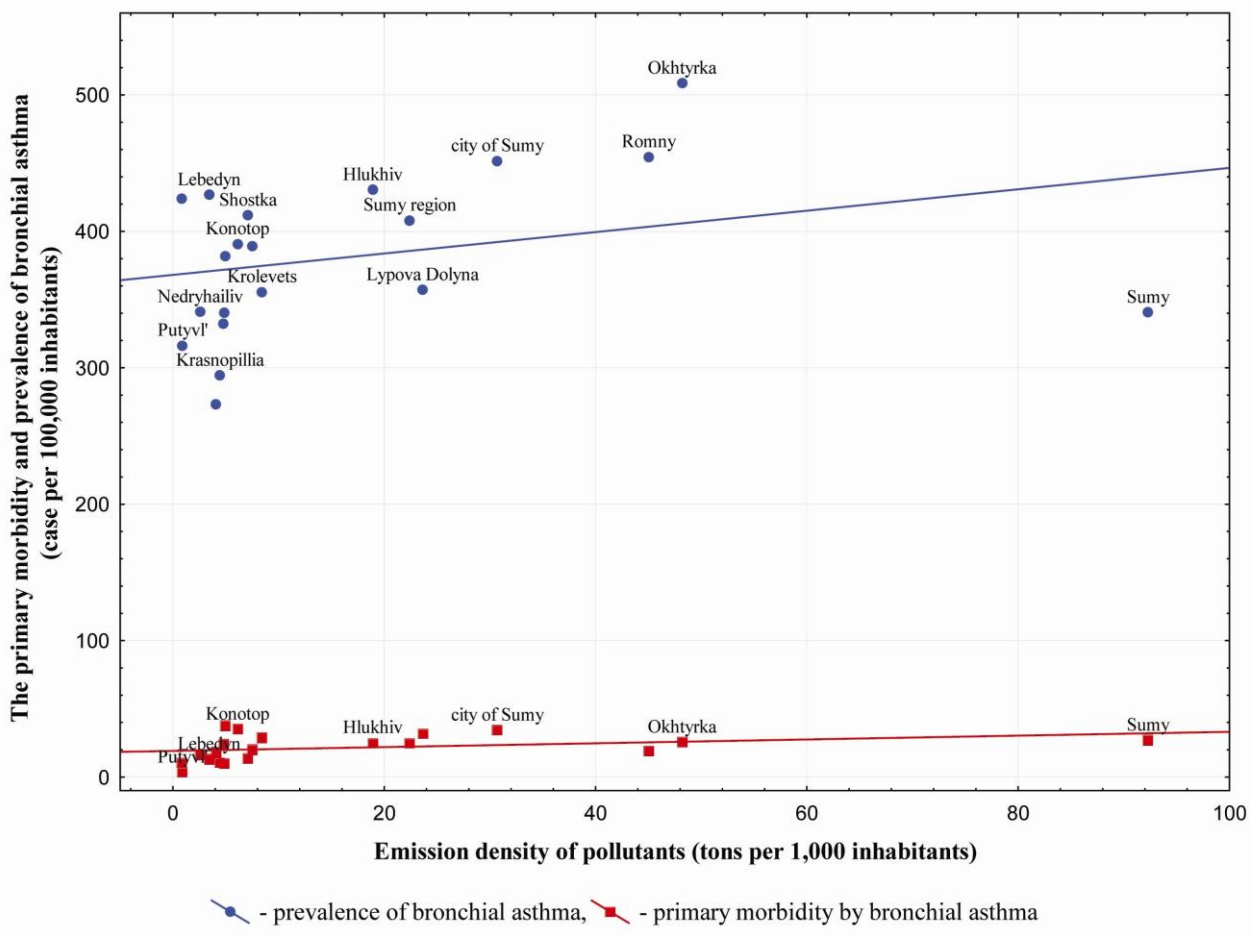

Fig. 1. The relationship between the primary morbidity and prevalence of bronchial asthma and the emission density of pollutants into atmospheric air of the Sumy region (Source: Own edition)

as well the primary incidence by this nosology ($r = 0.547$, $p < 0.002$) and the amount of pollutant emissions into the atmospheric air.

In general, the prevalence of bronchial asthma is very indicative in this regard – this indicator closely correlates with many ingredients polluting the air. However, the closest and with a high degree of reliability are the relationships between the prevalence of bronchial asthma and emissions of Nitrogen dioxide ($r = 0.629$, $p < 0.01$), Sulfur dioxide ($r = 0.715$, $p < 0.01$), as well emissions of Methane ($r = 0.495$, $p < 0.05$) and Non-Methane volatile organic compounds ($r = 0.487$, $p < 0.05$) (Fig. 2).

With the density of pollutants emissions into the air both in all terms and in terms of individual pollutants, especially SO_2, C and CO_2, are closely correlates with the prevalence of pulmonary diseases, including allergic and chronic rhinitis, nasopharyngitis, pharyngitis and the primary morbidity of the population of administrative units of the Sumy region by these pathologies.

Both the primary incidence ($r = 0.609$, $p < 0.01$) and the general prevalence ($r = 0.648$, $p < 0.01$) of respiratory diseases at all (Fig. 3) are related to the density of SO_2 emissions. A somewhat less significant, but noticeable, is the relationship is between the emission of CO into the atmosphere and the primary incidence ($r = 0.585$, $p < 0.01$) and the prevalence ($r = 0.482$, $p < 0.05$) of chronic rhinitis, nasopharyngitis and pharyngitis (Fig. 4), as well as the prevalence of bronchial asthma among residents of the Sumy region ($r = 0.523$, $p < 0.01$), the relationship of which with the quality of atmospheric air has already been mentioned above.

The technogenic factor also can cause other professional diseases – allergic rhinitis of office workers, carboconiosis of miners, aluminosis of metallurgists, and pneumoconiosis of electric welders. The accumulation in the air Carbon oxides, Sulfur, Nitrogen, Formaldehyde, industrial dust (and with it compounds of heavy metals, surfactants and other pollutants) leads to disruption of the function of the surfactant in lungs, enzymes in tissues of the respiratory organs, that resulting to autoallergic conditions (bronchial asthma, obstructive bronchitis, respiratory allergies) development (Chronic, 2019).

Natural factors are divided into abiotic (cosmic, geo- and heliofactors) and biotic (for example,

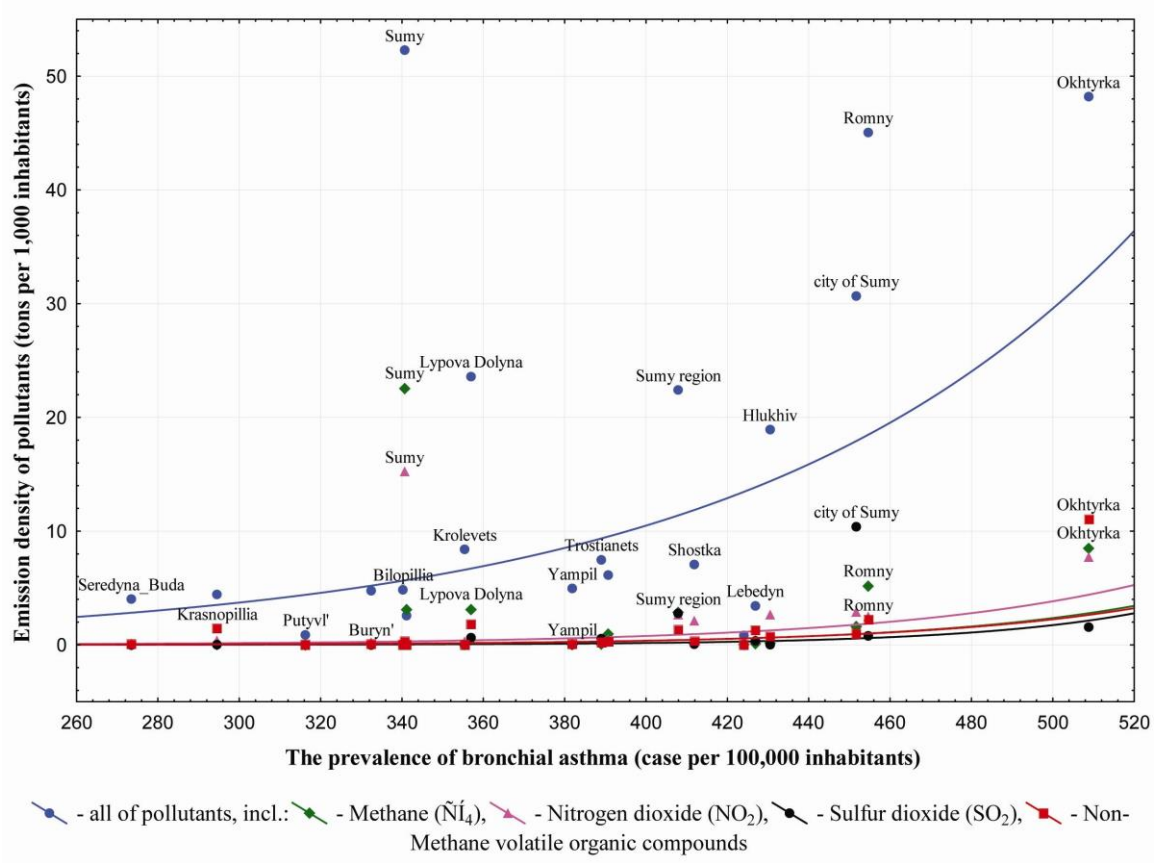

Fig. 2. The relationship between the prevalence of bronchial asthma and the emission density of some pollutants into atmospheric air of the Sumy region

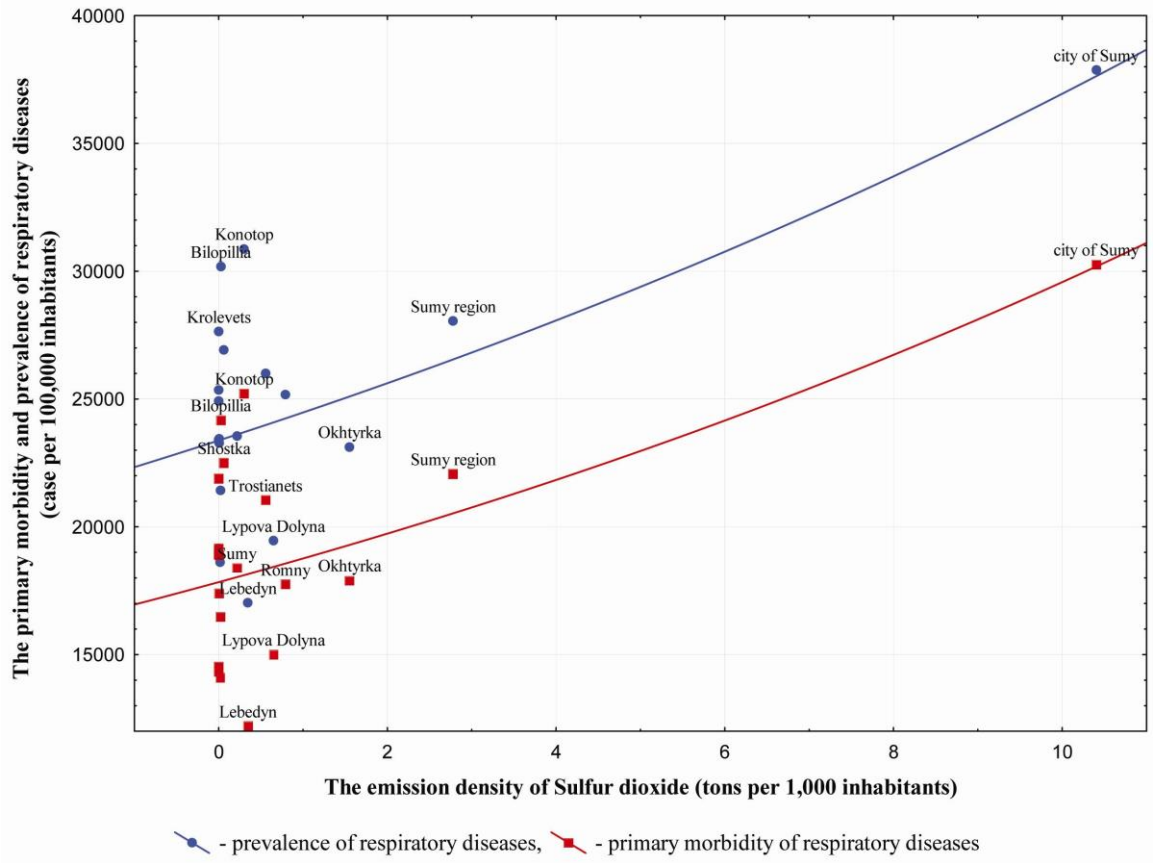

Fig. 3. The relationship between the primary morbidity and prevalence of respiratory diseases and the emission density of Sulfur dioxide (Source: Own edition)

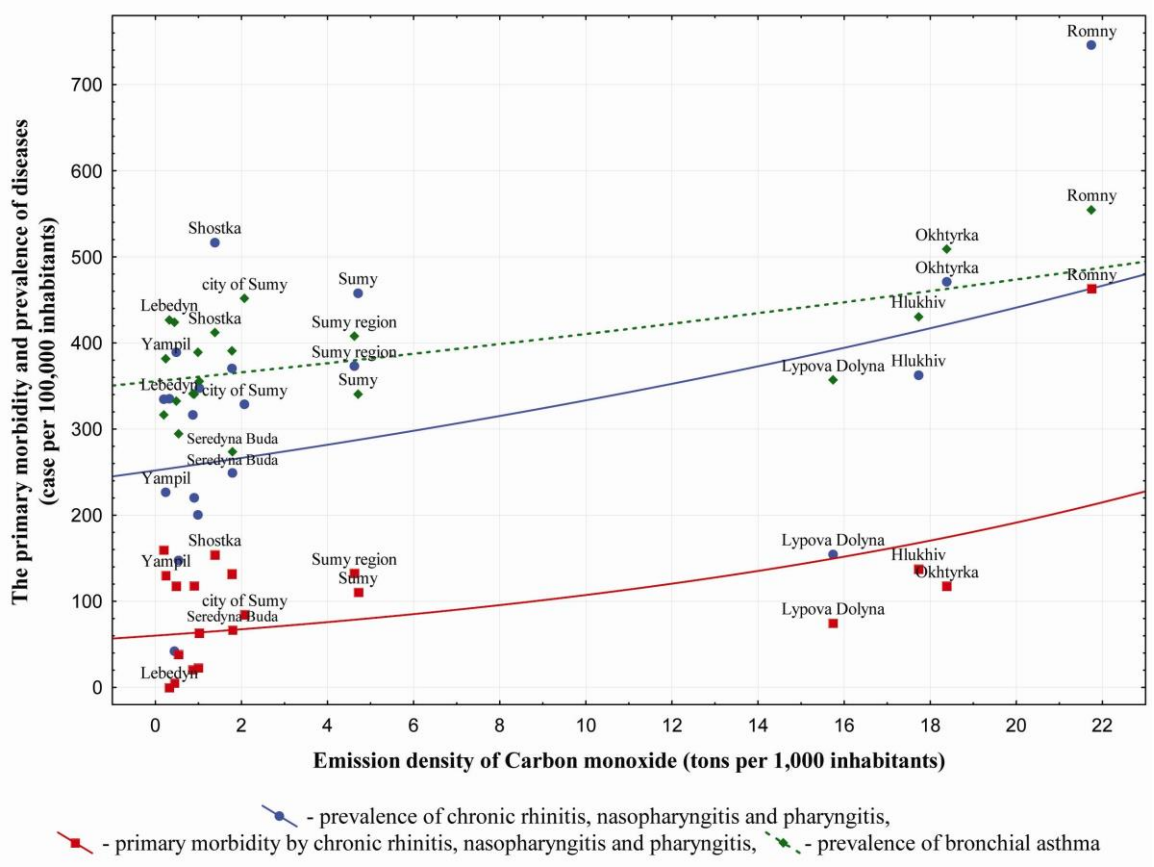

Fig. 4. The relationship between the primary morbidity and prevalence of some respiratory diseases and the emission density of Carbon monoxide in the Sumy region (Source: Own edition)

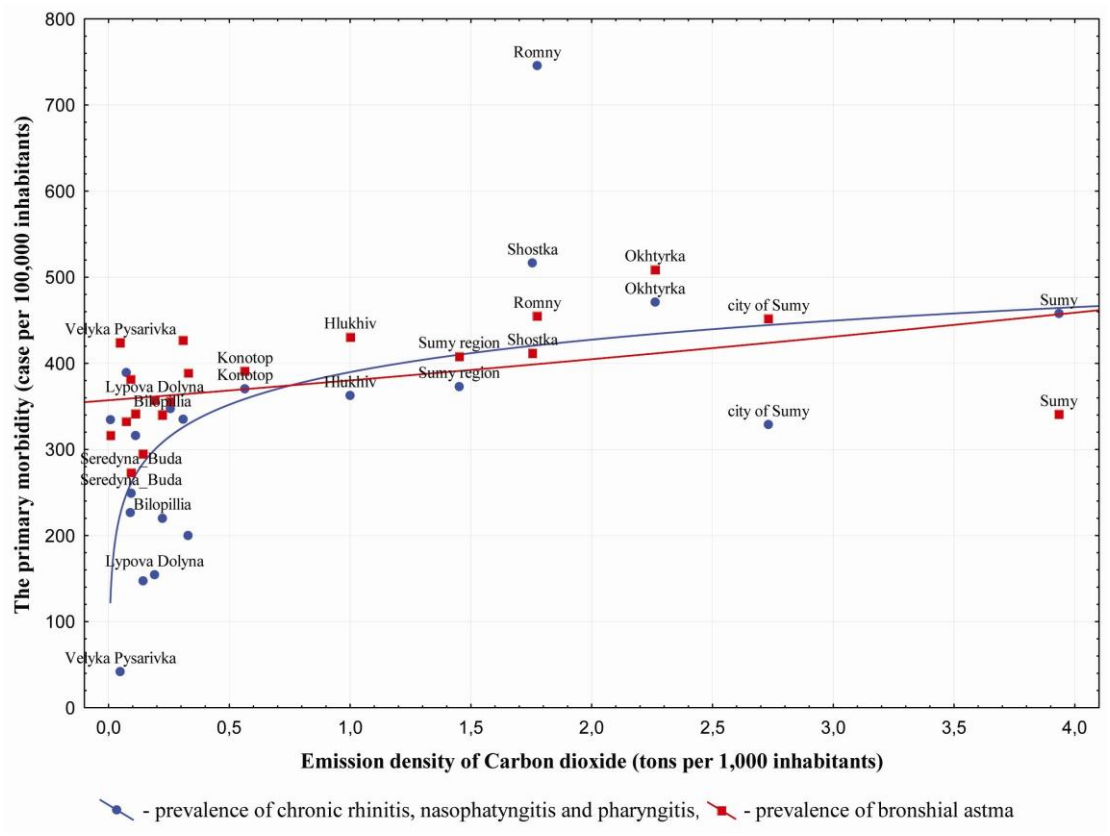

Fig. 5. The relationship between the prevalence of some respiratory diseases and the emission density of Carbon dioxide in the Sumy region (Source: Own edition)

bacteria and viruses). The latter cause the appearance of bronchitis, pneumonias, tonsillitis and pharyngitis, rhinitis, etc. Climatic and meteorological factors (humidity of air, atmospheric pressure, temperature) can lead to development of various inflammations of respiratory organs, exacerbations of chronic obstructive pulmonary disease, pneumonia, influenza and the like. The consequences of forest fires (Buts, 2018), geological factors, in particular the emission of Radon from the bowels of the Earth, can also provoke some diseases. For example, a Radon ejection is the second most important (after smoking) cause of lung cancer.

The prevalence rates of chronic rhinitis, nasopharyngitis and pharyngitis ($r = 0.581$, $p < 0.01$) and the prevalence of bronchial asthma ($r = 0.453$, $p < 0.05$) are correlate quite clearly with the emissions density of CO_2 (Fig. 5).

Important in the emergence and development of respiratory diseases is a socio-economic factor, which includes working conditions, population density, intellectual and cultural level of society development, bad habits (tobacco smoking, alcohol abuse, drug use, poor quality nutrition), conflicts, etc. It should be noted that this factor may exceed others. For example, smoking is the main cause of many lung diseases (tobacco smoke contains more than 4,000 chemicals, many of which are toxic and carcinogenic). It is estimated (Zdorove, 2014) that during the 20th century, 100 million people in world at large were died from smoking and this number will increase to 1 billion over the 21st century. In the EU, lung cancer kills more people than any other cancers (it accounts for about 20 % of all cancer deaths). Passive smoking also belongs to the important causes of respiratory diseases. More than 600 thousand people in world at large, who do not use tobacco products, die each year as a result of passive smoking (Zdorovie, 2014). More than 250 chemicals affecting the human body because of passive smoking are known as toxic or carcinogenic and can causing lung cancer, cough, obstructive and other pulmonary diseases.

Our research has established a fairly close and reliable relationship between the population density and the primary incidence by respiratory diseases of the Sumy region inhabitants ($r = 0.623$, $p < 0.01$), and the prevalence ($r = 0.660$, $p < 0.01$) of these diseases (Fig. 6).

The influence of socio-economic factors assessed through the search of correlations between the primary incidence or prevalence of diseases and the value of GDP per capita, the level of employment, incomes of the population, etc. In this context, we have found a relationship between the level of socio-economic development of administrative units of the Sumy region, calculated according to the method (Kornus, 2007) and the primary incidence ($r = 0.648$, $p < 0.01$) of their inhabitants by respiratory diseases and prevalence ($r = 0.678$, $p < 0.01$) of these diseases (Fig. 7).

As separate factor is the level of health care – the quality of medical services, their availability as well the availability of preventive measures and the availability of the appropriate profile doctors, places in hospitals. Usually, when the first clinical signs of these nosologies are appear, patients turn to family doctors or therapists, and when the diagnosis is confirmed, they are referred for examination or treatment to pulmonologists. To clarify the possibilities of overcoming the consequences of respiratory organs morbidity, it is important to analyze medical assistance for the population of the Sumy region. According to medical statistics, as of January 1, 2018, in the Sumy region pulmonological medical care for patients was provided by 13 pulmonologists, two of them are working in cities of Konotop and Okhtyrka. The remaining specialists are working in the regional center.

It should be noted there are no reliable links between morbidity or mortality rates from respiratory diseases and the staffing level by family doctors as well availability of pulmonologists. Therefore, the number of doctors or hospital beds is an indicator of assessing the availability of medical care, but not the state of public health. A big number of hospital beds do not mean at all that the health of the population in such regions is better than in those where their number is lower. This opinion is supported the results of studies by O. Krasnova (Krasnova, 2014), according to which an increase of number of a hospital beds is no way affects neither the prevalence of diseases, nor the primary morbidity.

Also to factors that determine the development and prevalence of respiratory diseases included the genetic factor, which is closely related to the state of environment and exposure of teratogenic factors (alcohol, drugs, smoking, industrial poisons, medicaments, food additives, etc.), which act during the time of embryogenesis and disturbing the development of tissues and organs. This can provoke severe pathological phenomena or lead to chromosomal and genetic mutations. In some people, an increased risk of lung diseases developing may be associated with a genetic predisposition inherited from the parents. Hereditary diseases are including congenital bronchiectasis, primary pulmonary hypertension, familial pulmonary emphysema, pulmonary alveolar microlithiasis, tracheobronchomegaly (Mounier-Kuhn Syn-

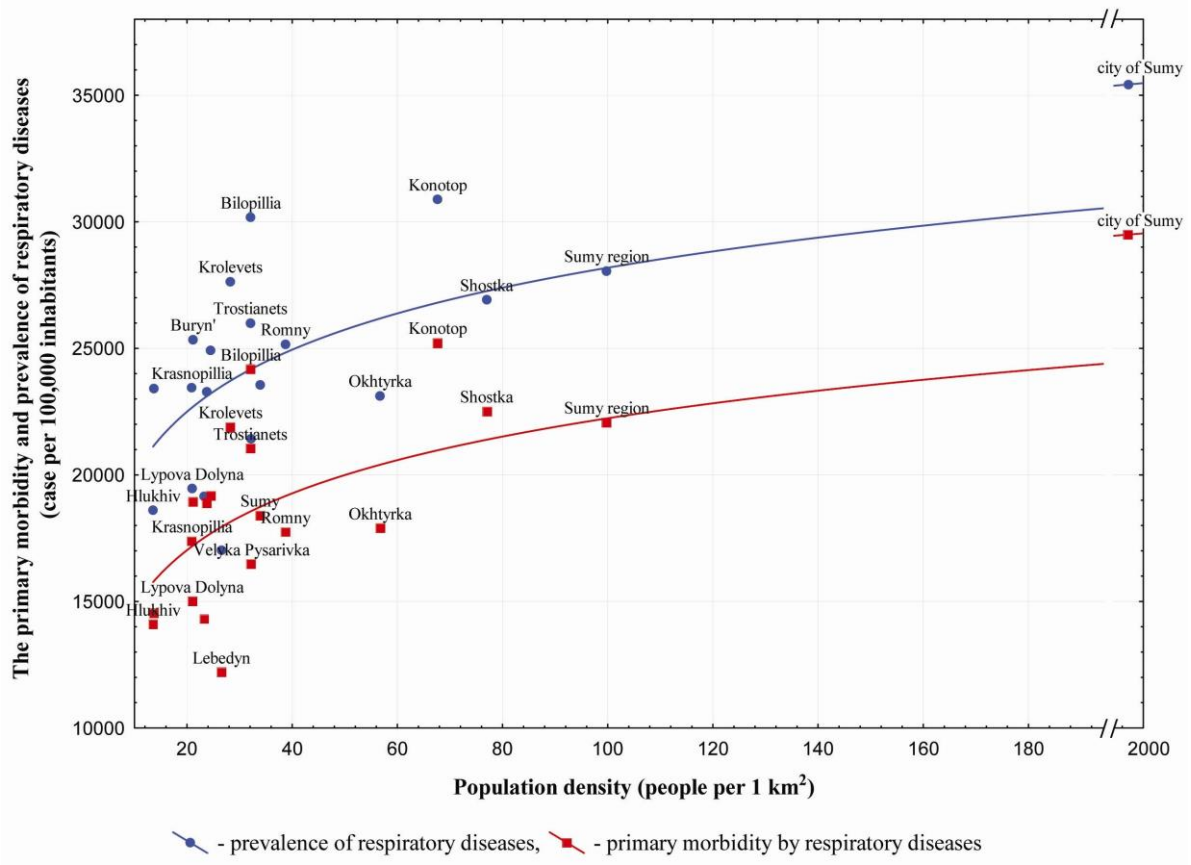

Fig. 6. Dependence the primary morbidity and prevalence of respiratory diseases among the population of the Sumy region from the population density (Source: Own edition)

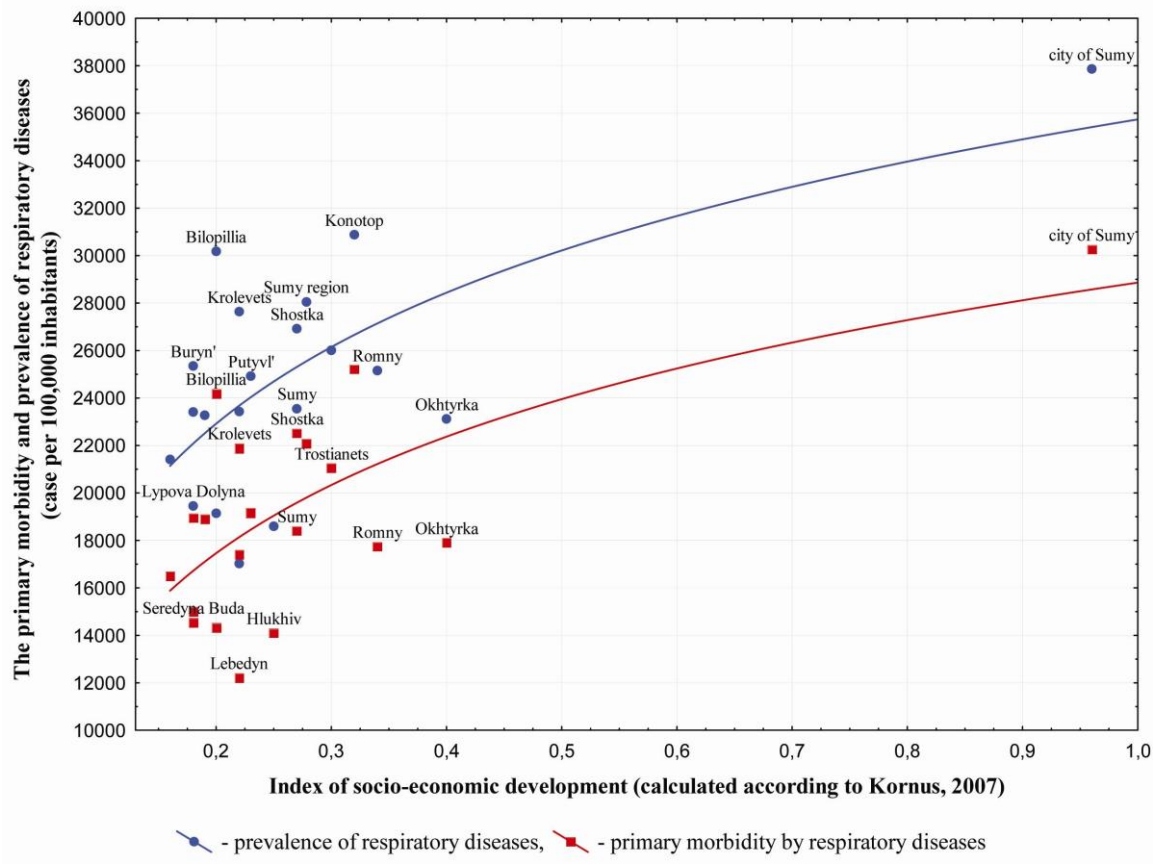

Fig. 7. Dependence the primary morbidity and prevalence of respiratory diseases among the population of the Sumy region from the level of socio-economic development of administrative-territorial units of the Sumy region (Source: Own edition)

drome), congenital bronchomalacia, immotile ciliary syndrome, Kartagener's syndrome (Novikov, 2007). The development of mucoviscidosis (cystic fibrosis) is associated with more than 1000 different mutations of the CFTR gene. COPD is develops in only about 20 % of smokers, which suggests a significant role of genetic factors for the development of this disease (Zdorove, 2014).

Conclusions. Analysis of the spatial and temporal structure of diseases of the respiratory organs of residents of the Sumy region made it possible to establish the territorial differences and the dynamics of the population morbidity and predict further scenarios of their development. During 2005-2017, there is an increase of the primary morbidity of the population as well as the prevalence of pulmonary diseases among inhabitants of the Sumy region. The leaders in terms of the primary morbidity and the prevalence of respiratory diseases among the population are city of Sumy and Konotop and Bilopillia districts.

Nosogeographic assessment of territory of the Sumy region, which was carried out according to the integral respiratory diseases morbidity index *(IMI)*, shows that today the highest values of *IMI* are obtained by analyzing the incidence rate in Putyvl' (1.01), Krasnopillia (1.02), Konotop (1.11), Buryn' (1.32) districts and in the city of Sumy (1.15). These are the districts where the incidence rate of respiratory diseases among the population has increased most of all during the study period. Low values of *IMI* are noted in Lypova Dolyna (0.63), Seredyna Buda (0.71), Velyka Pysarivka (0.72) and Nedryhailiv (0.79) districts. The higher is the *IMI* value, the worse the health level of the population.

The average index storage respiratory diseases *(ISD)* in the Sumy region in 2017 was 1.27, with polarization *ISD* value in some areas from 1.19 in Shostka, 1.22 in Konotop, 1.23 in Yampil' and Trostianets regions to 1.39 in Lebedyn, 1.42 in Romny and 1.61 in the Seredyna Buda districts. This indicates the predomination of chronic forms of diseases over acute ones and can be explained by the influence of environmental and socio-economic factors. It also points to the need to increase of attention of both the regional and state components of the health care system. Besides that, the issues of providing financial and human resources for the health care system in districts with high incidence rates of respiratory pathology require attention. The study of the primary morbidity and the prevalence of respiratory diseases trends is a prerequisite for the development of preventive measures in the Sumy region. They are also needed to assess the quality of medical care for residents who have the pulmonary diseases.

The factor analysis results are confirmed the importance of environmental and technogenic factors in formation of primary morbidity and prevalence of respiratory diseases among the residents of the Sumy region. However, the indicator of the provision of region's population by doctors characterizes the development of health care system, but not the level of population's health. Among the environmental and socio-economic factors, the closest and most reliable is the correlation between emissions of Sulfur dioxide and the prevalence of asthma ($r = 0.715$, $p < 0.01$), the level of socio-economic development and the prevalence of respiratory diseases ($r = 0.678$, $p < 0.01$), and between the prevalence of these diseases and population density ($r = 0.660$, $p < 0.01$).

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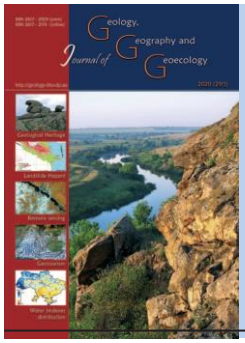

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Development of tourism is in the epoch of economically-politically reforms and war in Ukraine

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Abstract. Today, Ukraine is at the center of the world community, politics and the European market, in light of changes in the political, economic and military spheres. Undoubtedly, all this influenced the development of the country's economy and policy towards the countries of the near and far abroad, including the development of the tourism industry.

To characterize the current state of development of domestic and international tourism in Ukraine and served as the main purpose of writing an article. The research of the current state of tourism development in Ukraine was based on the application of a systematic approach using comparative, statistical, analytical methods, etc. The relevance of this study is determined by the clarification of the further direction of tourism development in connection with the deprivation of tourism industry as a priority in 2019, although it is one of the significant sources of filling the state treasury, as well as the impact on the tourist image of Ukraine, an aggressor country during the period of change of power and incomplete reforms. It is established that the tourist image of Ukraine is restored from 2016 due to the victorious participation of Ukrainians in international events, in particular, Eurovision-2017, but it should be noted that the main donor countries are the countries of close foreign countries. Visa tourism has been intensified with Ukraine through visa-free travel and pricing policies for tourist services. For example, when comparing prices with the tourist complex «Bukovel» or «Shayan» cheaper to rest in Poland or Hungary. One of the reasons was revealed: the population's low awareness of the tourist potential of the country; unreliability of domestic subjects of tourism activity; the lack of security in the places of rest, as well as the war in the east of Ukraine and the annexation of the Crimean peninsula. It was found that the length of stay of Ukrainians abroad depended on the location of the country. The farther the longer, which is associated with the cost of time and money. Also, you should not neglect tourist logistics. After all, almost all flights from Ukraine abroad are sent in the morning. Arriving in the evening, a tourist-Ukrainian is forced to seek a lodging for himself. While in Ukraine, on the contrary, tourists mostly come in the morning or in the afternoon. It should also be noted that the marked decrease in trips abroad is due to the poverty of the Ukrainian population. The main purpose of travel – rest on the warm seas of the seas for the best price and high quality of service for tourists. It is statistically reported that the geography of recipient countries is predominantly close to a foreign country, mainly the CIS countries, while, for example, most of Belarus comes to the EU. The development of domestic tourism, which tends to grow, is estimated. The main factors of its development are the desire of Ukrainians to travel even with a minimal budget. However, it should be noted the predominance of self-organized tourism. The main tourist areas with the predominance of a certain type of tourism were identified, for example Lviv – cultural-cognitive, Ivano-Frankivsk and Transcarpathian – active and eventful, Odessa – recreational types of tourism. The tendency of the steady development of tourism in Ukraine due to the development of transport infrastructure, information and communication environment, the election of the European development vector is revealed. In the near future it is expedient: to adjust the Law «On Tourism» in accordance with the EU directives in the tourism sector, as well as to direct the direction for the development of domestic and inbound tourism in Ukraine.

Key words: domestic and international tourism, Ukraine, development.

Розвиток туризму в епоху політико-економічних реформ та війни в Україні

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Анотація. Зважаючи на зміни у політичній, економічній та військовій площинах, сьогодні Україна знаходиться у центрі світової спільноти, політики та європейського ринку. Безперечно, все це вплинуло й на розвиток туристичної галузі. Констатовано, що туристичний імідж Україна втратила після анексії Криму та війни на сході держави. Відновлення його

наступило завдяки переможній участі у міжнародних заходах та проведення останніх в Україні, наприклад, «Євробачення-2017 р.». Авторами з'ясовано, що основними країнами донорами туристів є країни близького зарубіжжя. Це зумовлено входженням України в трійку найдешевших країн світу й покращення туристичної логістики. Сьогодні Україна починає відновлюватися на міжнародному туристичному ринку, хоч приймає у 10 разів менше туристів ніж сусідні держави, наприклад, Білорусь. Основними видами туризму в Україні є активний та культурно-пізнавальний туризм. Виявлено, що тривалість перебування українців за кордоном залежала від розташування країни. Чим дальше тим довше, що пов'язано з затратами часу та грошей. Цьому сприяла також туристична логістика. Статистично представлено, що географія країн-реципієнтів представлена близьким зарубіжжям. Оцінено розвиток внутрішнього туризму, який має тенденцію до зростання. Виявлено, що українці подорожують навіть з мінімальним бюджетом, з переважанням самоорганізованого туризму. У порівнянні з Білорусь кількістю внутрішніх туристів в Україні у двічі менша, незважаючи на більшу кількість населення. Це зумовлено щорічним зростанням заробітних плат, малим відсотком інфляції та стійким курсом валют в сусідній державі. Виявлено тенденцію поступального розвитку туризму в Україні завдяки: покращення транспортної інфраструктури, інформаційно-комунікаційного середовища, обрання європейського вектора розвитку. У найближчий час доцільно: постійно отримувати фінансову підтримку з боку держави, надавати юридичну допомогу суб'єктам туристичної діяльності, а також розвивати внутрішній та в'їзнмй туризм.

Ключові слова: внутрішній та міжнародний туризм, Україна, туристична галузь.

Introduction. The role and importance of the tourism industry in the development of the country's economy are rethinking and changing in the process of globalization of society. The tourist industry forms a peculiar (on the intersection of multicultural, multiconfessional, polyglot, communication-information, logistic, etc.) environment, which develops under the influence of external and internal factors. The influence of the latter is significant, in particular during the period of economic-political-military transformation in the state and in the world. Ukraine is now at the epicenter of all of the above-mentioned changes over the course of 5 years, which greatly influences the development of the country's economy, including the tourism industry.

In particular, the influence of an external factor manifests itself in the destabilization of security inside the country through the Ukrainian-Russian war in the east of the state and the annexed territories of the Crimean peninsula by Russia. Equally important are internal factors, in particular, investment climate, hryvnia inflation, exchange rate, economic crisis, social and religious conflicts, etc. Therefore, the development of the tourism industry in such conditions is dependent from the realities of the present, which determine the change in the domestic and international tourist markets. A similar picture of the events took place in Egypt in the first decade of the XXI century. In the course of the 2011 revolution and the political upheaval in 2013, tourism development in Egypt declined compared to 2010, falling by two-thirds in 2013. The economy of the country and the tourism industry were transformed (Springborg, Robert, 2017). For eight years from the start of the events, Egypt restores the image of a "safe country" and in the coming years it may "drag" the lion's share of tourists from Central Asia and Central and Eastern Europe.

The development of tourism in Ukraine can also develop under the Egyptian model. However, the return of the tourism industry to the previous status quo and its potential development is not encouraging. Doubts lie in: 1. the external factor – it is difficult to predict the reaction of an aggressor country during the period of change of power in Ukraine and incomplete reforms; 2. The internal factor is the development of corruption and the unfavorable investment climate.

Purpose of research – the monitoring of the tourism market will determine and identify the main trends of tourism development in the country, based on the analysis of tourist services markets of recipient countries, to determine the ways of resuscitation of the tourism industry.

The tourist image of Ukraine Tourism during 2018 and with the beginning of 2019 only begins to reborn. The works of domestic authors are devoted to the study of certain aspects of tourism development during the last five years (Sichka, 2016; Orlenko, 2016; Kalutsky, Kovalska, 2016).

Materials and methods of research In the third millennium, at the beginning of the twenty-first century, the development of tourism in Ukraine only begins with separate branches of the economy, unlike foreign countries, where tourism becomes a powerful branch of the economy. However, the formation, development and enrichment of the theoretical foundations of the development of domestic tourism can solve the problems associated with research and the formation of their own practical experience. The intellectual nuclei of tourism development are classical universities led by such figures as: O. Lyubitseva, M. Malskaya and others. Among contemporary domestic and foreign researchers who consider the importance of innovation and modeling the development of tourism (Koval, et al., 2010; Bogdan, 2014; Viyikis., Yakutis, 2014). and others are to be mentioned.

Research results. The research of the current stateof tourism development in Ukraine was based on the application of a systematic approach using comparative,

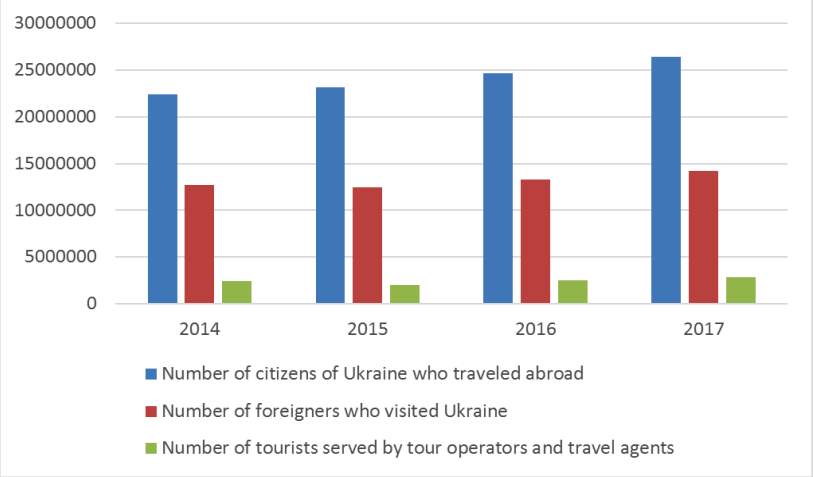

Fig. 1 Tourist flows, persons.
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Ukraine

statistical, analytical methods, etc. Thus, the purpose of the study is to analyze the conditions and factors of tourism development in the country in comparison with the recipient countries of the near abroad on the basis of statistical indicators and determine the prospects for the development of the national tourism market. Results and their analysis. State of state development determines the level of economic development. In Ukraine, given the destabilizing factors: political, military and economic, in particular: the war in the east of Ukraine, the annexation of the Autonomous Republic of Crimea, the impoverishment of the population, inflation of the hryvnia, bankruptcy of tourist firms, etc., the tourist industry was in a state of stagnation. Tourism development has almost stopped since 2014 (Fig. 1). Since the competitiveness of the tourism industry depends on the state policy, it should be aimed at the organization and regulation of financial and legal support for tourism. However, unlike in 2018, in 2019, the tourism industry is not mentioned in the priority of economic sectors, although it is one of the most significant sources of filling the state treasury. Namely, the gross domestic product from the provision of services for the temporary placement and organization of food in 2017 amounted to 18.1 billion UAH, while in the category "art, sports, entertainment and recreation" – 16.5 billion UAH, which in total is 34, UAH 6 bln.

According to the State Statistics Service of Ukraine (2018) for four years from 2014 to 2017, the number of visits by Ukraine to foreigners has a tendency to increase, although in small numbers – from 12.7 in 2014 to 14.2 million people. This was facilitated by mass international events and the victorious participation of Ukrainians in them, in particular, the song contest "Eurovision–2017"; the phobia of Ukraine as a "hot spot" by foreigners; development of domestic tourism. The donor countries of the people traveling to Ukraine are the Republic of Moldova, Belarus, Poland, the Russian Federation and Hungary. Analyzing the geography of incoming foreign citizens in Ukraine, it was found out that visitors from the near abroad are dominant (Fig. 2). In this proportion (only 14.2 million people in 2017), of course, there are workers, as well as transit tourists.

Leading countries include Israel, Germany, Turkey, Austria, Belarus and the Russian Federation. These countries were formed due to the recognition of Ukraine on the international scene as a country with a strong recreational and tourist potential, participation in international events, revival of national values. According epravda the news (2018) the increase in the number of foreign nationals has contributed to the entry of Ukraine into the three most poorest countries in the world, as well as improvement of tourist logistics (opening of new airlines: Lowcost, RyanAir, trains "Night Express", transformer cars, updated a fleet of passenger cars, etc.) and the development of infrastructure as a whole (laying roads, building accommodation and catering, etc.).

If we analyze the number of foreign citizens entering for the purpose of the trip – tourism – by 2017 compared with 2014, then it decreased by almost 3.8 times and amounted to 0.27%.

In comparison with Belarus, the number of tourists in 2015, which entered the country amounted to 300 thousand, which is 7.7 times more than in Ukraine. Among the leaders of the countries that visit Belarus should be distinguished: Germany, China, Italy, Latvia, Lithuania, Poland, France, Estonia. Consequently, the geography of countries prevails both close and far abroad. In Byelorussia as of 2017, for the purpose of "tourism", the country

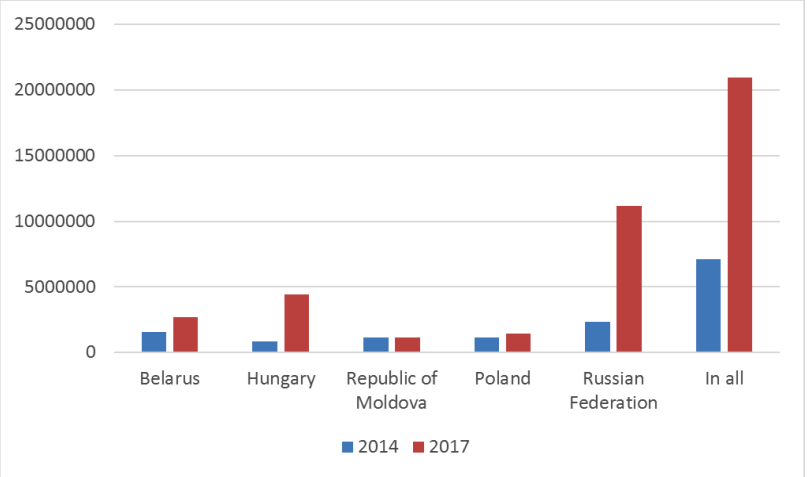

Fig. 2 Entry of foreign citizens to Ukraine by countries from which they arrived.
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Ukraine

visited about 0.34%. According to the State Official statistics Belarus 67.7% of tourists from Russia came to in Belarus 9.3% from Lithuania, 8.0% from Poland, 2.3% of tourists from Latvia, etc. Outbound tourism from Ukraine intensified during the conduct of hostilities in the east of Ukraine and the annexation of the Crimean peninsula. This was also facilitated Hungary, apartments (2 adults for 1 night) at BudaFlats Apartments II at a price of 1640 UAH, compared to Bukovel (Ukraine, Ivano-Frankivsk region), the cost of a similar night stay at the Hotel Stara Pravda in a suite – 2700 UAH. Thus, an adequate ratio of the price and quality of tourist services, a significant tourist opportunity of European countries and attracts

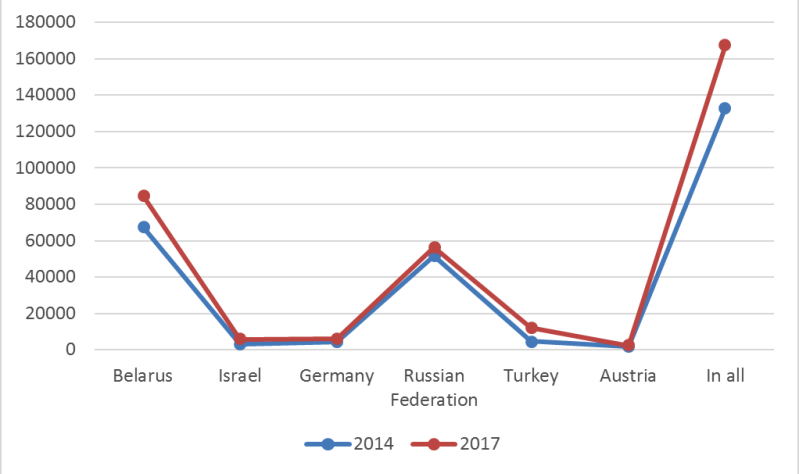

Fig. 3. Departure of foreign tourists to Ukraine by countries from which they arrived
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Ukraine

by: 1. Visa-free regime from June 2017. As reported golovni-novyni.112.ua. now Ukrainians have a visa-free regime with 118 countries. According to the State Statistics Service of Ukraine (2018), during this time, 400 thousand people used it. The most popular destinations for traveling from Ukraine in 2017 were Belarus, Moldova, and Poland (Fig. 4). 2. Price policy for tourist services. When comparing prices in Ukraine and neighboring countries, it should be noted that they are different. The price in some tourist complexes in Ukraine is high, so it is cheaper to rest in Poland or in Hungary. For example, in the capital of a significant number of tourists from Ukraine with different levels of income.

The average length of stay in each of the countries definitely depends on their location. Travels in distant foreign countries (Turkey, Spain, Germany, etc.) lasted longer than in neighboring countries. This is primarily due to the duration of travel and the cost of travel. In 2017, the number of nights spent bytourists in hotels in the EU has reached more than 3.2 billion, an increase of 5.1% compared with 2016. According to Eurostat (2017), Spain (471 million nights, + 3.6% vs. 2016) retains leading positions ahead of France

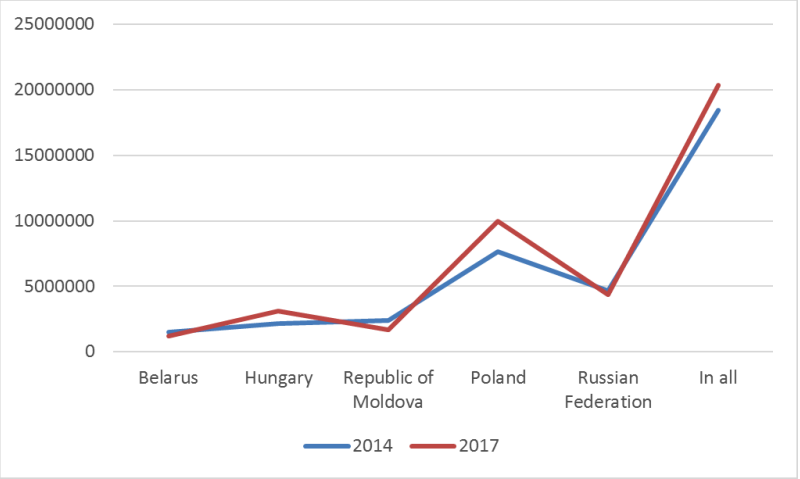

Fig. 4. The departure of Ukrainian citizens abroad.
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Ukraine

(431 million, + 6.6%), Italy (425 million, + 5.4%) and Germany (400 million, + 2.7%).

However, tourist logistics should not be overlooked. The vast majority of tourists choose aviation or rail modes of direct-dialing. Most flights from Ukraine arrive in the evening. Therefore, Ukrainian tourist is forced to search for a lodging for himself. For example, flight Boeing 737–800 Kiev Borispol (Ukraine) – Warsaw Frederic Chopin (Poland) arrives at 20:30, train 705 K Kiev Passenger

One of the reasons for the departure of Ukrainians abroad is: 1. The population's awareness of the country's tourism potential was low. On the basis of the survey, it was found that 11 out of 12 people from the eastern and north-eastern regions have virtually no knowledge of the tourist potential of the western and north-western regions. Except for some tourist or sanatorium-resort complexes, for example, Bukovel, Morshyn, Shayan, etc. 2. Lack of security in places of rest. During the meteorological winter of

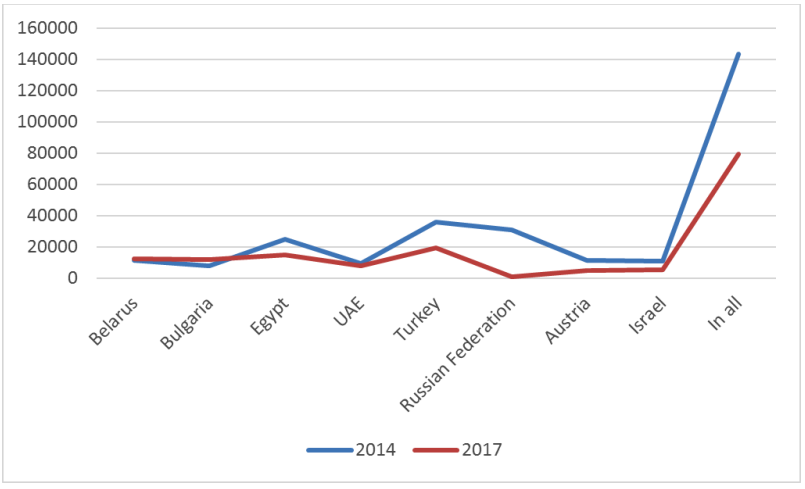

Fig. 5. The departure of Ukrainian citizens abroad for tourist purposes. Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Ukraine.

(departure time 06:50) – Przemysl (arrival time – 14: 58 years).

Compared to all trips abroad, a relatively small percentage leave the tourist destination. In addition, it has almost doubled in comparison with 2014. This can be explained by the poverty of the Ukrainian population. Geography of recipient countries is mostly close to foreign countries, mainly the CIS countries (Belarus, Moldova, Russia).

2018–2019 in the Carpathians there were fatal cases among tourists. In particular, on February 22, 2019 – two tourists were killed at the summit of Pip Ivan. May 06, 2019 – three tourists from Belarus as a result of a truck crash from a height of 40 m in the Black Cheremosh river, etc. According to the State Official statistics Belarus in 2015 the number of tourists leaving Belorussia was 533.8 thousand people (in the comparison, 4.4 times more than from Ukraine),

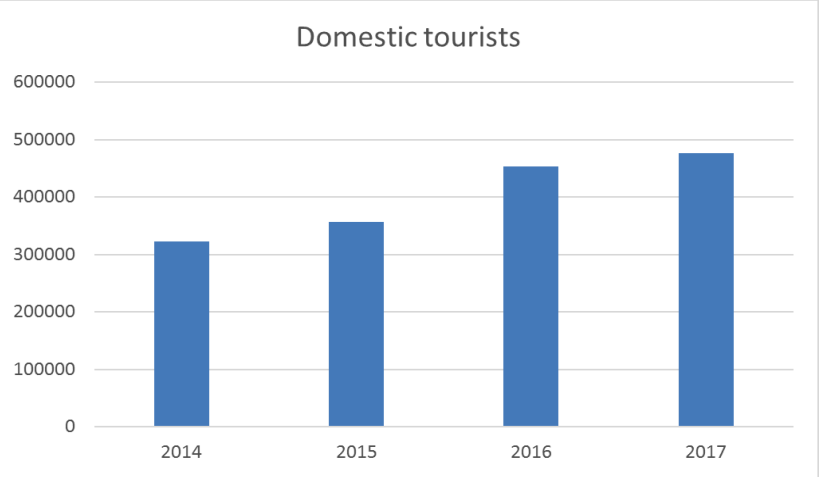

Fig. 6. Development of domestic tourism in Ukraine.
Source: developed by the authors on the basis of statistical data of the Main Department of Statistics in Ukraine.

most of them (87.6%), left countries not CIS. Among them: Greece, Egypt, Spain, Italy, Turkey and others. In 2017, from Belarus, 19.3% went to Turkey, 17.0% to Egypt, 12.5% to Ukraine, 8.6% to Bulgaria. The main purpose of travel – rest on the warm seas of the seas for the best price and high quality of service for tourists. Given the geography of donor countries and the purpose of staying tourists in Belarus, business and recreational tourism prevails in Belarus, unlikein Ukraine, it is active and culturally-cognitive.

As for the development of domestic tourism in Ukraine, it tends to grow. This is facilitated by the desire of Ukrainians to travel. As for their financial situation, this question is trivial. On the one hand, there was an increase in wages, an increase in the number of employees receiving salaries in the segment from 5 to 10, and more than 10 thousand hryvnias. The number of employees receiving less than UAH 3,200 has been reduced to a maximum. However, according to wages of workers of European countries, it is 10 and> times, the CIS countries are 5 and> less. For example, in Belarus, although the tendency towards wage reduction as of February 2019 is set at $ 465, and in Ukraine in April 2019, taking into account the increase, it is $ 382. According to the State Association of Ukraine hospitality industry, with a minimal budget, Ukrainians want to travel, but it should be noted – with the predominance of self-organized tourism, since today the average Ukrainian tourist for a day is ready to spend no more than 500 UAH.

The activity of domestic tourism development can be explained by the gradual growth (after 2016) of wages, a low percentage of inflation and a steady exchange rate. The development of domestic tourism is also affected by logistics. Amongdomestic passenger traffic, tourists choose rail and motor transport. The railroad prevails in the interregional, and the automobile – is transported locally. However, it should be noted that the maximum number of tourists, for example, in the western region of Ukraine comes from cities with direct access (Kiev, Zhytomyr, Odessa, Nikolaev, etc.). After all, tourists choose a variant of travel without transfers. Tourists from such administrative areas as: Sumy, Poltava, Chernihiv, Zaporozhye and others. taking into account the absence of direct communication with Ivano-Frankivsk, Transcarpathian, Ternopil and others are frequent guests.

Whereas annexed Crimea, the fighting near the Azov coast of the Black Sea waters Activity (Odessa, Mykolaiv, Kherson region) and Ukrainian Carpathians remain key tourist attractive area for domestic tourists. In the priority they are for the population from industrial centers: Dnipro, Kropivnitsky, Mariupol, and others. The opening of new directions in the railroad map will increase the convenience and speed of travel and reduce the cost of travel, which in turn will lead to the activity of domestic tourism.

In the domestic tourism, Lviv, as a cultural, Ivano-Frankivsk and Transcarpathian regions became popular among tourists – as centers of active and inclusive, Odessa region – recreational tourism. However, in comparison with Belarus, the number of domestic tourists in Ukraine is twice less, despite a larger number of the population.

The trend of steady development of tourism in Ukraine is accompanied by a number of subjective factors, in particular:

- the development of transport infrastructure (repair major highways, modernization of railway transport mode by domestic production and purchases from abroad, reanimuvannya air mode of transport (increase in passenger traffic, opening new airlines), attempts to offset the significant disparity of transport

(road transport occupy 80% of all traffic etc).

- in Ukraine, the tourism industry, in general, does not impede infrastructure flaws, and the lack of state financial support for this and other industries. For example, in Ivano-Frankivsk, Transcarpathian and others. The western, north-western regions of the country lack direct communication (air, rail) with the main centers of demand for tourist services (Kirovograd, Dnipropetrovsk, and other areas with a significant population). Government grants and grants from the Ministry of Infrastructure will facilitate the development and development of a transport network, including tourist logistics. While the actual state of the road network reflects the level of socio-economic development of the country as a whole, and not the tourism industry.

- the development of the information and communication environment (connecting tourists traveling in Europe through the Orange SIM card with the Mundo 2018 tariff). Its benefits are uninterrupted, high-speed Internet at a moderate price, for example, the cost of traffic per month: 10 euros for 2 GB, and at The condition of an early purchase for 10 euros will connect the 4 GB.International information support can also be tourist information centers, or individual elements of its infrastructure – tourist information kiosks that will allow you to booking rooms in accommodation establishments, reserve tables at catering establishments, view virtual tours, audio excursion, etc.

- poly-industry, scale and significant tourism underlines its belonging to the priority sectors of the national economy. The development of an innovative investment model for tourism development will enhance the attractiveness of this industry. The main direction of tourism development should be domestic and inward.

- by choosing the European vector of development, it is expedient for Ukraine to adjust the Law on Tourism in line with the EU directives in the tourism sector. In particular, pay attention to the EU Directive of June 13, 1990, № 90/314 of the EU on integrated tourism, recreation and tours.

Conclusions. Analyzing the conditions and fac- tors of tourism development in the country, it can be stated that the main donor countries of tourists in Ukraine are neighboring countries, and the recipient countries - tourist countries of the Front Asia. The entry and exit mobility to / from the country should be linked to the era of political and economic reforms in the country. Ukraine is one of the outsider of the tourism market in comparison with the CIScountries, including Belarus. Today, tourism is a multifunctional industry and its development will continue to depend on tourism logistics, the development of the information and communication sphere, the innovation and investment climate that wants to be better, but first of all from financial support and legal support of the state. The prospects of the national tourism market are seen in the development of integrated domestic and inbound tourism, recreation and tours.

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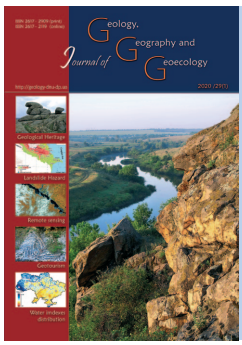

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Detection of Changes in Terrestrial Ecosystems of Ukraine Using Remote Sensing Data

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Abstract. In recent years, Ukraine has been affected by climate change. This has led to frequent extreme weather events (heavy / high rains, floods, droughts, squalls). As a result of droughts, desertification is one of the most dangerous and transient consequences of modern climate change. The research is devoted to the diagnostic assessment of the modern climate of Ukraine. Remote sensing data and instrumental observations of 30 weather stations of Ukraine were used. Temperature increase was registered in the study area by all stations, which significantly affected the level of precipitation. At the moment there is not enough moisture for the Earth's surface. Precipitation in Ukraine is currently characterized by an uneven distribution. It leads to accelerated processes of soil degradation and it's fertility loss. The aim of the study was to identify areas prone to desertification using satellite imagery and meteorological observations. Over the past 17 years (2000-2017), the average air temperature in Ukraine has increased by 1.5 ºC. Particularly anomalous warming has been recorded in recent years, starting in 2015. During the XXI century, a slight decrease in precipitation was observed in Ukraine. Both a decrease in precipitation and an increase in temperature may lead to a decrease in soil moisture levels. According to ground meteorological data, the tendency of dryness in Ukraine was confirmed. Lack of water leads to prompt manifestation of this process. Water indexes were used to estimate the moisture content of surface soils. It is possible to assess the susceptibility of the desert area to climate change. Relevant quantitative information on water availability in Ukraine is provided. Two water indices (Normalized Difference Infrared Index NDII and Ratio Drought Index RDI) have been taken estimate the moisture content. It can be estimated from the MODIS MOD13C2 product data obtained from the MODIS satellite sensor and used for regional research. The main conclusion of this study is to determine the changes in natural terrestrial ecosystems in Ukraine. This was shown on the basis of temperature and humidity. Such trends may lead to changes in the biodiversity of the territory and loss of natural soil properties.

Key words: remote sensing data, desertification, water detection, climate change, soil moisture, water index

Використання матеріалів космічної зйомки для виявлення змін у природних зонах України

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Анотація. В останні роки України перебуває під діями змін клімату. Це призводить до частих екстремальних погодних явищ (зливи, посухи, шквали). Одним із найзагрозливіших і швидкоплинних наслідків сучасної зміни клімату є розповсюдження опустелювання, причиною якого є посуха. В дослідженні проведена діагностична оцінка сучасного клімату України. Використовувалися дані дистанційного зондування Землі. та інструментальних спостережень 30 метеорологічних станцій України. Підвищення температури у регіоні дослідження фіксується всіма розміщеними в ньому станціями. На фоні підвищення температури значну роль відіграють опади, яких наразі не вистачає для достатнього зволоження земної поверхні. Опади в Україні мають наразі характер нерівномірного розподілу, що призводить до пришвидшення процесів деградації ґрунтів та втрати їх родючості. Завданням дослідження є виявлення схильних до опустелювання територій за допомогою супутникових даних та метеорологічних спостережень. За 17 (2000–2017) років на території України температура повітря підвищилася на 1,5ºС. Особливо аномально теплими в Україні були останні роки, починаючи з 2015 року. В Україні за роки XXI століття йде незначне зменшення кількості опадів, що свідчить про незначне ослаблення опадоутворюючих процесів. Зменшення кількості опадів при підвищенні температури може призвести до погіршення вологозабезпеченості при поверхневих ґрунтів.

За наземними метеорологічними даними була підтверджена тенденція посушливості в Україні. Нестача води, підвищення температури ведуть до більш швидкого прояву цього процесу. Для розрахунку вологовмісту при поверхневих ґрунтів були використані водні індекси. Це дозволило оцінити схильність території до опустелювання в умовах кліматичних змін. Надана відповідна кількісна інформація про вологозабезпеченість території України. Для розрахунків вмісту вологи були взяті два водних індекси Нормалізований Диференційний інфрачервоний індекс NDII та Індекс посухи RDI. Їх можливо розраховувати за даними продукту MOD13C2 з супутника MODIS та використовувати для регіонального рівня дослідження. Спираючись на отримані дані, головним висновком є виявлення змін у природних зонах, що показано на основі тепла та вологи. Таки тенденції можуть призвести до змін біорізноманіття території та втрати природних властивостей ґрунтів.

Ключові слова: дані дистанційного зондування Землі, опустелювання, вологовміст, кліматичні зміни, вологість ґрунтів, індекси вологості

Introduction. The effects of climate change that have emerged in recent decades have led to the expansion of desertification, which leads to droughts. Drought is causing enormous damage to many sectors of the economy as one of the greatest natural disasters. In its' negative consequences compared with other natural disasters, droughts are among the first.

Human activities significantly change the natural environment. This leads to the intensive decrease of biodiversity and productivity of ecosystem that turns into land degradation. In the UN Convention to Combat Desertification (UNCCD) it is defined as a form of dry land degradation (arid, semiarid, and dry sub-humid) provoked by climate and human activities (UNCED Report, 1992, UNCCD, 1994).Such definition is specified in the Annex I of UNCCD Regional Implementation for Africa (Gunin et al., 2004, UNCED Report, 1992). Thus an emphasis is placed on the territorial manifestation of desertification caused by climate. The other documents of Convention extend the investigated territory beyond drylands. The arid lands are supplemented with sub-humid and humid lands affected by degradation due to anthropogenic activity. This should be considered to evaluate the spreading of desertification. In the Annex II of Convention for Asia regional level, the term "parts of the territory that have suffered aridity or drought, or those that are under threat …" is used instead of "dryland" (Gunin et al., 2006, UNCED Report, 1992). The same is defined for the Annex III of Convention for Latin America and the Caribbean.

The territory covered by the convention is spreading more and more. The Annex IV is expanded to the Northern Mediterranean. It is characterized by "semi-arid climatic conditions over large areas, seasonal droughts, very high variability in rainfall, unexpected / random precipitation of high intensity" (Gunin et al., 2006, UNCED Report, 1992). Annex V of the Convention cover the Central and Eastern Europe. The territory is characterized by "a variety of land degradation in different ecosystems of the region. This takes into account the effects of drought and the risk of desertification in areas prone to water and wind erosion" (Gunin et al., 2006, UNCED Report, 1992). The main part of this territory is represented by humid lands. Land degradation here is also associated with the human activities. This territory is prone to episodic droughts, but the hazard of desertification is not significant. Annex V expands the area of the Convention operation. Here, the most actual is a struggle being waged with land degradation than with desertification. Later convention documents for Central and Eastern Europe deal with degradation, risks of desertification and drought.

At the national level, the concept of desertification is reflected in the National Programs to Combat Desertification (NPCD) of the Central and Eastern Europe countries. Within the Ukraine National Program the desertified areas of degraded lands are in sub-humid and humid regions.

That is, we should move away from the concept of "desertification", as shown in the documents on the implementation of the Convention. Additionally, we should talk about desertification within arid zones, and separately about the degradation of sub-humid and humid lands.

Ukraine, like every country, is vulnerable to climate change. Every year, our economy suffers considerable losses from natural disasters. Due to that, we have to take measures to mitigate and adapt our country to climate change. Global climate change also affects Ukraine by increasing the average air temperature and uneven distribution of precipitation, which can lead to significant changes in its climate and agricultural zones. The most significant consequence of climate change is not only gradual warming, but also increase of the number and intensity of extreme weather events: severe droughts, extremely hot days, etc. Therefore, there is an urgent need to adapt to climate change in certain sectors of the Ukrainian national economy. The urgency of this problem was confirmed by the Resolution of the Cabinet of Ministers of Ukraine dated on August 18, 2017, No. 20. As a result, a Coordination Council for Combating Land Degradation and Desertification was established. We are pleased to be a temporary consultative body of the Cabinet of Ministers of Ukraine until 2021 in order to

coordinate the formation and implementation of state policy on sustainable land use and protection, land degradation and combating desertification, mitigation of the consequences of drought.

In accordance with the recommendations of the Convention in case of Ukraine it is necessary to determine the boundaries of drylands and humid areas that may become arid. Special attention has to be paid on droughts in the context of climate change. Droughts are the strongest factor in the development of desertification processes. So, it is necessary to determine the peculiarities of spatial distribution of soil moisture within the territory of Ukraine.

At present, the feasibility of remote sensing data usage for desertification monitoring is no longer in doubt. Remote sensing technologies allow prompting identification and soil degradation risks assessment and Earth surface monitoring. There is a large number of scientific publications, both locally and globally, that demonstrate the benefits of satellite monitoring, as well as the use of satellite data for soil and vegetation monitoring (Boke-Olen et al., 2018; Lyalko et al., 2018; Kokhan et al., 2018; Zholobak et al., 2018; Movchan et al., 2014).

The task of the research is to identify areas susceptible to desertification in Ukraine by using water spectral indexes estimation based on remote sensing data processing.

Materials and methods. Diagnostic estimation of the modern climate of Ukraine is based on the data of instrumental observations. The values of monthly air temperatures and precipitation, soil temperatures at depths of 5, 10, 15, 20 cm were obtained from 30 meteorological stations. During the selected period of 2000 - 2016, the data were collected from 30 meteorological stations. The trend towards increased drought in Ukraine has been confirmed. Water scarcity and temperature increase lead to a faster manifestation of this process. In this case, water plays a leading role in both climate change and land degradation processes. The study is focused on the water exchange, with the application of all technologies, including aerospace research.

In order to determine the soil moisture for Ukrainian territories, the MOD13C2 data obtained by the MODIS / TERRA satellite were used. The MOD13C2 product is the monthly data of two vegetation indices: Normalized Difference Vegetation Index NDVI and Enhanced Vegetation Index EVI, as well as monthly spectral data in next bands: blue, red, NIR and MIR, with a spatial resolution of 0.05 degrees. MODIS (MOD13C3) is the most convenient product for regional studies of water supply and average values calculations over the years. According to Land Processes Distributed Active Archive Center (LP DAAC) (https://lpdaac.usgs.gov/products/mod13c2v006/), the MIR band in the MOD13C2 product is in the spectral range of 2105-2155 nm, which corresponds to the range of SWIR2 of the Landsat and Sentinel-2 satellites.

The MOD13C2 product is the sixth version and represents the Vegetation Index (VI) value in each pixel of the image. It includes two main vegetation layers. The first is the Normalized Vegetation Index (NDVI) obtained using the AVHRR radiometer which was developed by the National Oceanic and Atmospheric Administration (NOAA). The second vegetation layer is the Advanced Enhanced Vegetation Index (EVI), which is highly sensitive to biomass. While creating a monthly product, MOD13C2, the algorithm accepts all MOD13A2 products that are overlapped during the month period of scanning using an average timing value. All entrance pixels are of 1 km spatial resolution (nominally 6x6). As a rule, inputs are either transparent, clouded or mixed. Data can be obtained from the official website of the US National Geological Survey or the Earth Resource Surveying and Exploration Center (EROS), as well as from the Land Processes Active Archive Data Center (https://lpdaac.usgs.gov/). Averaging schemes could be applied as follows: if all the input pixels were transparent, all of it would be averaged to get one output value. If all the input pixels were clouded, the pixels data would be estimated from the historical database. If the input pixels were mixed (the part is transparent, part is clouded), only transparent pixels would be averaged to get one output value.

Several water indexes have been analyzed: DSWI (normalized difference infrared index), SR-SWIR (simple ratio SWIR), RDI (ratio drought index) (Abdullah et al., 2018) and NWI (normalized water index) (Sakhatsky, 2010). The possibility of using MOD13C2 product data for its estimation has been defined. Two indexes can be used for soil moisture content mapping over Ukraine: NDII (normalized difference infrared index) and RDI (ratio drought index). The MOD13C2 product contains the data of spectral bands that are applicable for these indexes estimation. These indexes are calculated using the formulas:

$$NDII = (NIR - SWIR1)(NIR + SWIR1) \quad (1)$$

$$RDI = SWIR1NIR \quad (2)$$

To estimate these indices for MOD13C2 data, the formulas acquire the following form:

$$NDII = (NIR - MIR)(NIR + MIR) \quad (3)$$

$$RDI = MIR1NIR \quad (4)$$

where, NIR - the monthly spectral brightness in near-infrared range, MIR - the monthly spectral brightness in shortwave infrared range.

The 2007 year was chosen for the research, as the local climate during that year was affected by drought. One of the most abnormal years at the global and regional scale is 2015. Year 2016 was chosen as a typical year of the XXI century with temperature increment. MOD13C2 monthly products were received for the period from April to October 2007, 2015 and 2016.

All data processing from MOD13C2 product was performed using the ERDAS Imagine imagery processing software. The work was carried out at the several stages:

1) Conversion of the input data of the MOD13C2 product from the .hdf format into .img format. The img format is the raster image in the Erdas Imagine. The conversion is done using Import / Export module. The following is Type - HDF Raster;

2) Seven channel images are formed. The images are made monthly from April to October. The years of study include 2007, 2015 and 2016. It is estimated for NIR and MIR bands with Interpreter module and Layer Stack function;

3) The MOD13C2 product data is presented worldwide. For the further work it is necessary to separate the territory of Ukraine in the NIR and MIR channels. It is done using the Subset tool of the Erdas Imagine and the Ukraine border in aoi format. Fig. 1. demonstrates the data obtained from NIR channel for the territory of Ukraine;

4) The conversion of NIR data and MIR on the territory of Ukraine with the rectangular coordinate system UTM / WGS84, 36 zone is released using Project function of Erdas Imagine software. A metric coordinate system should be used for the territory of Ukraine;

5) The estimation of the water indexes NWII and RDI values using the formulas (3), (4) for each month. Corresponding averages are estimated for 2007, 2015 and 2016 using Erdas Imagine, namely Spatial Modeler / Model Maker. On Fig. 2. a model is demonstrated calculating the values of NWII and RDI water indices according to the formulas (3), (4) for 2007 in the Erdas Imagine software (Fig. 2).

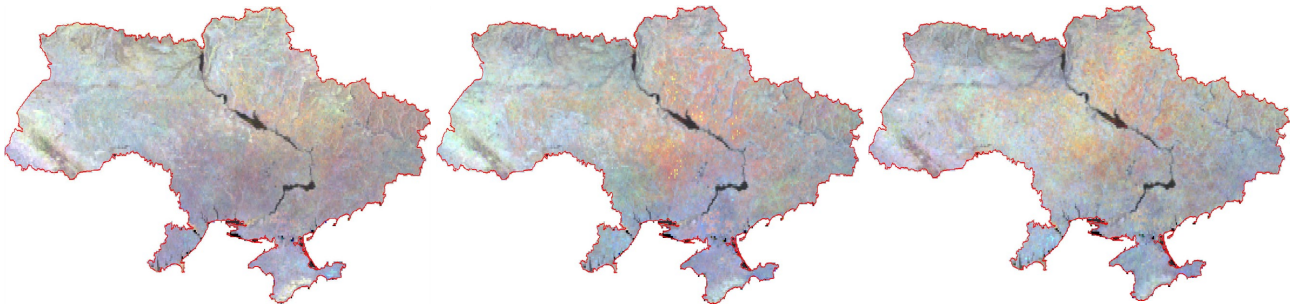
Results and discussion. Table 1 shows the air temperature deviation from the normal average in Ukraine during the years of the XXI century. For 17 years (2000 - 2017) the air temperature in Ukraine has increased by 1.5 ºC. In particular, the last years since 2015 were abnormally warm relatively to normal average annual temperature in Ukraine.

According to different models further air temperature increase is expected in Ukraine. By the end of the XXI century, it can increase by 0.7-3.0 ºC ("soft" scenario B1) in comparison to the period of 2001 - 2010, or by 2.6-4.6 °C ("hard" scenario A2) (Nakicenovic et al., 2000).

It's all happening against the backdrop of rainfall fluctuations. Fig. 3 shows deviations from the average amount of precipitation in Ukraine for the XXI century. It is clear that in the period of 2010 - 2016, the average amount of precipitation in Ukraine in the period of 2010-2016 was less than the average. There is a slight decrease in the amount of precipitation according to the data of in situ measurements. This indicates a slight weakening of the deposition processes.

Reducing the amount of precipitation with simultaneous temperature increase can lead to soil moisture deterioration.

The condition of the soil cover, namely the soil temperature regime, has been studied. Temperature regime is a combination of all phenomena of soil accumulation and heat exchange. Temperature regime is determined by estimation of soil temperature at different depths (5, 10, 15, 20 cm). This indicator was taken as a baseline for meteorological stations. Such depths characterize the arable layer. This soil layer is sensitive to changes in the thermal regime on the



a b c

Fig. 1. Highlight of the Ukraine territory from MOD13C2 product in the NIR channel: a) for 2007 year; b) for 2015 year; c) for 2016 year.

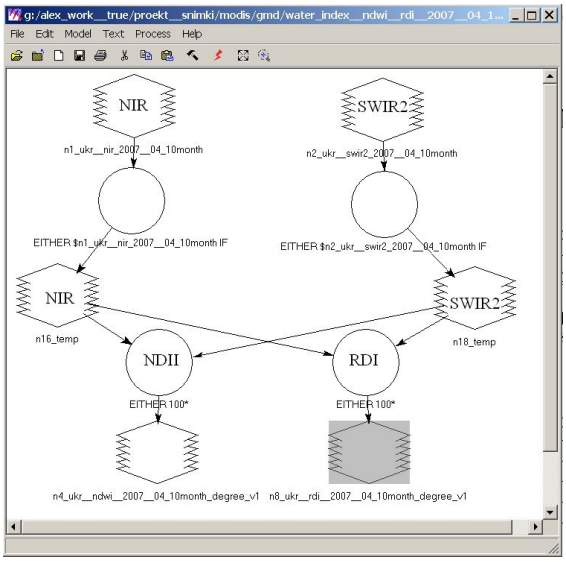


Fig. 2. Model for estimation of the values of NWII and RDI water index by the formulas (3), (4) for 2007.

surface and takes an active part in the formation of the surface air temperature regime.

Figure 4 and 5 demonstrates the soil temperature deviation at depths of 5, 10, 15, 20 cm in the forest-steppe (Fig. 4) and steppe (Fig. 5) zones for the period of 2000-2016. The received data is deviated from the climatic norm of 1961-1990. Soil is warmed up due to temperature increase. There are no negative deviations of the soil temperature at all the depths. Dry years and its' peaks are distinguished on the plots. For the forest-steppe zone one of the peaks belongs to 2007, which is confirmed by meteorological data.

Considering the received diagnostic estimation of modern climate changes it can be assumed that the negative climatic tendencies will aggravate over time in Ukraine.

Climate monitoring at different time scales can detect short-term wet periods during long dry periods and vice versa. Indexes can be used to simplify complex relationships and serve as a useful tool for informing users. Water indexes were used to estimate the soil moisture content. It is possible to assess the desertification inclination areas under climate change conditions and provide relevant quantitative information about the water availability of Ukraine. Indexes are presented as intensity and duration estimate of the moisture transfer process, which were obtained quantitatively. The most two common indices, NDII and RDI were taken. They can be estimated using the MOD13C2 MODIS product and used for regional research.

Table 1. Air temperature deviation (ΔT ºC) from the climatic norm on the territory of Ukraine for 2000 - 2017 years.

2000	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***
1,5	1,1	1,6	0,5	0,9	1,0	0,7	2,2	1,9
2009	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***
1,7	1,7	1,4	1,3	1,7	1,7	2,8	1,8	2,0

Normalized Differential Infrared Index (NDII), developed by Hardinsky (Hardinsky et al., 1983; Abdullah et al., 2018), Gao (Gao, 1996). Relative Drought Index (RDI) was proposed by Pinder (Pinder et al., 1999; Abdullah et al., 2018). These indexes are applicable within the infrared bands for content monitoring of water vegetation. Vegetation cover changes were used to detect a vegetation stress period caused by drought.

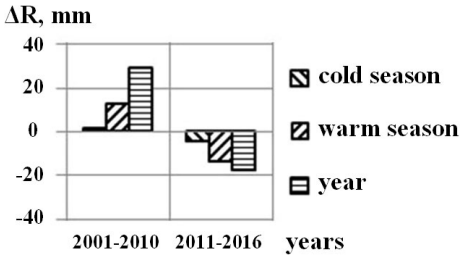


Fig. 3. Deviation of the average amount of precipitation in Ukraine over the 2000 - 2016 years (Elistratova et al., 2018).

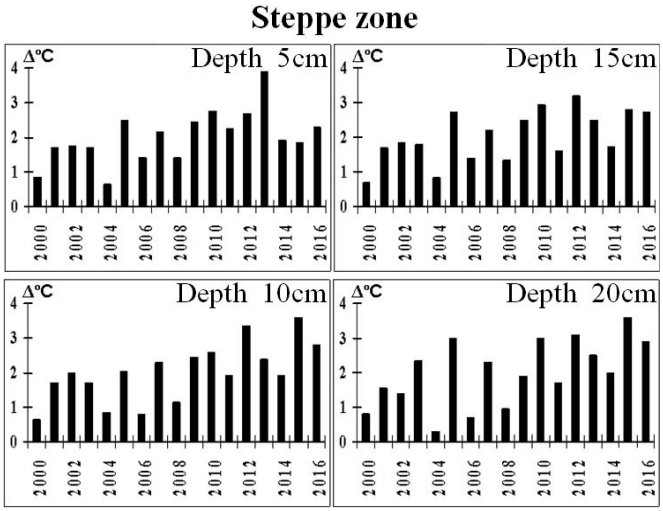


Fig. 4. Deviations of soil temperature values from the average multi-year period 1961-1990 at different depths in the forest steppe natural zone.

The indexes were estimated for the warm period of the year (April-October). These months were chosen due to the vegetation cover period. The average values of indexes for each three year period were calculated within the next step. The result of calculations allowed classifying the territory by soil humidity degree (Fig 6). The gradations of water indexes are shown in different colors in Table 2.

The number and seasonality of precipitation distribution, high temperatures are a significant factor of temporal changes of borders between the natural geographic areas in Ukraine.

The main sources of soil moisture are atmospheric precipitation and groundwater. Atmospheric drought leads to soil erosion under conditions of deep groundwater level, in Ukraine it is the most part of the steppe, forest-steppe, temperate deciduous forest zone and separate areas of the coniferous-deciduous forest zone. It shows up as a lack of moisture for the plants. Therefore, the main problem is referred to the increased dryness, when in condition of warmer and drier climate more precipitation for evapotranspiration balance is needed. The whole process of trend changes in air temperature and precipitation within the framework of modern changes will be aggravated by the frequency and severity of extreme situations (heat waves and droughts).In some cases, prolonged atmospheric drought causes hydrological drought – drying of small water objects. The analysis of Figure 3 showed the sharp moisture deficiency within the steppe zone (IV in Figure 3). For all years, the NDII and RDI indices of moisture availability in the steppe zone correspond to: dry, very dry, strong dry and, in particular, for 2007 (where there was a strong extreme drought) - a catastrophically dry range of index values. Comparison of this indexes with the actual data was

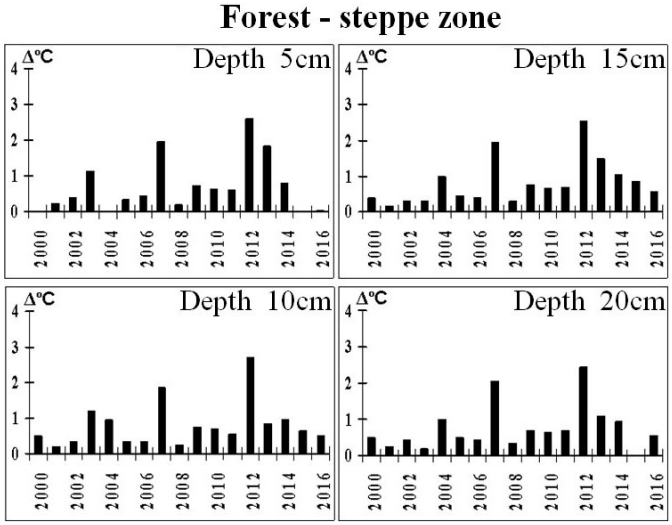


Fig. 5. Deviations of soil temperature values from the average multi-year period 1961-1990 at different depths in the steppe natural zone.

in previous studies (Lyalko et al., 2015, 2019). This is the most critical region of Ukraine in this regard.

According to our calculations, the process of drought is in full swing from 2007 to 2016. With further predicted warming of Ukraine, the climatic conditions of 2007 may be permanent. The significant changes may occur in both the air temperature and humidity.

With regard to the forest-steppe zone (number III), in the years with the highest air temperature (2007), the ranges of water values (dry, very dry) indicate the characteristic climatic conditions of the steppe zone. Thus, the index values that used to belong to the steppe zone are territorially displaced in the forest-steppe zone. This may indicate the pronounced manifestations of natural changes in zoning only in the second half of the XXI century.

The assessment of water indexes also indicated the proliferation of the processes of moisture deficit increasing during the growing season and on the territory of the temperate broad-leaf forests (Number II).

The zone of mixed coniferous forests (coniferous-leaved) in number I can not be attributed to zones of sufficient or excessive humidity, obviously due to

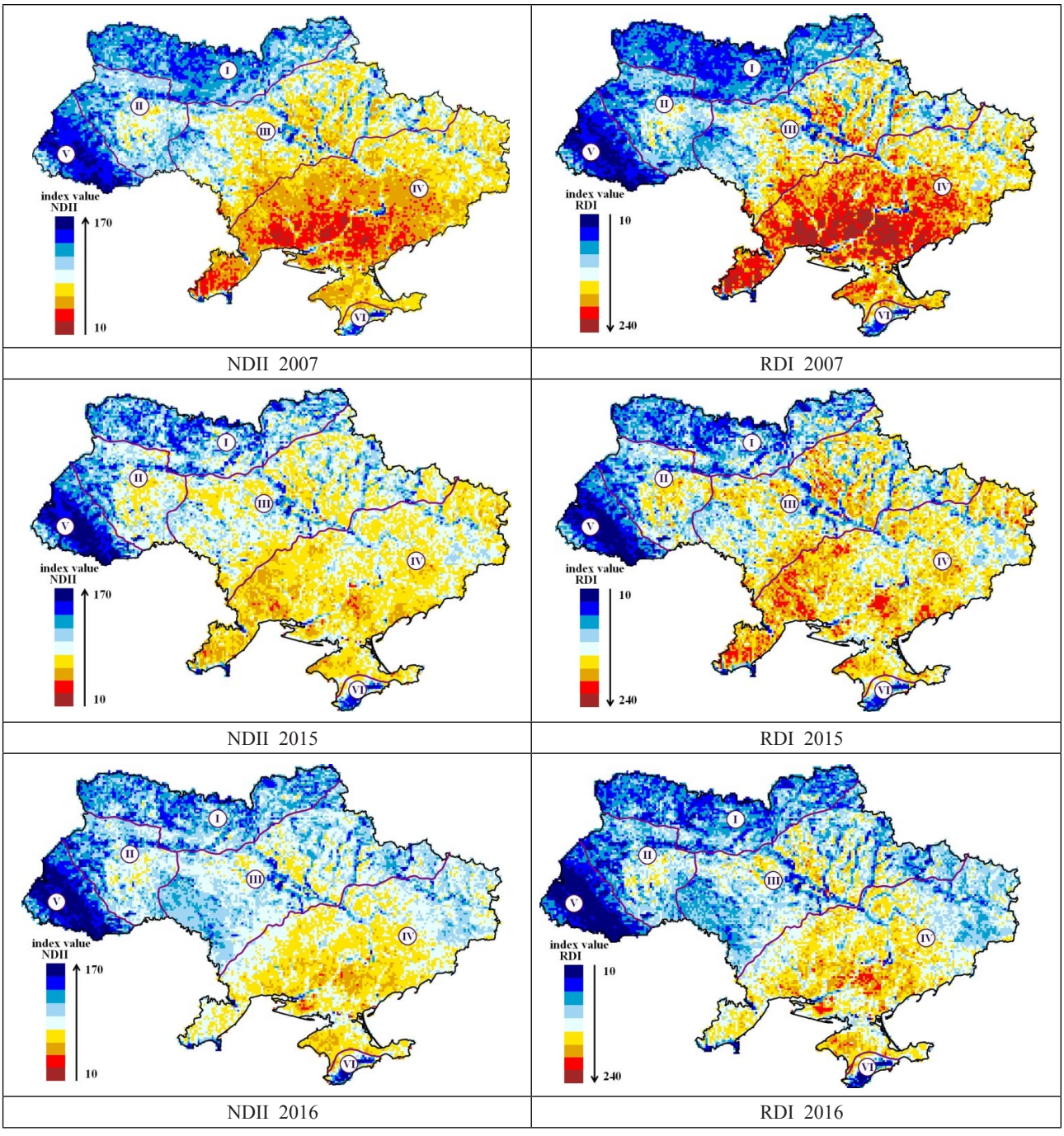


Fig. 6. Map of NDII and RDI water indexes distribution of Ukraine scale 1: 3700000.
I - zone of mixed (coniferous-deciduous) forests, II - zone of temperate broad-leaf forests, III - forest steppe zone, IV - steppe zone, V - Ukrainian Carpathians, VI - Crimean Mountains.

Table 2. Moisture of Ukraine and the corresponding NDII and RDI moisture indexes values.

№	Moisture content	NDII		RDI	
		color	index values	color	index values
1	Extremely moistened		>160		<126
2	Strongly moistened		150…160		126...136
3	Enough moistened		140…150		137...147
4	Moist		130…140		148...158
5	Not enough moistened		120…130		159…169
6	Arid		110…120		170…180
7	Highly dry		100...110		181…191
8	Strongly dry		90…100		192…205
9	Extremely dry		<90		>205

the variability of natural landscape conditions and a wide range of consequences of land reclamation. The ranges of calculated water indexes show the following categories: sufficient and strong moisture, so there are no changes in plant species within this territory.

Taking into account the results of the research, it can be noted that the growth of Ukraine's arid climate under the conditions of modern climatic changes and displacement of natural-climatic zones will have a significant impact on the landscape, especially on its biota. Such changes will be manifested in the replacement of zonal types of vegetation, shifting the boundaries of forests, changing the ratio of forest formations and forest types, reducing the resistance of forests to pests and diseases, its dryness. Thus, for the current period this process is especially noticeable in the southern regions of Ukraine.

Conclusions. Uncertainties in terms of feedback to the impact of climate change on natural ecosystems can be significant. On the one hand, currently there is not enough evidence that the expected reaction (changes in the zones boundaries, replacement of plant groups from one to the other, or its' complete loss) can be manifested promptly. However, received results of estimating the NDII and RDI water indices according to the MODIS multispectral satellite imagery data, make it possible to conclude this. In the future, significant losses in biodiversity should be expected as a result of the high temperatures and water stress effects. There will be a change in the natural zoning, as the main factor in the formation of natural zones is the balance of heat and moisture balance in Ukraine. It has been established due to the course of further climate change effects (air temperature increment). If the existing tendencies of aridity growth remain unchanged, the semi-desert zone may gradually shift to the territory of the modern steppe zone. The forest-steppe will be transformed into a steppe zone, and the transformation of temperate-broadleaved forests into a forest-steppe zone, respectively, will lead to the reduction of the forest-steppe zone. Only the speed of these changes remains a contentious issue.

This effect is very unfavorable from the environmental point of view. It may lead to the disappearance of some types of natural systems that are sensitive to climate change. It is necessary to carry out adaptation measures to reduce the negative impact on the use of natural resources at the state level.

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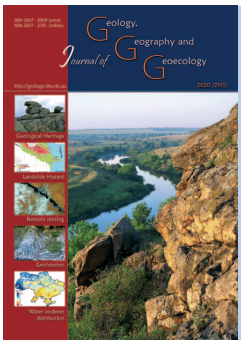

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Ukraine in the history of the movement for the conservation of geological heritage in Europe

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Abstract. The paper focuses on the history of the movement for preservation of geological heritage of Ukraine, closely related to the history of geoconservation in Europe; determines the relationship of the extent of geodiversity and geological structure of a certain country, political system, historical traditions and attitude towards wildlife and inanimate nature. Despite the fact that geodiversity and biodiversity have always been in parallel, traditionally all nations in all the continents have focused more on the preservation of so-called wildlife. The article describes that preservation of the so-called inanimate nature; provides a rather sufficient analysis of literature sources which report on the problem of preserving bio- and geodiversity not only in Ukraine, but also in other countries of Europe. In particular, the combination of biotic and abiotic constituents of nature proved to be an essential aspect in determining the place of the world`s first nature reserve and location of an important centre of Buddhism in Mihintale, Sri Lanka. The start of the movement for preservation of so-called inanimate nature in Europe could, with a certain extent of possibility, be considered the first historical written mention of the subject, which was declared in the 10th Chapter of Third Statute of Lithuania in 1588. That is protection of rivers against artificial change of their banks, change in currents and preservation of large erratic boulders. As an important stage of the beginning of the movement for preservation of the so-called inanimate, can be considered the year 1668, when in Germany the Baumannshöhle cave was preserved. It was first mentioned in the literature in 1565, and in 1646 the cave became an object of tourism. During the analysis of the historical stage related to the movement ProGEO, we emphasizes international events in which the representatives of the Ukrainian ProGEO group took part. Active work of the Ukrainian ProGEO group created conditions for transition to a new level of geoconservation, i.e. determination of the possibility of creating a new category of objects of the Nature-Reserve fund of Ukraine – geological parks (geoparks) as important locations for the development of geotourism and territories of complex conservation of the natural environment.

Key words: geoconservation history, geoheritage, geosites, geodiversity, geotourism, Ukraine.

Україна в історії руху за збереження геологічної спадщини в Європі

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Анотація. Розглядається історія руху за збереження геологічної спадщини в Україні у тісному зв'язку з історією геоконсервації в Європі. Встановлено зв'язок ступеня георізноманіття з геологічною будовою певної країни, політичним устроєм, історичними традиціями та відношенням до живої і неживої природи. Попри те, що георізноманіття і біорізноманіття завжди були поряд, традиційно у всіх народів на всіх континентах перевага віддавалася збереженню об'єктів так званої живої природи. Визначається, що справа збереження так званої неживої природи ускладняється неможливістю відновлення геосайтів на відміну від об'єктів живої природи. Наведено досить вичерпний аналіз літературних джерел, в яких висвітлюється проблема збереження біо- і георізноманіття не тільки в Україні але й в інших країнах Європи. Саме поєднання біотичної і абіотичної складових природи стало вирішальним при визначенні місця першого в світі заповідника та місцем розташування осередку буддизму у Міхінтале на Шрі-Ланці. Початком руху за збереження так званої неживої природи в Європі з певною мірою ймовірності можна вважати першу історичну письмову згадку, оприлюднену у 10 главі Третього статуту Литви у 1588 році. Йдеться мова про захист річок від штучного змінення берегів, змінення напрямку їх течії і збереження великих ератичних валунів. Важливим етапом початку руху за збереження так званої неживої природи цілком доречно визнати 1668 рік, коли у Німеччині уже зберігалася печера Боуманшолле. Вона вперше згадується у літературі у 1565 р., а у 1646 печера стала об'єктом туризму. При розгляді історичних етапів пов'язаних з діяльністю ПроГЕО акцентовано увагу на тих міжнародних подіях, в яких брали участь представники української групи ПроГЕО. Активною діяльність української групи ПроГЕО створено умови для переходу на новий рівень геоконсервації, а саме на вивчення можливості створення нової для України категорії об'єктів

Природно-заповідного фонду – геологічних парків (Geoparks), як потужних осередків розвитку геотуризму та територій комплексного збереження природного середовища.

Ключові слова: Geoconservation history, Geoheritage, Geosites, geodiversity, geotourism, Ukraine.

Introduction. The history of the movement for preserving geological heritage in different countries of the European continent has a lot in common, as well certain differences, conditioned on the one hand by the geological structure of one or the other country and the corresponding extent of geodiversity, and on the other hand by the country`s political system, historical traditions and attitude towards wildlife and inanimate nature in general. Therefore the history has been long and controversial with its main feature being integral connection with the history of the movement for preservation of wildlife. Geodiversity and biodiversity have always been closely related, but traditionally all nations in all continents have focused more on preserving objects from the so-called wildlife. And that was despite the fact that as for the inanimate system, which is the main source of material values and within which not the least role belongs to mineral deposits, the task of its preservation is complicated by impossibility of its renewal, unlike wildlife (Fig.1).

Mankind has gradually understood that by destroying the biosystems and inanimate systems – mineral reserves, air, water bodies, it creates conditions incompatible with its existence. The previously unchallenged paradigm of the non-exhaustiveness of mineral resources was refuted by the realities of life in the light of the massive scale of exploitation of the land by man, whose needs increase in geometric progression. Currently not only most scientists, but also the subjects of the economy understand the necessity of protection and preservation of inanimate nature, particularly, the geological environment.

Results and their analysis. One of the most complete analyses of the history of preservation of geological monuments of nature (geosites) is the book of the European Association for the Conservation of the Geological Heritage (ProGEO) "Geoheritage in Europe and its Conservation." which is a collective study by the members of ProGEO from different countries of Europe and Asia edited by Wimbledon, W.A.P. & Smith-Meyer, S., and published in 2012. (Geoheritage, 2012). In historic sequences, the main stages of determining and preserving geosites and motivation of the necessity for their preservation were analyzed and substantiated by the corresponding legislative acts. The review manner of provision of the material does not allow one to completely understand the problem of preserving geosites of Ukraine in their historical context. Among other works regarding the history of preserving the geological heritage, the most significant is the compilation of materials of the special Conference of the Geological Society of London on the history of geoconservation ("The History of Geoconservation.", 2008). Not only is the condition of the geoconservation in Great Britain analyzed, but also in some countries of Europe, Australia, the United States of America, etc. The participants of the Conference emphasize that preservation and geoconservation are not the same things. Geoconservation is an action aimed at preserving and strengthening the

Fig. 1. A tree can be grown, and rocks…?

Fig 2. Stonehenge, cromlechs – the earliest example of use of mountain rocks for sacral purposes. (https://simple.wikipedia.org/wiki/Stonehenge)

geological and geomorphological peculiarities, processes, locations and examples. The notions geoheritage and geoconservation, and history of geoconservation are also discussed in the study by Brocx and Semeniuk, published in 2007 in the Royal Society of West Australia (Brocx, Semeniuk, 2007). According to the authors, geoconservation should include all important geological peculiarities from regional scale to separate crystals. It is important to range them by importance and distinguish five types of objects: international, national, state-wide, regional and local. The authors think that the United Kingdom in particular should be considered as the birth place of geoheritage and systematic geoconservation, which now is a component integrated into education, tourism, planning and management (Brocx, Semeniuk, 2007). History of geoconservation is also described in the study by Scottish scientists Vanessa Brazier, John E. Gordon et al. "The Parallel Roads of Glen Roy, Scotland: geoconservation history and challenges." (Brazier, Gordon, Faulkner, Warner, Hoole and Blair, 2017); by the president of ProGEO José Brilha (Brilha, 2015); Ian Houshold and Chris Sharples "Geodiversity in the wilderness: A brief history of geoconservation in Tasmania" (Houshold, Sharples, 2008) etc.

Fig. 3. This spectacular combination of biotic and abiotic elements of nature became a place for the world`s first nature reserve and important Buddhist site for a good reason (Mihintale, Sri Lanka http://litetrip.ru/shri-lanka-mixintale-mihintale-gora-missionera-maxindy.html). A fragment of the Deccan Plateau, or one of the erosive remains of ancient crystalline rocks characteristic of the relief of Sri Lanka.

There are no special publications on history of geoconservation or preservation of objects of geological heritage in Ukraine, but the problem has been described in different years in the studies by A. Ivchenko (Ivchenko, 1998a, 1998b, 2003), V. Grytsenko (Grytsenko, 1995, 2001, 2003,2005), Y. Zinko (Zinko, 2011,2012), N. P. Gerasimenko (Wimbledon, Gerasimenko, Ishchenko, Lisichenko G.B. & Lisichenko K.G., 1999), V. Manyuk (Manyuk, 2004,2005, 2006, 2016).

The history of discovery and preserving of geological monuments is integrally related to the history of preserving nature in general and formation of the nature-reserve fund, which most completely was described in the studies by one of the most notable Ukrainian environmentalists V. Y. Boreiko (*Boreiko*, 1997, 2001, 2002, 2014). Particularly based on the obvious relation between wildlife and inanimate nature, we shall trace back the historical sequence of formation of attitudes to objects of the geological constituent of the natural environment and attempts to preserve it in Ukraine. For restoring the complete picture of this process, if possible the first steps towards preserving geosites will be traced in other countries of Europe.

Since the appearance of the first tribes, mankind has began to understand the cult significance of nature, therefore as religions emerged, primitive peoples` communities created special sacred places in the natural environment (mountain tops, highlands, valleys, forests, groves, etc) (Fig.2). The first law on the protection of the natural environment and wildlife is considered to be the law which was adopted in Sri Lanka (Ceylon) in III century B.C. At the same time, in a town called Mihintale, King Devanampiyatissa created the world`s first nature reserve (Boreiko, 2001) (Fig.3).

Fig. 4. Presentday view of Ishkel National Park in Tunisia (https://flic.kr/p/9ot9HK)

The first legislative acts on the protection of natural relics in the territory of Ukraine were introduced during the Kiev Rus. Therefore, "Ruska Pravda" by Yaroslav Mudry made hunting for beavers and some rare species of birds a criminal offence. The order of Danylo Halytsky (1220-1264) declared large nature reserves within current Bilovezka (Belarus) and Umanska (Ukraine) forests. Those were the first incarnations of nature reserve objects, which were the object of taboo. Entering such places was restricted, and violators would face various penalties.

The first mentions of the protected status of territory now known as Ishkel National Park (within nowadays Tunisia) dates back to the XIII century, when then ruling Hafsid Dynasty of the Arab caliphate prohibited hunting there. In 1997 it was announced a biosphere reserve by UNESCO and in 1980 was enlisted in the Global Heritage. In that same year it received the status of National Park protected by the Ramsar Convention (Fig. 4).

In the Middle Ages, in Europe attention was paid to preserving productivity of lands for hunting. For this purpose special areas were allocated; there, hunting of any kind was for some periods banned with the purpose of restoration of prey populations. West-Ukrainian lands were affected by nature-protecting orders of Polish, Lithuanian and Hungarian Kings. Particularly, the Lithuanian Statute of 1529 included the first legislative act on protection of waters, according to which anyone who poisoned a lake or river would be fined, destroying beaver-inhabited virgin land in a protected water strip and cutting trees and bushes were prohibited.

During the Zaporizhia Sich, for aesthetic reasons, the forest tract on the Monastyrsky Island on the Dnipro was taken under protection. In such way, at that time, a well-known forest on the Vorskla has been preserved thanks to Ohtyrka Monastery, and also a tract of *Pinus sylvestris* var. *cretacea* – thanks to the Sviatohirsky Monastery. The forest tract Kytaevo, Koncha-Zaspa and Holosiivsky Forest near Kyiv have been also preserved by monks (Boreiko, 1995) (Fig. 5).

The beginning of the movement for the preservation of so-called inanimate nature in Europe can, with a certain degree of certainty, be considered the first historical written records in the 10th Chapter of the Third Statute of Lithuania in 1588. That is the protection of rivers against artificial alteration of banks, change of the direction of the current and preservation of large erratic boulders (Geoheritage, 2012).

A significant stage in the movement for preservation of so-called inanimate nature is considered to be 1668, when in Germany Baumannshöhle Cave was already being preserved (Grube, 1994). It is first

Fig. 5. Examples of preservation of forests thanks to monasteries: 1 – Ohtyrka Holy Trinity Monastery; 2 – Holy Assumption Monastery; 3 – Forest tract Kytaievo (http://mesta.kiev.ua/nature)

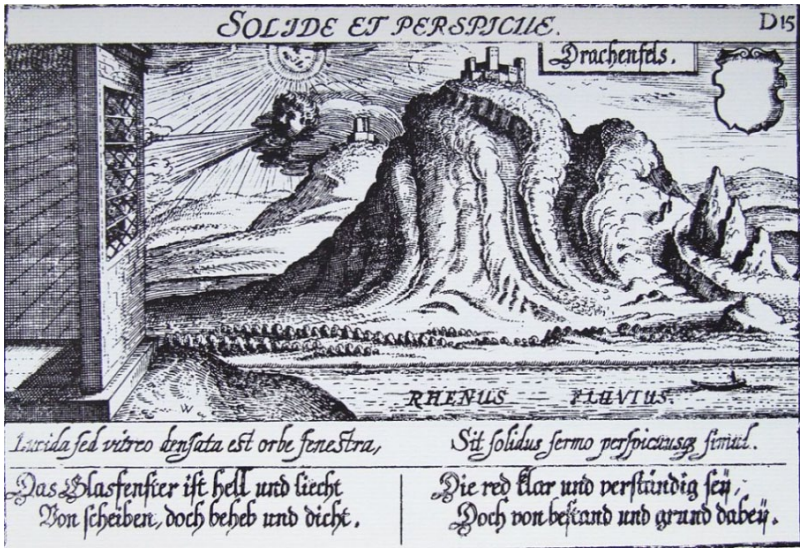

Fig. 6. The Drachenfels in 1624 by Matthäus Merian.

Fig. 7. The ruins of Burg Drachenfels (https://en.wikipedia.org/wiki/Drachenfels_(Siebengebirge)

mentioned in the literature in 1565, and in 1646 the cave became a touristic object. In 1668 it was also an object of a decree on nature protection issued by Duke Rudolf Augustus, which controlled entry to the cave. An important example of preserving geological heritage (considered the earliest not only in Germany, but in the world) is preservation of the "Quarry on the Hill" (quarrying of the hill) – Drachenfels near Bonn (Fig. 6,7,8). This place was bought by Prussian Crowned Prince Frederick Wilhelm in 1832. In 1840, a gorge made by the valley of the Danube in the rocks of the Jurassic system near Weltenburg was taken under protection by the Bavarian King, and in 1844 the granodiorite rock called "Totenstein" in Saxony was subjected to protection.

An important role in the preservation of the natural heritage in general and particularly geological heritage belonged to the Societies of Nature Researchers which were created in large administrative centers of Russia in the XIX century. The first and the most influential was the Moscow Society of Nature Researchers created in 1805. The Society aimed not only at studying various aspects of natural environment and its popularization, but also nature protection.

As for other European countries, the next example of attempts to preserve geological objects can be considered the local regulation of visits to the caves in Hungary, where in 1839 ruination and collecting of dripstones in the Baradla cave was banned. In Austria, first attempt to protect nature dates back to 1856. As proposed by Franz Karl Heinrich, the Assembly of German Scientists and Doctors of Germany purchased erratic boulders in the Helvetian zone of Upper Austria in order to preserve them from quarrying (Fig. 9). On a gigantic boulder, which is now considered the first geotope in Austria, one can still read words devoted to the notable geologist Leopold von Buch (Geoheritage, 2012).

In that period, in Ukraine, first botanical gardens, dendrological and zoological parks were created, areas of virgin steppe were subjected to protection, fish reserves and numerous park monuments of garden

Fig. 8. Trachyte Quarry remains since Roman times in Drachenfels (https://en.wikipedia.org/wiki/Drachenfels_(Siebengebirge)

Fig. 9. The first geosite in Austria, devoted to Leopold von Buch (Geoheritage, 2012).

design were established. For example, in 1852 the botanical garden in Lviv was created, the first aviaries for birds in Askania-Nova were constructed; in 1883 in Eastern Ukraine a part of virgin steppe obtained protection (eight dessiatins were fenced off), the land was donated by F. E. Falz-Fein from his own property (Boreiko, 1995) (Fig.10).

In 1879 academician G.P. Helmersen was first in Russia to note the necessity of preserving large erratic boulders. He collected data on over 60 boulders left after melting of covering glaciers in the territory of Estonia (Viiding, 1976) (Fig.11).

The oldest specifically geological objects of Czech Republic, taken under protection in 1884, were the Barrande Rocks which are a part of the Barrandien geological structure, named after French paleontologist and geologist Joachim Barrande, who made a great contribution to the work on provision of geoconservation to paleontological, stratigraphic and geological objects (Geoheritage, 2012) (Fig.12). Most famous are the Czech karst, a location of trilobites of Carboniferous period in Skryje Rakovník District.

In 1886, count, ornithologist and forester W. Dzieduszycki established the first nature-reserve in Western Ukraine – Pamiatka Peniatska on 20 ha of his land near Peniaky village (Brodivsk raion of Lviv Oblast) for preservation of beech forest and s population of white-tailed eagles. Most of the

Fig. 10. Biosphere nature reserve Askania-Nova named after Friedrich Eduardovych Falz-Fein
(modified after https://rudana.com.ua/news/kryvorizki-atovci-ta-yihni-ridni-vyrushyly-na-ekskursiyu-do-askaniyi-novoyi)

Fig. 11. Käsmu field of boulders, Estonia (https://www.visitestonia.com/ru/валунное-поле-кясму)

Fig. 12. Barrande rocks (https://www. hej-zolotoj-lixoradki-v-krayu-rycarej)

protected objects at that time were in private, state or monastery ownership with utility (hunting, forestry, fishery), scientific, esthetic and religious purpose of preservation. Therefore, the first official state reserve in Russia was Barguzinsky Nature Reserve established in Zabaykalie on 29.12.1916 (Fig.13).

In Ukraine, at that time, around 150 private dendroparks and park monuments of garden design were established. By 1917, there were around 30 other larger nature reserve territories of different status (Fig. 14-16). Prototypes of present-day nature reserves in Ukraine, with scientific and protective functions, began to be established in the 1880s. One can say that since that historic moment, nature protection began its development as a sphere on a professional basis.

An important historical event was founding of Russia`s first society of nature protection with approved status, emblem and signet on 21st May of 1910 in Khortytsia village of Katerynoslav governorate. The founder of the Society was Petro Pylypovych Buzuk, who worked as a teacher of nature science and the Russian language in Khortytsia Central College (district of current city of Zaporizhia). The purpose and tasks of the Society were formulated in the Statute: "The Society aims at preserving nature within the animal, plant and mineral kingdoms of nature, based on the understanding of preserving integrality, beauty and diversity of their representatives and spreading ideas about the wise use of the gifts of nature among the local population". It is important to emphasize that this is not only the date of creation of the first society of nature protection, but also the first written record stipulating that not only wildlife, but inanimate nature should be preserved. A bright example of active work of the Society is as follows. In order to save the rocks on the Dnipro near Kichkas and Khortytsia villages from ruination, the Society bought them from the owners (Fig.17, 18). On this occasion P.P. Buzuk wrote: "The Dnipro, as we know, from Katerynoslav to Oleksandrivsk, for 70 versts fascinates us and is beautiful. And these picturesque views, beautiful rocks are daily destroyed by the locals and outside contractors…" (Ninety years to the Khortytsia Society of Nature Protectors, 2000).

Fig. 13. Postage stamps devoted to the anniversary of the nature reserve and presentday landscape of the Barguzin Nature Reserve

Among the countries of Western Europe, we should note the Netherlands, where in 1905 the

Fig. 14. Arboretum Oleksandriya

Fig. 15. Stryisky Dendropark

Fig. 16. Cherkasky dendropark

first nature protection organization was established (Natuurmonumenten). As they announced, one of their activities was geological conservation (geoconservation). However, on the practical level, the volunteers of the organization emphasized activity mostly on biodiversity issues. In 1970 there existed only several nature reserves where erratic boulders were preserved. The beginning of movement for preservation important constituent of that Act. The Act stated: "protected areas can be established to protect wild plants and animals and geological and mineralogical sites". The first geosites protected by this act were the island in the Oslofjorden and erratic boulders in the southwest Norway (Geoheritage, 2012). In Spain, in 1916, the Ministry of Development announced the Act designed for creation of National Parks. Between 1920

Fig. 17. Khortytsia Island, Zaporizhia (https://www.photoforum.ru/photo/770813/)

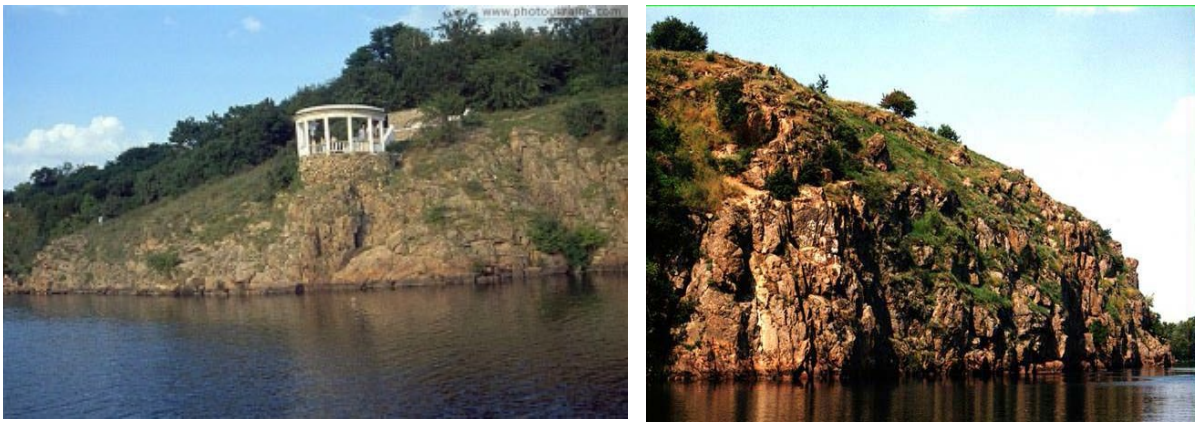

Fig. 18. Outcrops of plagiogranites of Khortytsia complex ($p\gamma AR_3$ hr) on Khortytsia Island

of inanimate nature in Ukraine is similar to the one in Norway. In 1910, when the Charter of the Khortytsia Society of Nature Protection was promoting protection of not only wildlife, but also the mineral kingdom, Ireland obtained its first Act on nature protection, in which geology was clearly indicated as an and 1930, in Spain, 6 sites of national interest were established and declared objects of geological heritage. In Denmark, on whose small area 38 geosites are located, which are characterized by astonishing geodiversity, the first law on the nature protection appeared in 2017 (Geoheritage, 2012). Moreover, due to

Fig. 19 Pine and beech forests of the Crimean Nature Reserve (https://zen.yandex.ru/media/kaiart/aipetri-peshkom-iz-alupki-razvedka-tropy-5b4ebbf86e028100a85b706f)

support of the state and the movement for preservation of geological heritage, the country`s first geopark has been established – Odsherred Geopark, in which signs of Ice Age are safeguarded (Odsherred Geopark – Denmark, 2019).

Examples of establishing the first nature reserves in the European countries are also Lassee (Austria, 1902 and 1914), Olympus (Greece, 1938), Graesholm Island (Denmark, 1926), three reserves on islands and seashores – Inish Keel, Lough Oughter and North Bull Island (Ireland, 1930), Covadonga Naational Park (Spain, 1918), Veluwezoom Park (Netherlands, 1911), Nordmarka National Park near Oslo (Norway, 1932), Saint-Isle Reserve (France, 1912), Abisko, Sarek and Garphyttan National Parks (Sweden, 1909).

The first reserve in the territory of modern-day Ukraine and the second after the Barguzinsky Nature Reserve in the territory of the former USSR (which included Ukraine) was the Crimean Nature Reserve, established on 10th March 1919 at the initiative of G.F.Morozov on a territory of 16,350 ha area (now 44,175). In that same year, chronologically only 20 days after (April 1st) after the Crimean Reserve, the Askania Nova Reserve was established, which had formally existed since 1874 when Count F. E. Falz-Fein set up the first aviaries for birds (Boreiko, 2015). And after 10 more days, on April 11 1919, the Astrakhan Reserve was established in the delta of the Volga River, which for some reason was for a long time considered the first one in the territory of the Soviet Union. Apart from the Reserves there are other examples of wildlife protection. In the Crimea, for example, in 1910 the following objects were subjected to protection: pine forest on the Yalta slope of the Ai-Petri mountain, a beech forest near the Kosmo-Damianovskiy Monastery, juniper forests in Hanaki-Tuatska forest dacha between Alupka and Sudak, protected fauna in the Babugan tract (Fig.19,20). In the territory of the reserve Chatyra-Dag (1,527 m), Kemal-Egerek (1,529 m), Demir-Kapu (1,542 m) mountains and the highest Crimean mountain Roman-Kosh (1,545 m) are located (Fig. 21).

The uniqueness of the geodiversity of the Crimean Mountains allows one to consider this territory of Ukraine the most favourable for the development of geotourism and establishment of future geoparks (Manyuk, 2007). The presence of the marbled Upper Jurassic loams which compose the upper parts of these mountains, their fracturing, division of the relief, significant amount of atmospheric precipitations and presence of thick horizons of groundwaters contributed to the development and distribution of various forms of karst: sinkholes, ponors, pit holes, pit caves, grottos, caves, etc. (Fig. 22).

A reason for creating first nature reserves was the Soviet Project “Decree of the Soviet of the Peoples` Commissars on State Protection of areas of land, water and mineral resources for scientific purposes” developed in January of 1919 by M. M. Podiapolsky in Moscow after meeting V. I. Lenin, who recognized the scientific protection as “allocating areas of virgin nature from any interference by humans”.

An important event was the creation in 1912, with active participation of Ivan Parfenovych Borodin, of the Regular Nature Protection Commission of the Russian Geographical Society. The head of

Fig. 20. Tithonian Upper Jurassic loams in the Crimean Nature Reserve

the Commission was A. S. Yermolaev, his deputy I. P. Borodin. Borodin I. P. wrote: "We cannot avoid joining a broad movement for protection of nature, which is spread across Western Europe: this is our moral debt to the Fatherland, humanity and science. No matter how many protected areas our neighbours have established, they cannot replace our future nature reserves. Being scattered on a giant area in two parts of the globe, we are the owners of in their way unique nature treasures, it is easy to destroy them, but impossible to recreate them."

In Switzerland in 1913, the first International Conference on Nature Protection took place, starting the history of today's national parks, nature reserves and zakazniks. The representative of Russia at that Conference was Borodin I. P.

In 1918 the Ministry of Horticulture of the Ukrainian National Republic established a Department of Protection of Nature Relics. In 1926 The Ukrainian Central Executive Committee and the Soviet of Peoples` Commissars of Ukrainian Soviet Socialistic Republic adopted the "Regulations on the Monuments of Culture and Nature", which became the first legislative act of Ukraine in the sphere of Nature Protection. This regulation set out the rules for registering objects of nature, types of monuments, costs of their preservation. At the same time, under the Peoples` Commissariat of Education, the Ukrainian Committee of Protection of Nature Relics was established. Sometime earlier, in 1923, the first Law on Nature Conversation (Nature Conservation Act) in Finland came into force, but Finnish representatives of ProGEO think that fac-

Fig. 21. The highest peaks of the Crimean Mountains within the Crimean Nature Reserve

Fig. 22. Various karst speleothems in the Emine Bayir Hasar cave

tually the conception of nature preservation appeared in the country in the late 1800s. In 1928, in Bulgaria the Temporary Committee of Nature Protection was created, which later was transformed into the Union of Native Nature Protection. One of most important steps after this union was the announcement of the first protected objects of Nature Heritage of Bulgaria. The Special Law on Nature Protection was adopted in 1930 in Romania, based on which in 1935 the first National Park in the Retezat Mountains was established (Geoheritage, 2012).

As at 1930, in Ukraine, around 200 specifically nature protection objects existed, and also, according to some sources, around 300 hunting reserves. A whole network of reserves emerged, various nature objects were distinguished and certain trees, steppe and forest areas, swamps, lakes, places of birds` nesting, parks, rocks, etc were subjected to protection of the state. The Committee was represented by 4 inspectorates: Kharkiv, Kyiv, Odessa and Dnipropetrovsk (Fig.23).

Therefore, there is every reason to consider the foundation of the Ukrainian Committee of Protection of Nature Relics as the beginning of the movement for preservation of not only wildlife but the inanimate nature in Ukraine. So, the bright proof of it is the selfless work of Mykola Karpovych Leshchenko in the Dnipropetrovsk Committee of Nature Protection, who at that time was the representative of the Scientific-research Department of Geology of the Dnipropetrovsk Mining Institute. During the study of the Naddnipri-anski granites (terminology of that time) M. K. Leshchenko noted rocks in Shevchenko Park as a monument of nature, and at his initiative they were taken under protection (Fig. 24).

In fact, it was the first protected geological nature monument in the post-Soviet countries .(Fig. 25).

In order to preserve and promote this “Natural Mineralogical-Petrographic Museum of the Dnipro Bank”, as M.K. Leshchenko defined the rocks, he thought of bringing them into order and publishing a guide about them.

Fig. 23. In these Oblast centers local inspectorates were established: Kharkiv, Kyiv, Odessa and Dnipropetrovsk

In 1932 the first catalogue of nature protected objects of Ukraine was published, “Reserves and Natural monuments of Ukraine” by M.S. Shalyt, and in 1937 the ultimate resolution of the Ukrainian SSR “On the State Nature Reserves of USSR” which halved the area of the main nature protected territories. In 1946 the Soviet of Ministers of the Ukrainian SSR adopted Ukraine’s

Fig. 24 The first geological monument of nature (geosite) in the city of Dnipro – Monastyrski Rocks

first in "Regulation on the State Nature Reserves and Nature monuments", which initiated the division of the objects by republican and local significance and also allowed the Oblast Executive Committee to approve only the Chornomorsky and Ukrainian Steppe Reserves (Fig. 26).

One of the units of the Ukrainian Steppe Reserve is a unique object of geological heritage – Kamiani

Fig. 25 Monastyrski Rocks

establishment of the new reserves of local significance. At the same time, the Resolution of the Soviet of Ministers of the Ukrainian SSR №1273 from 26 July 1946 granted official status to the Ukraine Nature Conservation Society, which still plays an important role in the development of nature protection.

In fact, the history of the Society begins with the start of organized public movement for nature protection in Ukraine, which emerged on the basis of the Students` Circle of Friends of Nature of Kharkiv University, the first gathering of which took place on the 1 November of 1906. This particular date is considered the beginning and prototype of the Ukraine Nature Conservation Society. Formally nature protection in Ukraine somewhat intensified from the late 1950s and early 1960s, though another round of destruction of nature reserves in 1961 was unavoidable, leaving Mohyly, which was taken under protection in 1927 and is located within Zaporizhia and Donetsk Oblasts. The reserve is considered one of the promising objects for establishing a geopark. There are all necessary and compelling conditions for creating geopark in the reserve, including good geodiversity of the territory with geosites of international significance and sufficient area (400 ha) and possibility of development of geotourism and presence of exotic peculiarities of relief which are characteristic only of Pryazovia (Fig. 27).

An important incitement to notable revival of the movement for the preservation of geological relics was the publication of the brochure "Geological Relics of Ukraine" written by the prominent geologist academician V.H. Bondarchuk in 1961. The large print run of this brochure (18 thousand copies) ensured that it received the attention it deserved and

Fig. 26. Ukrainian Steppe (Cretaceous flora) (A) and Chornomorsky (B) State Reserves

contributed not only to increase of interest in geological monuments, but also adoption of some important regulations, instructions, laws on geological heritage. According to V.H. Bondarchuk, "Geological monuments - the witnesses to events of the remote past – are seen everywhere. Some of them are well-known masses of sand, clay, detritus that level up the immense landscapes. The others look like sheer cliffs, picturesque rocks and ravines, which create unique landscapes" (Bondarchuk, 1961) (Fig. 28).

Under pressure from the Ukraine Society of Nature Conservation, in 1967 the Government of the Ukrainian SSR established a State Committee on Nature as a Central Organ of Power. This occurred three years before the Environmental Protection Agency in USA had been created and 21 years before the establishment of similar state organs in Moscow. Since 1991 it worked at the rank of ministry, and in 2018 it was integrated into the Ministry of Energy and Environmental Protection. In 1972 the Soviet of the Ministry of Ukrainian SSR adopted the resolution "On measures for enlarging the network of state nature reserves and improvement of nature protection", which approved the "Classification of nature protected and other territories of Ukrainian SSR which are protected by the State", which included such categories as: nature reserves, reserves, nature parks, nature relics, park monuments of garden design of republican and local level.

The next notable event in the work on protection

Fig. 27. Objects of geological heritage in the Kamiani Mohyly Nature Reserve (metamorphic rocks of the complex dated to the Upper Proterozoic Eon, of West-Pryazovia series of the Lower Archean Eon)
(Manyuk, 2018, https://uk.wikipedia.org/wiki/Кам%27яні_Могили)

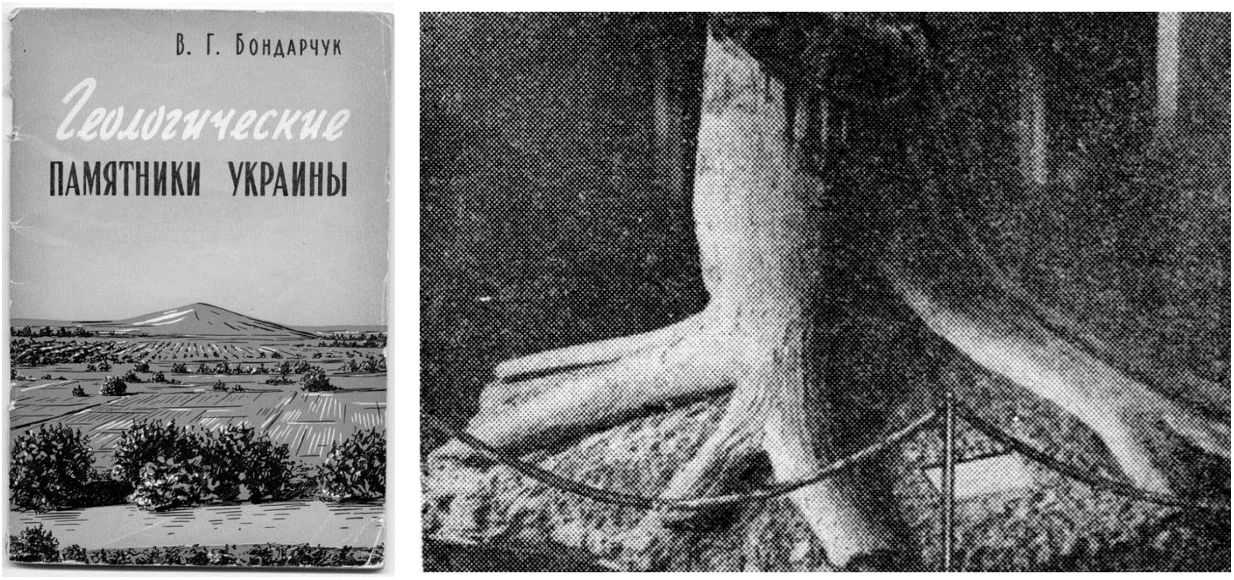

Fig. 28. Book by Bondarchuk V.H. "Geological monuments of Ukraine" and a photo of fossil trunk of *Sigillaria* tree from the book.

of geological natural monuments was the creation of the Republican Section of Protection of Mineral Resources of the Ukraine Nature Conservation Society during the gathering in the Institute of Geological Sciences of the Academy of Science of Ukraine on 4th February of 1974. The Section was continuously, over 35 years, ruled by the Candidate of Geological and Mineral Sciences, Oleksa Stepanovych Shchyrytsia. Particularly due to the laborious work of the geologists in the section and surveys by geologists, in 1985 the publication of the guide "Geological Monuments of Ukraine" became possible. The guide played an important role not only in the preservation of natural geological monuments, but became the first complete register of both active objects of the nature protection fund and promising ones (Geological Monuments of Ukraine, 1985). The Guide, without exaggeration, became the handbook for a whole generation of those concerned about preservation of the geological heritage. The book provides a description and illustrations of 179 geological natural monuments and has a map with locations of the objects in the Oblasts of Ukraine.

The following history of the movement for preservation of geological monuments of Ukraine is closely related to the emergence and rapid development of the European Association for the Conservation of the Geological Heritage or ProGEO. A notable event that has determined the change in the philosophy of views on geological heritage was the establishment of first a working group and then, in 1988, the European Association for the Conservation of the Geological Heritage (ProGEO) in the Netherlands. The ideas of ProGEO, the head of which in those years was Carl-Erik Johansson from Sweden, have rapidly spread across many countries of Europe. In 1989 in Austria, in 1990 in Norway, the first meetings of the ProGEO working groups took place. However, the actual start of ProGEO as the leading organization on preservation of geological heritage, no doubt was the year 1991, when in Digne-les-Bains, France, with the support of UNESCO, the I International Symposium of ProGEO was held, at which a historic declaration, the "Declaration of the Rights of the Memory of the Earth", was adopted (Fig 29).

Thanks to the information the future president of ProGEO Todor Todorov gave to the Journal "Survey and Protection of Mineral Resources" (1991) regarding the results of the I International Symposium of the Association of the Conservation of Geological Heritage, the ideas of ProGEO have spread among many of those from various European and post-Soviet countries who are concerned about the future of unique objects of geological heritage. The first person in Ukraine who joined the work of ProGEO was a notable geomorphologist scientist from Lviv, the head of the Lviv Oblast Center of Support of the Development of Rural Green Tourism, Yurii Zinko. He participated in the meeting of the European working group (EWGESC - future ProGEO) in 1992 in England (Weymouth), in the session of ProGEO which took place in Hungary in 1994 (Budapest), in the work of the General Assembly of ProGEO which was held in Sweden and Finland in 1995 (Sigtuna, Stockholm County) and the first Conference of the Central European Group (WG – Central European Working Group) which, thanks to Y.V. Zinko, Ukraine has joined (Fig. 30). The main orientations of the work of Regional working groups were realization of the ProGEO ideas on creating a national network of geosites, evaluation of the resources of the

geological heritage; survey, inventoring, cataloguing and developing a computer data base of geological monuments in every country, development and implementation of means regarding the touristic aspects of use of geosites for their promotion and preservation for posterity, preparation and selection of the objects which must be included in the lists of European and Global levels, development and introduction of the legislative base intended to protect the unique objects of geological heritage against damage and ruination.

Since the Group has been established in 1997, conferences were held in Prague in 2000, where the previous results of the development of the network of geosites in the countries of the group were discussed and in ancient Polish city Krakow in 2003, where for the first time the computer programs on the data bases in Poland and the Czech Republic were presented, various aspects of the problems of selecting geosites and their evaluation, legislative base regarding their protection and preservation, relations between geosites and ecological networks were discussed. The conceptual notions on preservation of geological heritage in Ukraine were described in the reports of V.P. Grytsenko, V.V. Manyuk and A.S. Ivchenko, the full format of which were published in a Special Edition of the Polish Geological Institute in 2004 (Proceeding of the Conference, 2004).

In 1993 in Germany, in Mitwitz-Köln, the First International Assembly was held, where ProGEO was formally established with adoptions of its statute. This particular date is considered the official date of the establishment of the Association. At that meeting, at the initiative of G. Gonggrijp, a decision was adopted to prepare a project on publishing a guide "Preservation of the Geological Heritage in Europe" which would describe the national laws and practical condition regarding protection of geological natural monuments in each European country. This question was later raised again a number of times by the president Todor Todorov and others, but so far no practical implementation of it has been made. After working meetings in Sweden and Finland, in 1995 ProGEO had prepared to the II Symposium, which was held at a high level in the Italian Capital Rome in 1996. That Symposium contributed to increase in the authority of ProGEO around the world and soon UNESCO invited the heads of the organization headed by C. E. Johansson to represent ProGEO at the 30th International Geological Congress in China.

Fig. 29. The ammonite slab in Digne-Les-Bains (https://www.sciencephoto.com./media/852231/view/ammonite-slab-digneles-bains-france)

Important for popularization of the ideas of ProGEO and revival of the movement for preservation of geological monuments in Ukraine was the brochure "Geological Natural Mmonuments of Ukraine: problems of study, conservation and rational use", written in 1995 by the next after N.P. Gerasimenko head of

Fig. 30. Members of the Central European working group of ProGEO

Ukrainian ProGEO V.P. Grytsenko with co-authors A.A. Ishchenko and others. For the first time the concept of preservation and rational use of unique geological monuments of nature as components of the geological heritage of Ukraine were described, the book proposed a quite successful broadened classification of geological relics and described the experience of preservation of geological natural relics in other European countries on particular examples, and included an overview of condition of protection of the monuments in Ukraine, ways of using them for educational and touristic purposes.

The next step in the movement for preservation of geological heritage took place in 1997 when the State Enterprise Geoinform of the State Survey of Geology of Ukraine established the project "Systemizing and description of geological monuments of Ukraine, development of recommendations on their popularization, use and protection", responsible for which was an active member of the Ukrainian National Group ProGEO, a prominent geologist of Geoinform, senior research specialist of the Institute of Geography A.S. Ivchenko. This person is worth a separate mention. Andrii Ivchenko can be objectively considered the founder of the new wave of the movement for conservation of geological heritage in Ukraine. In 1996 he took part in the work of the II Symposium on the Conservation of Geological Heritage held in Rome as the only representative of Ukraine with the report "Transeuropean geological monuments as a symbol of our geological heritage". Later he visited Tallinn, Estonia, in 1997 for participation in the Second General Assembly of ProGEO with the report "Databases of the Ukrainian geological heritage sites", Krakow in the same year (together with Ukrainian representatives of ProGEO Zhanna Matviischina and Natalia Herasimenko, who at that time was the head of the local committee of the European Association for the Conservation of Geological Heritage in Ukraine) with two reports. Also, he represented Ukraine in Bulgaria (Sofia, 1998) with the report "The most important geosites of Ukraine as the component of geological heritage of Europe", Tallinn in 1997 ("Databases of the Ukrainian geosites (past, present and future"), Poland (Krakow, 1999) ("Geosites of the Ukrainian Carpathians as candidates of the geosites representative of Central Europe."), etc.

Tallinn also held the Second General Assembly of ProGEO with the support of the Geological Service of Estonia, and in 1998, at the initiative of the new president of ProGEO Todor Todorov, a Conference Geological Heritage of Europe in Bulgaria (Belogradchik) took place, gathering the participants from most countries of Europe for exchange of thoughts about preservation of geosites (Fig.31).

In 1999 in the Spanish Capital Madrid, on 23-27th November, the III Symposium ProGEO was held, under the motto "Towards balanced management and preservation of Geological heritage in the new Century". At the Symposium in Madrid, the executive secretary of ProGEO W.A.P. Wimbledon for the first time presented the project GEOSITES of the International Union of Geological Sciences (IUGS), supported by the UNESCO and orientated at creating the global register of geosites of global significance. The representative of Ukraine at the Symposium was N.P. Gerasymenko from the Institute of Geography of the National Academy of Sciences of Ukraine, who at that time was the head of the National Group of ProGEO in Ukraine and became a member of the III Symposium. At the initiative of N.P. Herasimenko,

Fig. 31. Geosites of Bulgaria (Belogradchik Rocks and Pobiti Kamani)

in 1997 the book "Problems of the Protection of the Geological Heritage of Ukraine" was published, the first author of which was W.A.P. Wimbledon, with whom N.P. Gerasimenko, A.A. Ishchenko, H.V. Lysychenko and K.V. Lysychenko worked (Fig. 32). The book was published in Ukrainian and English, and was of great importance for promotion of the movement for the conservation of the geological heritage in Ukraine (Wimbledon et al., 1999).

In the research, the authors for the first time gave a pattern of comparative evaluation of geological monuments of Ukraine, analyzed the criteria and methods of evaluation and selection of geosites, described the GEOSITES project started in Europe and its use in the conditions of Ukraine.

An important event in the work of ProGEO was the Conference: «Natural and Cultural Landscapes: geological foundation» in Dublin, Ireland, in September 2002. At the Conference, representatives of ProGEO of 26 countries of Europe participated, including Ukrainian members of the movement for conservation of geological monuments of nature: V.P. Grytsenko (Kyiv National University) and V.V. Manyuk representing the State Geological Service of Ukraine and Dnipropetrovsk National University. At the Conference, the participants discussed issues of conservation of geological monuments of nature in the countries of Europe, integral approach to integration of geo- and biodeiversity of nature, protection and management of landscapes at the international, national and local levels; touristic aspects of conservation of geosites, anthropogenic impact on the landscapes, etc. In the process of approval of the declaration of the Conference, the idea of holding one of the following symposiums in Ukraine was proposed and supported for the first time.

Increase in the authority of ProGEO around the world was persuasively proved by participation

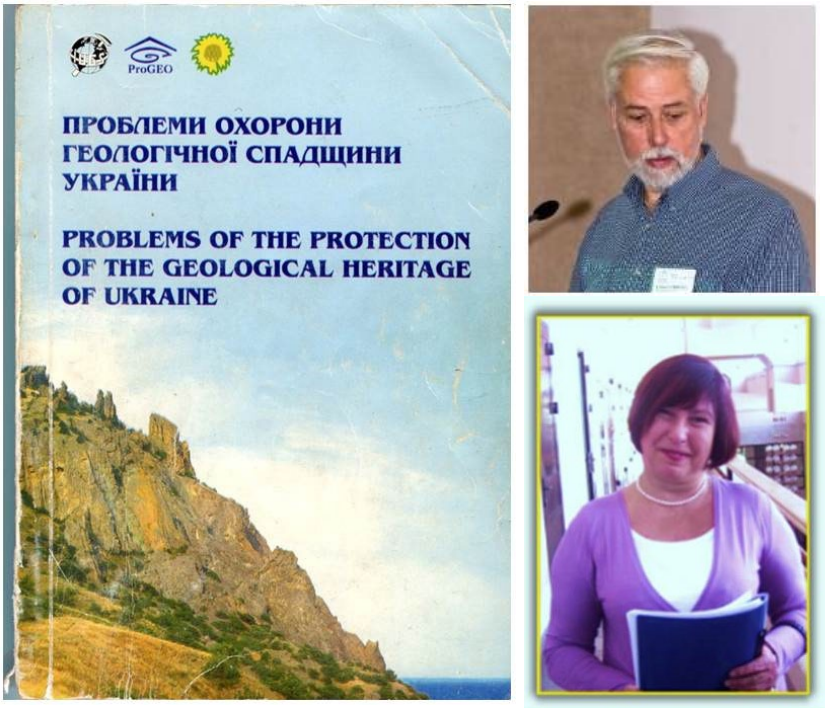

Fig. 32. The book "Problems of the protection of the geological heritage of Ukraine" and first authors (W.A.P. Wimbledon & N.P. Gerasimenko)

Fig. 33. Abstracts of Braga symposium and Azores (Volcanism of Azores Archipelago) (https://mishka.travel/blog/index/node/id/4522-10-veshei-kotorie-nujno-sdelat-na-azorskih-ostrovah)

of its members in the main geological event of the geological community of the world, the 32nd International Geological Congress held in Florence in 2004. Problems of the work of ProGEO were the object of discussion in two sections:

- Geology – the creator of cultural and geological heritage: geosites in danger.
- Geological heritage and tourism

Published materials of the Congress included the theses of the representative of Ukrainian ProGEO V.V. Manyuk "New strategy for conservation of geosites in Ukraine" (Manyuk, 2004).

The next step in the work of the European Association for the Conservation of geological heritage was thorough preparation of and holding at high level of the IV International Symposium of ProGEO in Braga, Portugal (13-16 September of 2005). A total of 312 participants from 35 countries took part in the Symposium (Fig. 33). The main goals, which the participants of the Symposium successfully achieved, were as follows:

- Discussion of the current condition of development and methodology in the strategy of geoconservation
- Presenting successful examples of the practice of geoconservation which could be copied in other countries
- Discussion of the legal basis for support of geoconservation at European and international levels
- Evaluation of relationship between European and non-European specialists of geoconservation

The materials of the Conference included reports by V. P. Grytsenko (Geological and Cultural Heritage of the valley of the Middle Dnipro) (Grytsenko, 2005) and V.V. Manyuk (Peculiarities of geoconservation in Ukraine). (Manyuk, 2005).

In May of 2003, in Kyiv, at the meeting of the panel of the State Geological Service of Ukraine the exceptionally valuable document "Complex programme of work on scientific-methodological provision of regional geological surveys in Ukraine" was considered. The programme pays special attention to such tasks which correspond to the fundamental orientations of geological science. Therefore, a significant and timely step was the suggestion by V.V. Manyuk to include the problem of study, inventorising and development of a computer data base of geological relics in Ukraine in the programme.

Furthermore, at that time, the programme of forming the national ecological network of all oblasts of Ukraine was being developed, based on the "State programme of National Ecological Network of Ukraine for 2000-2015", adopted by the Law of Ukraine from 21.09.2000, designed for further processing, improvement and development of the legislation of Ukraine with correspondence to the recommendations of the European strategy of preserving biological and landscape diversity for forming of the European ecological network. Taking everything together, according to the fact that the geological environment is the most important constituent of the natural environment and creates incredible diversity of its landscapes, became a real stimulation of the practical realization of the task of the general complex programme and in the same year the State Geological Service initiated the publication of the updated variant of the book "Geological Landmarks of Ukraine", based on the abovementioned report of the State Geological Enterprise Geoinform, with obligatory elaboration of the lists of geosites, descriptions of geological monuments and, if possible, addition of photographic materials (Fig. 34). The idea of re-publishing the book was expressed earlier, but

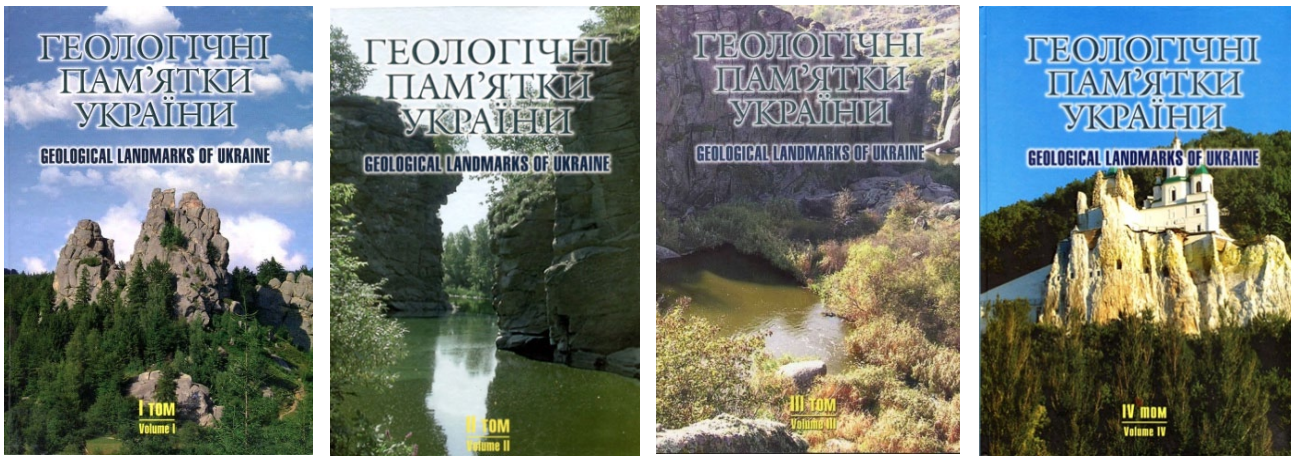

Fig. 34. Geosites of Ukraine (Geological monuments of Ukraine)

the essential for its implementaion was the work of Ukrainian representatives of ProGEO promoting the idea of conservation of geological heritage both at state and international levels.

Over 2003-2004, i.e. in a short period of time, field surveys and cameral work on the collected materials were performed. Finding, field survey, selection of samples of rocks and minerals, fossil fauna and flora, photographing of the objects, geographic connection with the determination of coordinates and detailed sketching, inventorisation, cataloguing and composing the computer data base of geological monuments of Ukraine were undertaken. The works were coordinated with the departments of the protected territories of Oblast managements of ecology, the workers of which consulted on the condition and location of current geological monuments in the territory under their protection.

Thus, materials on publishing the updated variant of the book "Geological Landmarks of Ukraine" were prepared by the specialists of geological institutions and scientists and published in 2006-2012. It was a 4-volume, large, full-coloured, well illustrated bilingual (in Ukrainian and English) edition, the first volume of which was presented to the participants of the V International Symposium of ProGEO held in Kyiv and Kamianets-Podilsky in September 2006. Holding the first symposium of such level for the countries of the former USSR was possible due to the active work of Ukrainian representatives of ProGEO in the international work of the European Association for the Conservation of the Geological Heritage and was planned during the conference in Ireland in 2002. Organization of the Symposium in Ukraine was intended to contribute to the development of nature protection in the geological sphere and approximate it to the European standards, improve the relations between various branches of power responsible for the development of nature protection. The main topics of the Conference were as follows:

- Development and elucidation of normative-legislative base regarding the status of geosites of different level of significance (local, national, European and global)
- Development and implementation of the methods and criteria of selecting geological objects of nature-protection fund
- Legalizing geosites at national levels with definition of their statuses in state and local institutions of power, including them in the State Land Cadastre of member counties of ProGEO
- Development and approval of typical measures for protection of geosites with determination of the system of financing and their practical use.

Fig. 35. ProGEO symposia. W.A.P.Wimbledon (UK) & Y.Kazakova (Kazakhstan).

A very important consequence of holding the V Symposium in Ukraine can be considered the increase in the authority of ProGEO and its innovative ideas in the circle of scientists and practitioners of geological and nature-related institutions, and, eventually, introduction of a new type of work into the geological

Fig. 36. Volodymyr Manyuk oral presentation «The problem of creation of a network of geoparks in Ukraine»

enterprises – monitoring of geological relics.

From 6 to 14 August 2008, the 33rd International Geological Congress was held in the capital of Norway, Oslo, gathering over 6300 delegates from all over the world under the roof of a giant congress hall. At this giant meeting of ProGEO geologists, four symposiums have already been presented, unlike the previous congress in Florence, with one section in operation (Fig. 35). At the symposium Geological Heritage and Society the following sections worked: The main contribution to geological heritage and society, earth surface: science, education and development, geosites and landscapes – strategy of preservation and management and geoparks and tourism. From Ukraine only one report was presented – "The problem of creation of a network of geoparks in Ukraine", delivered by V.V. Manyuk at the section IES-04 (Geoparks and tourism) (Fig. 36).

In May 2011, Kamianets-Podilsky held the II International scientific-practical Conference Geological Monuments Bright Proofs of the Earth`s Evolution (Fig. 37). The main topics of the conference were:

- Geological monuments (definitions, classification, geological structure, lithological-facies peculiarities, etc)
- Legislative base of geological heritage, relevance and perspectives of establishing geological parks
- Management, monitoring and protection of geological heritage
- Tourism and popularization of geological relics
- Geological monuments – museums under the open sky. Geological heritage in the expositions of museums.

In 2012 in Brisbane in the East of Australia the 34th International Geological Congress took place. The congress was visited by 6,012 delegates from 112 counties of the world, 3,712 reports and 1,469 posters were presented (34th International Geological Congress, 2012).

The heads of the section were the famous leader of the movement for preservation of geological heritage in Australia, professor Bernie Joyce and the future president of ProGEO (process of his election took place right after the Congress) Jose Bernardo Brilha from Portugal. The key moments were the reports by William Wimbledon (at that moment president of ProGEO, Patrick McKeever from Ireland, Nikolas Zouros (vice-president of ProGEO) from Greece and Ross Dowling from Australia. Compared with the previous congresses, the geography of the participants broadened: Brazil, England, Vietnam, Sweden, Ireland, Russia, South Africa, China, Poland, Serbia, Spain, Finland, Iran, Uganda, etc. No representatives of ProGEO Ukraine were present that time.

Conclusion. After preparation and publication of the book "Geological Landmarks of Ukraine" the work on inventorisation of the geological heritage and development of the computer data base has not

Fig. 37. Kamianets-Podilsky – location for the II International Scientific-practical Conference of ProGEO

stopped, but has continued in a new format. Geological enterprises of the State Service of Geology and Mineral Resources of Ukraine implemented the work on monitoring of geological heritage, including systematic examination of the objects on site, updating the information on the condition of their preservation, additional, more detailed study on all aspects of the monument, photographing, taking samples and many others. The condition of geoconservation in Ukraine, entire fund of the objects of geological heritage were evaluated, their inventorisation and cataloguing was performed, and the specialists of the Ukrainian State Geological Survey Institute have developed the computer data base and interactive map of the country`s geosites (Map of geological monuments of Ukraine, 2019), making possible the transition to a new level of geoconservation. The prospects for introducing a category of new objects to the nature-reserve fund of Ukraine – geoparks are being studied. The territories promising for creating geoparks and ideas for their establishment as objects of geotourism and protection of areas and preservation of geological heritage are presented in the studies by Zinko Y.V. (Zinko, 2006, 2008, 2011, 2012), Gritsenko V.P. (Gritsenko, 2004), Manyuk V.V. (Manyuk, 2006, 2007, 2008, 2008a), Golturenko I. (Golturenko, Artamonov, Manyuk, 2010, 2011), Kravchuk Y. (Kravchuk, 2012), Yaholnyk O.V. (Yaholnyk, Manyuk, 2017) and others.

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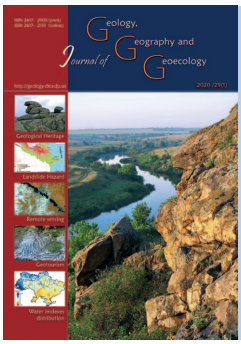

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Remote and ground-based observations of land cover restoration after forest reclamation within a brown coal basin

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Abstract. The Semyonovsky - Golovkovsky brown - coal deposit is located within the boundaries of the Dnieper basin geological group and is located in the Alexandria mining region on the watershed of the Ingulets and Beshka rivers. Overburden rocks are loess - like, red - brown and glauconite - containing loams, kaolin and carbonaceous clays quartz, glauconite - containing and carbonaceous sands. The total area of reclaimed land was about 1006 hectares, of which 39 % was used for agriculture, 2 % was pasture and 59 % under forest reclamation. Geomorphologic assessment of the studied area was performed using Sentinel-1 satellite radar interferometry. Multispectral imagery of Sentinel -2 satellite system was used for remote assessment within the study area. We assessed the state of the *Robina pseudoacacia* plants growing under various forest conditions, in plantations created on the reclaimed landscapes of the Semenovsky - Golovkovsky brown coal basin. The processes of self-regulation and restoration of fertility on the reclaimed lands at the first stages of their biological development were slowed down. This significantly reduced the resistance of phytocenoses, both pure and mixed, to the conditions of the environment to which they were exposed. A comparison of the inventory stem wood of the black locust showed the superiority of monoculture plantations to mixed stands of pine - black locust and maple - black locust. The forest-forming process progresses with age. Remote assessment of the territories was conducted to assess the future prospects of biological conservation of reclaimed lands. The influence of the anthropogenic factor is observed throughout the section and is manifested in the man-made formation of the relief, reshaping of dumps, removal to the surface of overburden rocks. It is established that the height values can vary from 85 m to 213 m. 82.8 % of the surveyed area has not undergone significant changes in relief. About 15.5 % of the territory was under the influence of alluvial - diluvia processes. There have been corresponding changes in the share of vegetation according to vegetation cover fraction (VCF) over the past three years. The highest moisture content at the level of 0.2 - 0.3 relative units in 2015 was recorded in the territory occupying 78.4 % . Meanwhile, the shares of land cover with this level of humidity increased by almost 9% during the following 3 years to 2018. The highest density of vegetative cover was recorded in the North -Western part of the study area of forest reclamation. Thus, considering the potential suitability of the area for forest reclamation, we should note the important role of geomorphological, geological and water resources for the growth and development (formation) of plant communities

Key words: forest reclamation, land cover, remote sensing

Дистанційні та наземні спостереження відновлення земельного покрову після лісової рекультивації у буровугільному басейні

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Анотація. Семеновсько-Головківське буровугільне родовище знаходиться в межах геологічної групи Дніпровського басейну і розташоване в Олександрійському районі на вододілі річок Інгулець і Бешка. Воно являє собою відпрацьований кар'єр на денну поверхню якого винесені гірські породи надвугільної товщі. Розкривні породи представлені лесоподібними, червоно-бурими і глауконітвміщуючими суглинками, каоліновими і вуглистими глинами, глауконітовими і вуглистими пісками. Загальна площа рекультивованих земель склала близько 1006 га, з них під сільськогосподарськими угіддями – 39 % території, пасовищами – 2 % і під лісовою рекультивацією – 59 %. Геоморфологічну оцінку досліджуваної території було проведено із застосуванням супутникової радарної інтерферометрії Sentinel-1. Багатоспектральні знімки супутникової системи Senti-

nel-2 було використано для дистанційного спостереження досліджуваної території. Наведена оцінка стану насаджень робінії звичайної, що вирощується в різних лісорослинних умовах штучно створених на рекультивованих землях Семенівсько-Головківського буровугільного розрізу. Процеси саморегуляції та відновлення родючості на рекультивованих землях на перших етапах їх біологічного освоєння були сильно загальмовані. Це значно знижувало стійкість білоакацієвих фітоценозів, як чистих, так і змішаних, до умов наданого їм середовища. Прогрес формування лісових насаджень відбувається з віком. Дистанційна оцінка територій проводилася з метою оцінки перспектив біологічної консервації рекультивованих земель. Вплив антропогенного фактору спостерігається по всьому розрізу і проявляється в техногенному формуванні рельєфу, переформуванні відвалів, виносі на поверхню розкривних порід. Встановлено, що значення висоти можуть варіюватися від 85 м до 213 м. 82,8% обстеженої території не зазнали істотних змін рельєфу. Близько 15,5% території перебувало під впливом алювіально - делювіальних процесів. За останні 3 роки відмічені і відповідні зміни частки рослинного покриву через проективне покриття рослинності. Найбільший вологовміст на рівні 0,2 - 0,3 відносних одиниць в 2015 році зафіксовано на території, що займає 78,4 %. Тим часом, частка ґрунтово-рослинного покриву з такою вологістю збільшилася у 2018 році майже на 9 % протягом трьох років. Найбільша густота рослинного покриву відзначена в північно - західній частині досліджуваної території лісомеліорації. Таким чином, розглядаючи потенційну придатність території для меліорації лісів, слід відзначити важливу роль геоморфологічних, геологічних і водних ресурсів для зростання і розвитку (формування) рослинних угруповань

Ключові слова: лісова рекультивація, земельний покрив, дистанційні спостереження

Introduction. Overburden rocks in the mining process are removed by excavation. This leads to permanent changes in topography and geological structures, and disrupts the surface and subsurface hydrologic regime (Shrestha and Lal, 2011). In particular, fertile soil mixed with fragmented rocks is transported to form large - scale dumps (Zhao et al., 2013) and forest vegetation is removed with some forest biomass harvested and most bulldozed into piles and burned (Amichev et al., 2008). The natural succession process of both soil and vegetation in dumps requires a lot of time, during which, the dumps are exposed to wind and water erosion processes (Zhao et al., 2015). Thereby, restoration of soil and vegetation within a short-time period is a high priority for opencast coal mine reclamation. Meanwhile, the reclaimed mined ecosystem could be regarded as an "empty cup" with large potential to store tremendous amounts of soil nutrients and vegetation biomass (Chatterjee et al., 2009), which provides a platform to conduct both remote and ground based sensing of the development of soil and vegetation from scratch.

Composition, properties, natural overgrowth and suitability of overburden rocks for land reclamation are described in numerous case studies (Zipper, 2000; Sobek et al., 2000; Likus-Cieślik and Pietrzykowski, 2017). The suitability of dumps for afforestation with different tree and shrub species has been studied on the basis of different approaches (Casselman et al., 2006; Schaaf et al., 2000). Normal practice for re-vegetation is selecting drought-resistant, fast growing crops or fodder crops which can grow in nutrient deficient soils. In certain areas, the main factor in preventing vegetation is acidity. Plants must be tolerant of metal contaminants typically present at such sites (Caravaca et al., 2002; Mendez and Maier, 2008). Compaction and texture of replaced soil during reclamation of surface - mined land can limit tree growth (Cleveland and Kjelgren, 1994). Re-forestation with black locust (*Robinia pseudoacacia*) is considered a successful technique that is often used for the reclamation of open-cast mine areas (Vlachodimos et al., 2013; Sytnyk et al., 2016). *R. pseudoacacia* as a nitrogen-fixing plant enriches soil with organic and inorganic nitrogen and organic matter to a greater extent than natural grasses. Most physicochemical properties in reclaimed mine soils under *R. pseudoacacia* monoculture forest become considerably elevated with the duration of the reclamation period compared to undisturbed soils. The duration required to attain the nutrient level in undisturbed soils was about 10 years of reclamation. Overall, *R. pseudoacacia* has shown strong adaptation to poor soil conditions after reclamation and has markedly ameliorated soil succession in dumps (Yuan et al., 2018).

The reactions to mixture of ores and their change along a gradient of site conditions depend on the respective limiting factor and the species' potential to overcome the limitation (Forrester, 2014). Complementarity in exploitation of water and mineral nutrients is most effective and growth accelerating on sites with limitation in water and mineral nutrients. Mixed stands of Scots pine and European beech have significantly higher structural heterogeneity than monocultures of Scots pine and European beech (Pretzsch et al., 2016). Comparison based on total biomass production may bring different results, as mixing tree species can change stem-crown allometry (Pretzsch, 2014; Liang et al., 2016; Vallet and Perot, 2016) and also tree ring width and wood density (Zeller, 2016). Tree species mixing can significantly modify individual tree morphology and reduce or improve wood quality (Pretzsch and Rais, 2016).

A successful reclamation programme must include a monitoring component to identify areas of successful reclamation, as well as areas where man-

agement problems exist or where reclamation practices are failing (Lein, 2001). Monitoring of the natural environment, especially areas degraded by mining activities, is connected with the constant need for precise and up - to - date land use/land cover maps (Szostak et al., 2015; Townsend et al., 2009). Novel techniques including geoinformation technologies such as those used in making land use and land cover change maps are used for characterizing the morphometry and determination of the spatial structure of vegetation on reclaimed post-mining areas (Chmielewski et al., 2014; Dudzińska - Nowak and Wężyk, 2013; Szostak et al., 2014; Wężyk et al., 2014). Remote sensing data are useful for the investigation and monitoring of vegetation change in open pit mining areas over a long period of time. This method is useful to identify areas where vegetation may be stressed, or where reclamation requires integrated approaches (Szostak and Nowicka, 2013; Maiti et al., 2019).

The aim of our research was to make a geospatial assessment of land cover after the extraction of brown coal and the technical stage of reclamation of disturbed areas.

Materials and methods. The Dnipro brown coal basin occupies an area the size of more 60 000 km^2. 12 brown coal areas are part of this basin. The surface of the basin is characterized as an elevated gently undulating plain, sometimes dissected by river valleys and a dense network of gullies and ravines.

Expressed dismembered relief causes the development of surface runoff. This is a factor in the formation of eroded lands with varying degrees of washout. This part of the area is affected by deep erosion. Artificial landforms in the basin are also observed together with natural geomorphological forms. These are quarry pits, trenches, overburden dumps, deformed surfaces, etc. A characteristic feature of the climate is quite a significant fluctuation in temperature and rainfall over the months.

Availability of soil productive moisture for plants is average. Approximately every fourth to fifth year is dry, due to insufficient rainfall in the spring and summer. Quite often there is a decrease (less than 50 % of the field moisture capacity) of moisture reserves, which coincides with the air drought – dry winds. Common species of forest stands are oak, ash, maple, elm, and linden).

The Semyonovsky-Golovkovsky brown - coal deposit is located within the boundaries of the group of the Dnieper basin and is located in the Alexandria mining region on the watershed of the Ingulets and Beshka rivers. Overburden rocks are loess - like, red - brown and glauconite - containing loams, quartz, glauconite -containing and carbonaceous sands, kaolin and carbonaceous clays. The total area of reclaimed land was about 1006 hectares, of which under agricultural land occupied 39 % of the territory, pastures 2 % and land under forest reclamation – 59 %.

Overburden rocks are characterized by different texture and origin. Their uptake to the earth's surface, together with man-made dismemberment of the terrain, creates many options for the development of various forest trees and shrubs. 15 sample plots (SA) were laid in the last decade of the 20th century in the Alexandria forestry. Forest species were planted in five sites (blocks) of different age (5 - 30 years), composition of stand (pure and mixed) and different technozem composition. Rocks were represented by deposits of neogenic and anthropogenic periods with different textures: loamy, clay, sand. The sites selected for the creation of forest plantations were characterized by state of moisture and attachment to different elements of the relief. The survey of the structure and productivity of the forest stand was carried out in accordance with the requirements of forest inventory. Plantations of black locust (*Robinia pseudoacacia*) on technozems occupied 150.6 ha, representing 27 % of the total reclaimed area. Due to its biological features and environmental needs, the culture of black locust was used for various applications in the restoration of disturbed lands. Mixed stands occupy an area of 58 ha, of which pine or *Pinus sylvestris L.*(*P.s.*) – black locust or *Robinia pseudoacacia* (*R.p.*) account for 47 % of the territory and maple-black locust – 33 %.

Geomorphological assessment of the studied area was performed using multitemporal satellite radar interferometry. Multispectral imagery of Sentinel-2 satellite system was engaged for remote land cover assessment within the study area. Relative soil moisture for the territory of the Semyonovsky – Golovkovsky brown-coal deposit area was estimated using the Sentinel-2 Multispectral Instrument (MSI), Landsat-8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) optical multispectral data. Standard preprocessing operations including radiometric calibration, atmospheric correction and cloud masking were applied to input multispectral images. The Landsat-8 OLI/TIRS 30 m spatial resolution imagery was used to calculate true (not radiant) temperature *T* of land surface, while the Sentinel-2 MSI 10 m spatial resolution imagery produces the Normalized Water Index (NWI) (Sakhatsky and Stankevich, 2007). Both *T* and NDWI maps after co-registration was fused into land surface water content distribution (Zhang and Zhou, 2016). Normalized Difference Vegetation Index (NDVI) was computed to determine Vegeta-

tion Cover Fraction (VCF) (Zhang et al., 2006) based on Sentinel-2 Alexandria – Golovkovka 2015.08.09 and 2018.06.19 images.

Results and discussion. There is a wide variety in the spatial structure of phytocenoses in the studied plantations of black locust, depending on the diversity of forest growth conditions. The influence of the anthropogenic factor is observed throughout the coal basin and is manifested in the technogenic formation of relief, reshaping of dumps, uptake of overburden rocks to the day surface of the lignite deposit. Elevations alternate with depressions. This causes the diversity of the soil cover, both in fertility and moisture. Dynamics of forest mensuration indices of pure stands of black locust are shown in Fig.1.

– year - old *Robinia pseudoacacia* stands, which are in decline and are represented by loamy sediments, occupy the largest area. The range of moisture varies from moist to wet loams. The height of the stand was 11 - 12 m, diameter – 12 - 14 cm, wood reserves – 83 - 96 m^3/ha, respectively. It should be noted that the average growth rates reached the maximum values at the age of 20 - 25 years – 3.84 – 4.15 m^3, and the current in 15 - 20 years – 7.8 - 9.5 m^3.

Some approaches have been applied in connection with the slow growth of forest crops on the dumps to intensify the growth processes. Use of methods of biological intensification of growth of tree cultures gave good results. One of them is the introduction of nitrogen fixing species into the forestry culture. Thus,

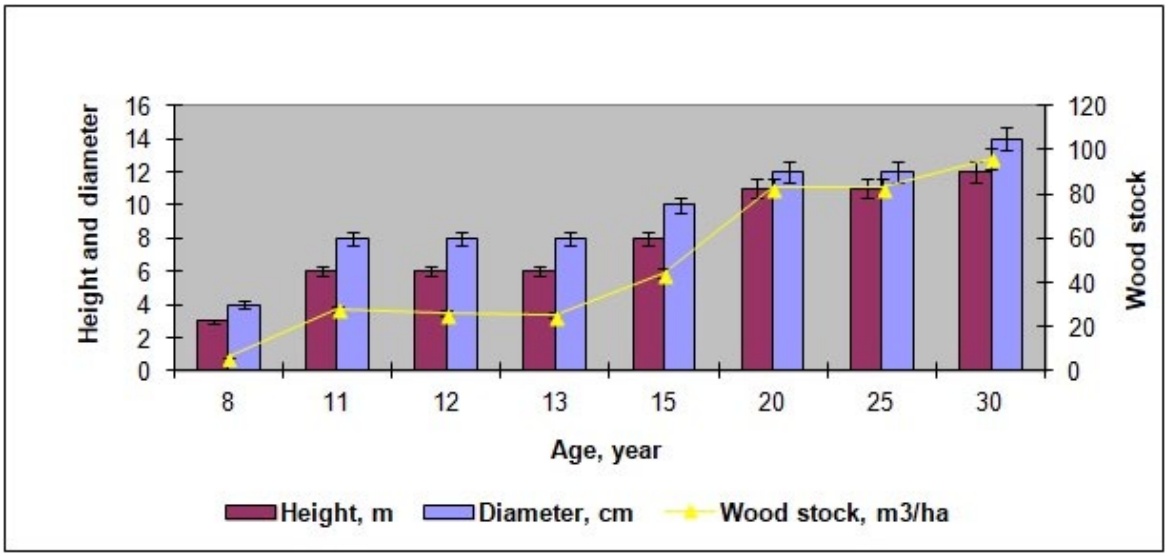


Fig. 1. Dynamics of parameters of plantations of *Robinia pseudoacacia*

Eight-year plantings were located on the slope of the eastern exposure and differed in the lowest indices of forest inventory: height – 3.0±0.034 m, diameter – 4.01±0.06 cm, wood stock is 6.03±0.06 m^3/ha.

The virgin plantings of black locust at the age of 11 - 13 years reached a height of 6.12±0.08 m and a diameter of 8.1±0.10 cm. There was a differentiation of wood stocks of 25 - 28 m^3/ha and fluctuations in the average growth from 1.92 to 2.55 m^3. 15-year-old plantations of *Robinia pseudoacacia* in the ravine thalweg on loamy rocks in wet conditions of moisture were surrounded by steep slopes of the south-western and north - eastern exposures. The forest stand had an average height of 7.98±0.10 m, an average diameter of 10.04±0.15 cm, wood reserves – 44.03±0.25 m^3/ha. Black locust aged 20 years has a stock of stem wood 83.1±0.40 m^3/ha. Maximum forest growth effect of acacia on reclaimed lands was expressed in the average growth achieved at this age. The mono 25 plantations were created in which 40 % was occupied by Scots pine and 60 % by *Robinia pseudoacacia* (Fig.2).

Plantings with the composition of the stand 6R.p.4P.s. formed in the upper third of the waste of the Western exposure on loamy sediments. Wood reserves amounted to 12.07 ±0.12m^3/ha. Black locust had a height of 4.05±0.07 m, diameter – 6.06±0.09 cm, pine – 3.03±0.07m and 3.98±0.09cm respectively. It was found that with this ratio of tree species to 11 years of age, *Robinia pseudoacacia* was ahead of pine in terms of growth. The advantage of pure pine plantations was established on all parameters (altitude 33%, diameter by 50 % and stocks of wood at 100 %). Plants of *Robinia pseudoacacia* of natural origin penetrate with a decrease in the completeness of the monoculture of pine from the surrounding areas, ahead of the growth of the 11 - year - old pine (10P.s. + R.p.). In the future, with age (19 and 21 years),

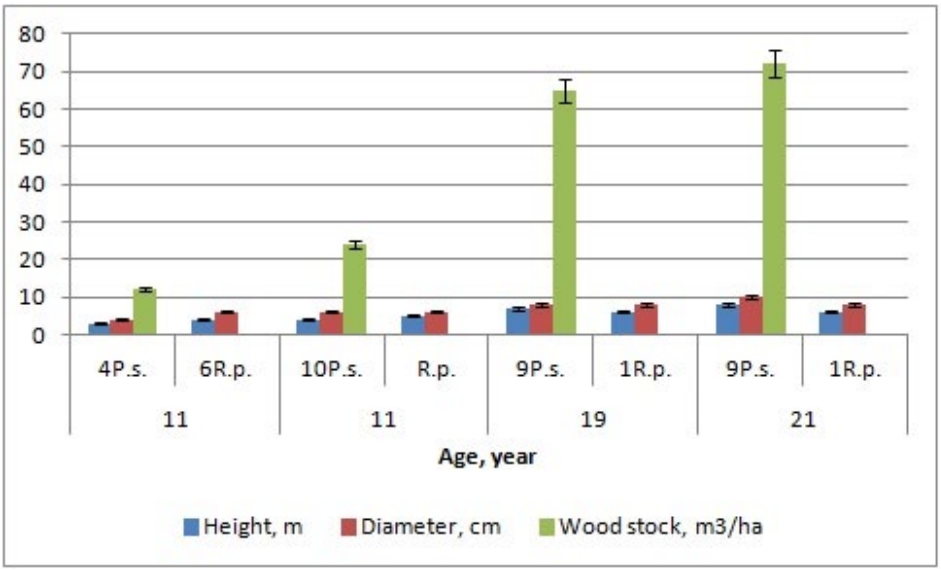


Fig. 2. Wood stocks in mixed forest stand of pine (*P.s.*) and black locust (*R.p.*)

Robinia pseudoacacia of natural origin is introduced into the monoculture of pine by 10 % (9P.s.1R.p.). However, it is significantly inferior to the growth rate of the main plant, especially in terms of wood reserves.

Mixed stands of the same age with different structure of the forest stand with the participation of *Robinia pseudoacacia* present another area of interest. Two sample areas had the same composition of 7 Black locusts + 3 Maples or *Acer pseudoplatanus L.*(*A.p.*) aged 10 years, but differing in geological conditions, which led to a change in the parameters of forest taxation (Fig. 3).

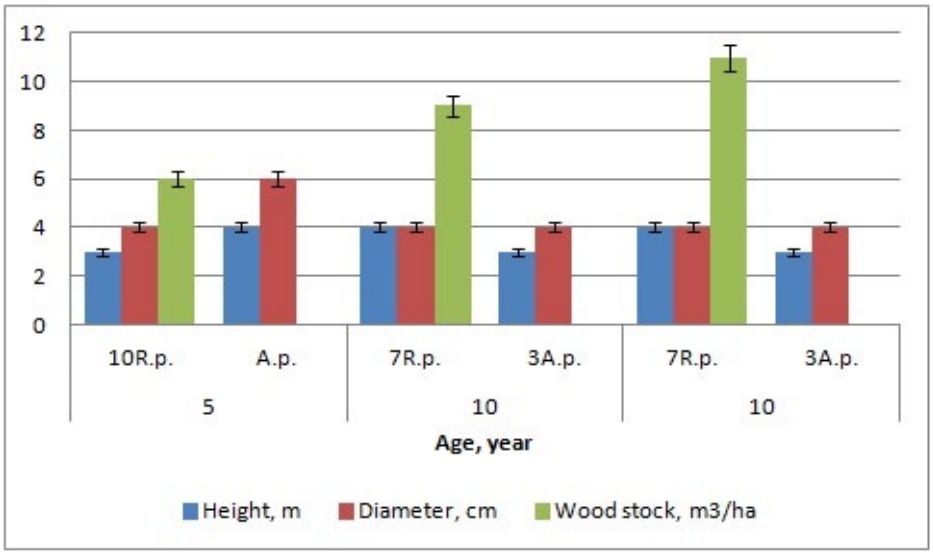


Fig. 3. Wood stocks in mixed forest stand of pine and black locust

Maple at the age of 10 years occupies up to 30 % of such areas. Comparing the same structure of the forest stand phytocenosis (7R.p. + 3A.p.), growing in different conditions on washed and leveled areas, we can note that the wood reserves on the leveled areas were 22 % higher due to greater completeness.

Results of previous similar case studies comparing the same experimental pure and mixed-species plantations have shown that productivities were either similar or greater than the same species grown in monocultures (Piotto et al., 2003; Alice et al., 2004; Petit and Montagnini, 2004; Petit and Montagnini, 2006). Meantime, it was established that mixed - species plantations have greater potential advantages than monocultures (Mao et al., 2017). The greatest use of melioration in forest plantations is through the combination of a Nitrogen (N) - fixing and a non - N - fixing tree species (Kelty, 2006). N - fixing tree species may increase the supply of available N in the soil, benefiting both N - fixing and non - N - fixing trees. Strong facilitative effects of N - fixing species on the

growth of non - N - fixing species were found on a site with low soil N, but not on a site with high soil N (Bouillet et al., 2013).Trees and shrubs in the territory of a lignite deposit after the biological stage of reclamation were both in pure and in mixed condition.

Thus, *Robinia pseudoacacia* monocultures on territories of reclaimed mines had higher values of height, diameter and productivity. These plantations at the age of 5 - 11 years exceeded at this stage the dynamics of growth and wood reserves of mixed plantations. The similar results have been obtained in case studies (Bouillet et al., 2013; Mao et al., 2017; Kelty et al., 2006; Pretzsch, 2014).

The highly dynamic process of the secondary forest succession has been shown on the tested areas of sulfur mines (Szostak et al., 2015).

Results of remote sensing of geomorphological features of the reclaimed area (terrain relief features formed in the post-reclaimed period). The studied area terrain elevations are shown in Fig.4.

The influence of the anthropogenic factor is observed throughout the section and is manifested in the man-made formation of relief, reshaping of dumps, removal to the surface of overburden rocks. It is established that the height values can vary from 85 m to 213 m. The results of these changes in the microrelief for the last 3 years (from 2015 to 2018) are presented in Figure 5 and Table 1.

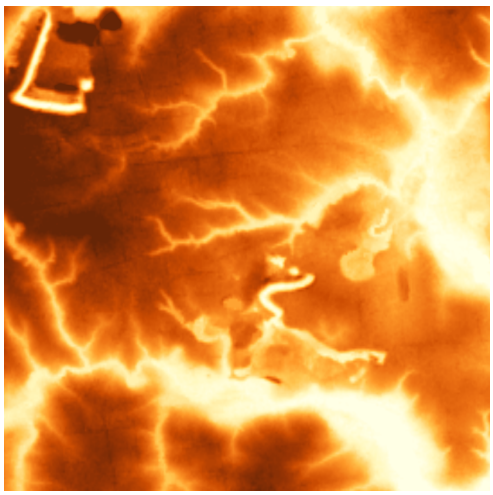


Fig. 4. Terrain elevations within the study area (Sentinel-1A Alexandria – Golovkovka 2018.06.08 / 2018.06.20 interferometric pair)

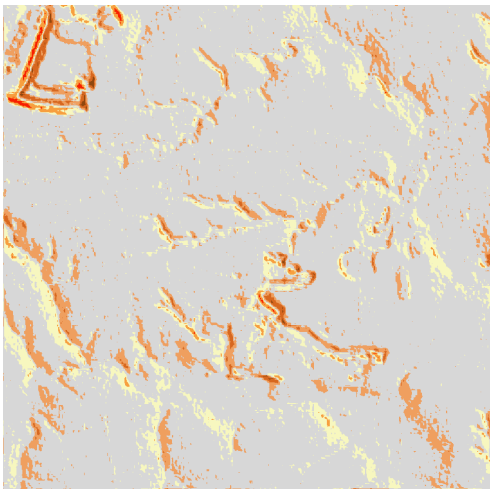


Fig. 5. Terrain elevation change within the study area (Sentinel-1, Alexandria – Golovkovka 2015.08 – 2018.06)

Table 1. Legend of terrain elevation change

Code	Colour	Class	Difference	Percent
0		Unclassified	no data	0.0000
1		Strong Down	< –0.30	0.1223
2		Moderate Down	–0.30 .. –0.15	0.7967
3		Weak Down	–0.15 .. –0.05	8.0757
4		No Change	–0.05 .. 0.05	82.7699
5		Weak Rise	0.05 .. 0.15	7.3865
6		Moderate Rise	0.15 .. 0.30	0.7891
7		Strong Rise	> 0.30	0.0597

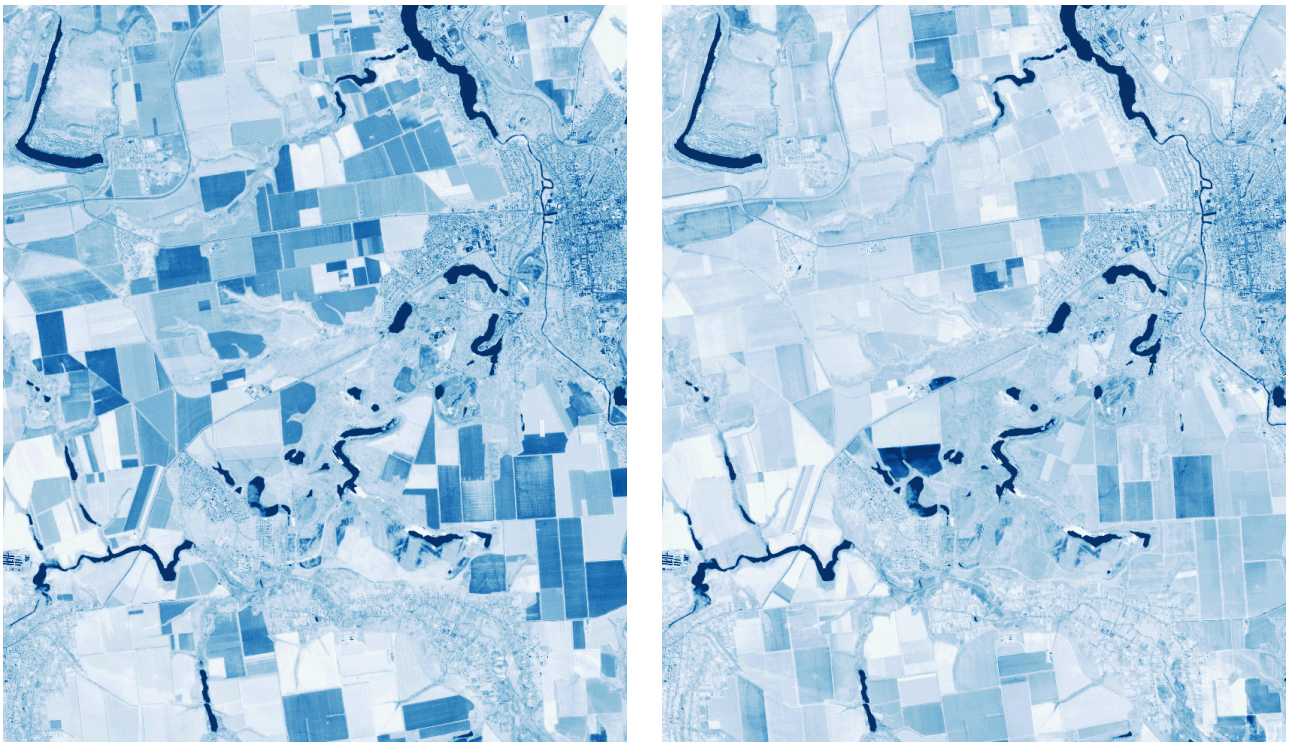
According to the data obtained, 82.8 % of the surveyed area has not undergone significant changes in terrain elevation. About 15.5% of the territory was under the influence of alluvial-diluvia processes.

Data on the distribution of land surface water content in the summer of 2015 and 2018 within the surveyed area are shown in Fig.6 and Table 2. The logarithmic regression relationship between the $^{(NWI+1)}/_{T}$ parameter and relative water content was restored therefor.

Elevations alternate with depressions, which causes the diversity of the soil cover, both in fertility and moisture.

The highest moisture content at the level of 0.2 - 0.3 relative units in 2015 was recorded in the territory occupying 78.4 %. Meanwhile, the shares of land cover with such humidity increased by almost 9% over the next 3 years.

VCF image differencing is successfully used to follow the long-term success of reclamation (Sarp,

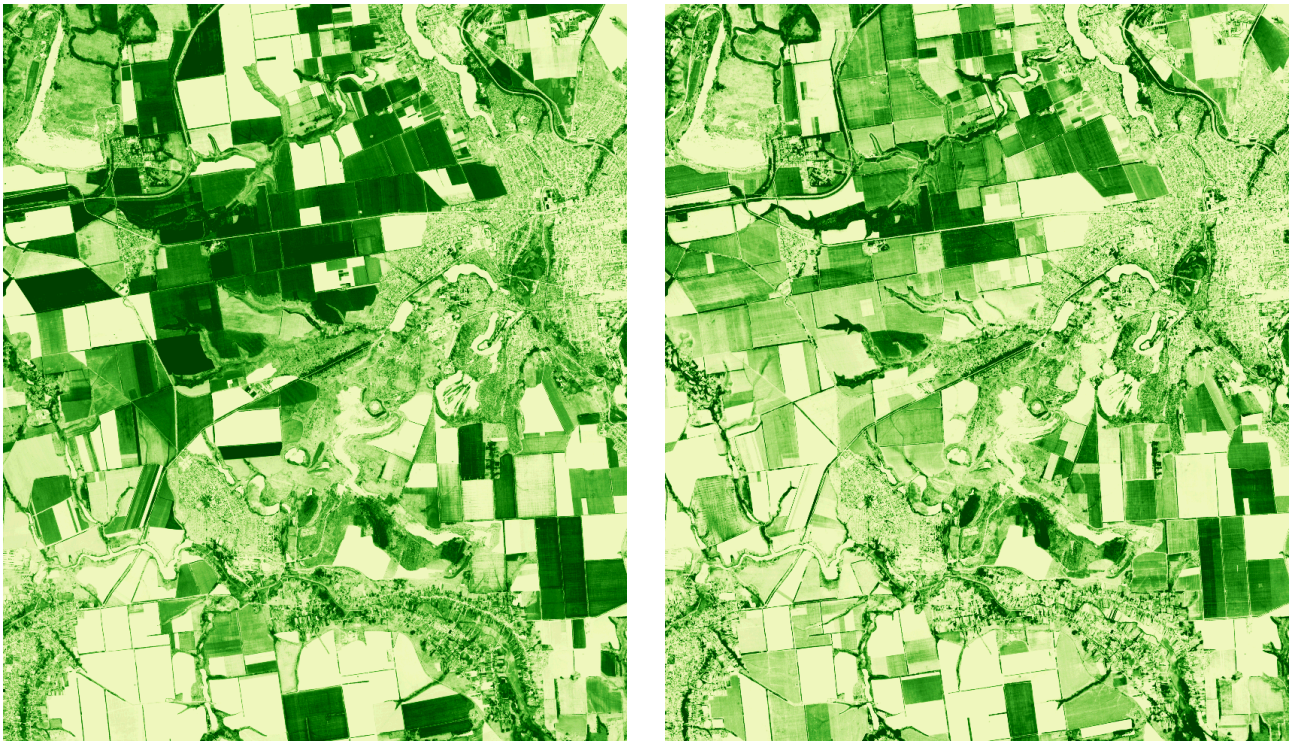


2015.08.09 2018.06.19

Fig. 6. Water content distribution maps, Sentinel-2, Alexandria – Golovkovka

Table 2. Legend of water content estimation

Code	Colour	Value	Percent	Value	Percent
		2015.08.09		2018.06.19	
0		no data	0.0000	no data	0.0000
1		0.0 – 0.1	0.0003	0.0 – 0.1	0.0014
2		0.1 – 0.2	1.3803	0.1 – 0.2	2.8939
3		0.2 – 0.3	78.3774	0.2 – 0.3	87.2895
4		0.3 – 0.4	18.1562	0.3 – 0.4	7.3259
5		0.4 – 0.5	0.3683	0.4 – 0.5	0.7078
6		0.5 – 0.6	0.2010	0.5 – 0.6	0.2217
7		0.6 – 0.7	0.2854	0.6 – 0.7	0.3207
8		0.7 – 0.8	0.9052	0.7 – 0.8	0.9199
9		0.8 – 0.9	0.3259	0.8 – 0.9	0.3192



2015.08.09 2018.06.19

Fig. 7. Vegetation cover fraction maps, Sentinel-2, Alexandria – Golovkovka

Table 3. Legend of VCF parameters

Code	Colour	Value	Percent	Value	Percent
		2015.08.09		2018.06.19	
0		no data	0.0000	no data	0.0000
1		0.0 – 0.1	25.6841	0.0 – 0.1	29.2965
2		0.1 – 0.2	8.6552	0.1 – 0.2	12.5878
3		0.2 – 0.3	9.0779	0.2 – 0.3	12.7751
4		0.3 – 0.4	9.4638	0.3 – 0.4	11.4648
5		0.4 – 0.5	8.6933	0.4 – 0.5	8.8962
6		0.5 – 0.6	7.6262	0.5 – 0.6	7.1871
7		0.6 – 0.7	6.3338	0.6 – 0.7	6.5164
8		0.7 – 0.8	7.1992	0.7 – 0.8	5.2522
9		0.8 – 0.9	10.3037	0.8 – 0.9	3.9347
10		0.9 – 1.0	6.9628	0.9 – 1.0	2.0892

2012). The classic method for NDVI-based VCF calculating from Carlson & Ripley paper (Carlson and Ripley,1997) was used:

$VCF(x, y) = [(NDVI(x, y) - NDVI_0)/(NDVI_1 - NDVI_0)]^2$,

where $VCF(x, y)$ is VCF value inside (x, y) image element, $NDVI_0$ and $NDVI_1$ are NDVI thresholds values for vegetation-free and full vegetation cover terrain respectively.

Data on the state of vegetation cover in the summer of 2015 and 2018 in the surveyed area are shown in Fig.7 and Table 3.

The VCF differentiation allows separation of vegetated areas from areas with little or no vegetative

cover. High VCF values are mostly indicated for reclaimed and vegetated areas. The highest density of vegetative cover was recorded in the North-Western part of the study area of forest reclamation. At the same time, vegetation cover fraction over the past three years decreased by codes 8-10 and increased by codes 1, 3, 4. Thus, considering the potential suitability of the area for forest reclamation, one should note the important role of geomorphological, geological and water resources for the growth and development (formation) of plant communities.

Conclusion. The processes of self-regulation and restoration of fertility on reclaimed lands at the first stages of their biological development were slowed down. This significantly reduced the resistance of phytocenoses, both pure and mixed, to the conditions of the environment provided to them. A comparison of the inventory stem wood of the black locust showed the superiority of monoculture plantations to mixed stands of pine-black locust and maple - black locust. Progression of the forest-forming process takes place with age. Remote assessment of the territories was conducted to assess the future prospects of biological conservation of reclaimed lands. The influence of the anthropogenic factor is observed throughout the section and is manifested in the man - made formation of relief, reshaping of dumps, removal to the surface of overburden rocks. It is established that the terrain's height values can vary from 85 m to 213 m. 82.8 % of the surveyed area has not undergone significant changes in relief. About 15.5 % of the territory was under the influence of alluvial - diluvia processes. There have been corresponding changes in the share of vegetation using the VCF value codes over the past three years. The highest moisture content at the level of 0.2 - 0.3 relative units in 2015 was recorded in the territory occupying 78.4 %. Meanwhile, the shares of land cover with such humidity increased by almost 9 % over the next 3 years. The highest density of vegetative cover was recorded in the North - Western part of the study area of forest reclamation.

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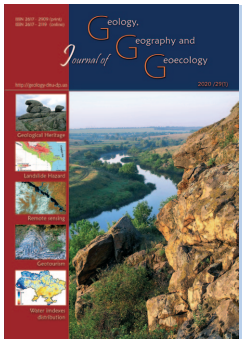

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The Late Cretaceous phosphatized ichnofauna fossils from the Eocene basal horizon of the Middle Dnieper area

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Abstract. The object of our study was phosphated remains of ichnofaunas from the basal horizon of the Kanivska suite (Eocene), which transgressively onlaps here the eroded top of the Burimska suite. The goal of the research was to reconstruct some sedimentation features of the final stages of the Late Cretaceous basin's existence and during of the Early Eocene transgression on the Middle Dnieper area (Ukraine). The specimens of the basal horizon of the Kanivska suite (P_2kn) were sampled from the outcrops in the Melanchin Potik gulley and in a branch of the Glyadovy gulley. It is a complex of rough-medium grained gravel sandstones with shark teeth, fish bone fragments, detritus of Bivalvia and Brachiopoda. The nature of preservation and arrangement suggests that the fossils were relocated. The sample from the Glyadovy gulley is an agglomeration of phosphatized debris of various types of ichnofauna, cemented with a phosphate and sand substrate. The first type, in our opinion, is a fragment of a burrow nucleus of a crayfishlike decapod *Thalassinoides* Ehrenberg ichnogenus, as indicated by the surface , absence of a constructed wall and its size. The phosphorite features of the second type are cores of the burrows of the *Ophiomorpha* Lundgren genus with a characteristic ophiomorphic sculpture in the form of knobbles on the outer surface. The structures of the second type have certain differences in the distribution and nature of phosphate material. The described cores are interpreted as domichnia: dwelling places of fossil fauna. They were not known earlier within the Middle Dnieper area. The animals constructed a system of void ducts in the well ventilated middle ichnofossil layer with depth up to 60 cm (as can be inferred from the diameter of *Thalassinoides*). Although crayfish burrows can be present in any formation, it is generally thought that they are more specific for the littoral and shallow water environments. Based on the fauna composition and the phosphated debris preservation, we can assume the age of ichnofaunas is Late Cretaceous. An indirect indication of this can be the bones and teeth of Cretaceous vertebrates, found in the same basal layer, in particular, ichthyosaurus genus (*Platypterygius* sp.) and a phosphate concretion with ammonite remnants. Besides phosphatized ichnofauna debris, the basal level contains black odd-shaped nodules and microconcretions, composed of amorphous phosphate minerals. They contain a considerable amount of microscopic fossils of presumably phytoorganic nature and fragments of undeterrmined groups. From the fact that the phosphate material is not completely decrystallized, and that some microfossils have their initial composition, we infer that they belong to the Early Eocene.

Keywords: paleogeography, Cretaceous Period, Eocene, Kanivska suite, phosphatized remains, ichnofauna

Фосфатизовані рештки іхнофауни з базального горизонту еоцену Канівського Придніпров'я

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Анотація. Об´єктом нашого дослідження були фосфатизовані рештки іхнофауни з базального горизонту київської світи еоцену, яка в межах Канівського Придніпров´я трансгресивно залягає на розмитій поверхні верхньої крейди. Мета роботи - на основі дослідження мінеральних компонентів, органогенних решток та слідів життєдіяльності базального горизонту з'ясувати особливості умов осадконакопичення на заключних етапах існування крейдового моря і під час ранньоеоценової трансгресії на території Канівських дислокацій. Базальний горизонт в основному складений масивними середньо-грубозернистими гравелітистими слабозцементованими кварцовими пісками і пісковиками з поодинокими включеннями фосфатних стяжінь неправильно округлої форми та з численною фауною представленою зубами акул, фрагментами кісток риб, детритом двостулкових молюсків і брахіопод. Характер розташування стулок і ступінь їхньої збереженості говорить про те, що фосилії були перевідкладені. Зразок, відібраний з Глядового яру представляє собою скупчення фосфатизованних уламків іхнофауни різного типу, зцементованих фосфатно-піщаним матеріалом. Перший тип, на нашу думку, представляє собою фрагмент ядра нірки десятиногого ракоподібного іхнороду Thalassinoides Ehrenberg, на що вказує характер поверхні, відсутність побудованої стінки і його

розміри. Фосфоритові утворення другого типу представляють собою ядра нірок роду Ophiomorpha Lundgren з характерної офіоморфною скульптурою у вигляді бугорків на зовнішній поверхні. Описані нірки інтерпретуються як Domichnia – житло викопних організмів і раніше в межах Середнього Придніпров'я не відомі. За життя тварини формували систему незаповнених ходів середнього, добре вентилюємого іхноярусу глибиною до 60 см (виходячи з діаметра Thalassinoides). Найчастіше вони характеризують різноманітні умови прибережної області і мілководдя. Виходячи зі складу фауни, явно перевідкладений характер нірок тощо, цілком імовірно, що дані уламки мають крейдовий вік. Непрямим підтвердженням чого можуть слугувати знахідки в цьому ж базальному горизонті кісток і зубів представників крейдової фауни, зокрема іхтіозаврів (Platypterygius sp.). Крім уламків фосфатизованних решток іхнофауни в базальному горизонті присутні стяжіння чорного кольору неправильної форми та мікроконкреції, складені аморфними фосфатними мінералами. У складі мікроконкрецій в значній кількості знаходяться мікроскопічні рештки, імовірно, фітоорганіки. Виходячи з того, що фосфатний матеріал ще не роз кристалізований, а частина мікрофосилій зберегла свій первинний склад, ми вважаємо, що дані мікроконкреції є наймолодшими у складі базального горизонту і мають ранньоеоценовий вік.

Ключові слова: палеогеографія, крейдовий період, еоцен, канівська світа, фосфатизовані рештки, іхнофауна.

Introduction and background. The Cretaceous period is characterized by an extensive development of shallow epicontinental basins, where the sedimentation was controlled by three factors: eustatic variations of the sea level, epeirogenesis and climate (Naydin et al., 1986). The whole sedimentary rock mass, deposited during the Late Cretaceous in the epicontinental seas of the western part of Eurasia, is referred to as the chalk-glauconite litho-tectonic complex ("formation", introduced by N.S. Shatsky) with the paragenesis of chalks, chalky marlstones, silica clays, glauconite rocks, phosphorites and grey-coloured terrigenous sediments (Shatsky, 1965). This complex was formed during a single eustatic cycle, which started with a slow transgression and ended with a rapid regression at the end of the Cretaceous. These changes of sedimentation environment determined its structure: lower layers are glauconite sands and sandstones, the main part of the formation are carbonate rocks, and the end of the cycle is characterized by regressive sequences: sands, sandstones and sandy carbonate rocks.

Within the Middle Dnieper area the lower part of the formation is represented by rocks of the Burimska suite **(K_{1-2}*br*)**, composed of glauconite-quartz sands and sandstones, which were deposited mostly in the littoral environment. Upwards in the cross section the sands acquire more carbonate material, and in certain areas tracing interlayers appear with carbonate nodules of considerable sizes. The top of the Cretaceous outcrop is a rock mass of writing chalk stone and marls of the Genichevsky horizon **(K_2*km*)**, distributed along the western and south-western boundary of the Kaniv dislocation region (Tsyba et al., 2012). All boundaries between different lithologies are concordant (wherever they can be traced). Higher in the succession the Cretaceous rocks are overlapped with Paleogene, Neogene and Quaternary formations (Fig. 1).

We studied the basal horizon of the Kanivska suite (Eocene), which transgressively onlaps here the eroded top of Burimska suite. Its lower part is represented by fine-grained dark-green quartz-glauconite, carboniferous or loamy sands, with interlayers of coarse grained sands. This sequence outcrops in the gulleys of Kaniv area.

These formations and the whole area are rather well represented in the literature. The study of

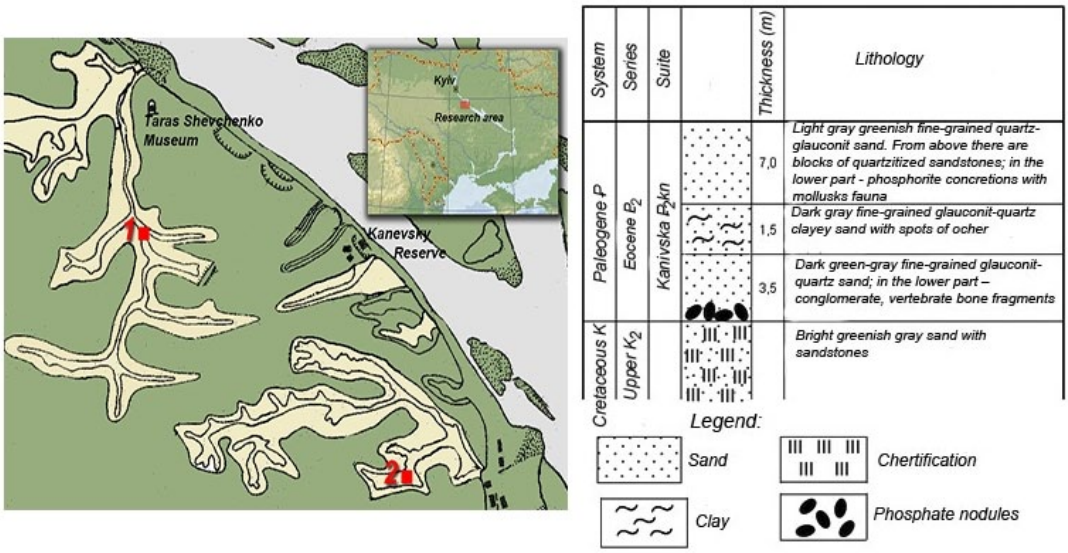

Fig. 1. Study area, lithology of Upper Cretaceous and Lower Paleogene rocks, outcrops of basal horizon of Kanivska suite (the stratigraphic column acc. to *(Sokolov and Makarenko, 1983)*): 1 – Melanchin Potik gulley, 2 – Glyadovy gulley

these rocks was initiated in the late XIX and early XX century timeframe by G. Radkevich and P.Ya. Yermashevsky (Syabryay, 1963). G. Radkevich was the first to distinguish and describe the lower stratum of the Kanivska suite under the name "*Horizon a*" (Radkevich, 1900). The basal layer in the floor of the Kanivska suite on the contact with Senoman deposits was also described in (Sokolov and Makarenko, 1983). Its outcrops in the area of Kaniv dislocations were also described elsewhere (Syabryay, 1963; Kaptarenko-Chernousova, 1971; Palienko et al., 1971; Krochak et al., 2016).

Goal, materials and methods. On the base of the analysis of petrography and fossils in the basal horizon of the Kanivska suite, we studied the sedimentation and deposition environment in the final stages of the Late Cretaceous sea's existence and during the Early Eocene transgression in the area of Kaniv dislocations. We used both literature and our own collected data for the analysis. The specimens of the basal horizon of the Kanivska suite (**P_2kn**) were sampled from the outcrops in the Melanchin Potik gulley and in a branch of the Glyadovy gulley (points 1 and 2 in Fig. 1 respectively) for the petrographic (a polarizing microscope *Micros MC 300(S)* was also used for research) and paleontological analysis. The results of the study are presented below.

Principal results and discussion. In Melanchin Potik gulley, ca. 50–70 m from its mouth, in the right wall of the gulley, at a height of 7 m from the gulley thalweg, there is an outcrop of a layer of sand and sandstone in the sedimentary rock mass. The outcropped rock is a strongly cemented greenish-grey medium- and coarse grained gravelite sandstone with carbonate cement (Fig. 2). It has a pronounced boundary with lower strata. The layer is mostly composed of massive medium- and coarse grained gravellite quartz sandstone with occasional inclusions of phosphate nodules of irregular rounded shape. Apparent bed thickness is up to 15 cm. Numerous inclusions of carbonate organics are seen in the upper part of the layer. They are represented by almost intact 3-5 cm shells and detritus of bivalvia Pectinidae, Gryphaeidae (*Exogyra conica*) and one brachiopod species from the *Rhynchonellida*e order. The phosphatized organic fossils contain shells of inarticulated brachiopods of the Lingulidae family, small (up to 1 cm) fragments of bones, a fishbone and a shark tooth with a length of 1.5 cm. All remnants of Bivalvia and Brachiopoda are from benthic fauna. The layout of shells and their condition indicate at the redeposition of fossils.

The deposits also contain a considerable amount of phosphate contractions of irregular form, with sizes 1-3 cm.

This coarse grained quartz sandstone (non-lithified sand in some outcrops) is markedly traced in the area of Kaniv Nature Reserve and presents a basal horizon of the Kaniv suite (Krochak et al., 2016, Popova et al., 2015).

This basal level is also outcropped in Glyadovy gulley (near Khmilna village). The bed thickness there reaches up to 25 cm. A large amount of phosphate nodules with varying sizes, petrified wood, invertebrates: bivalvia, ammonites, brachiopods, as well as teeth of sharks, fish bones, and remnants of marine reptiles are encountered there. A bedrock specimen was sampled from this level in the left wall of the first right ravine tributary of Glyadovy gulley at a height of ca. 1.5 m from the thalweg.

The sample is an agglomeration of phosphatized debris of various types of ichnofauna, cemented with a phosphate and sand substrate. Such kind of phosphate

Fig. 2. Gravellite sandstone with detritus of benthic organisms (general outline)

structures are widely known in Cretaceous deposits of the East European platform (Shvanov, 1987). The phosphatized constituents of the sample with different shapes, colours and sizes can be classified into three types according to their morphology.

The first type is the largest straight rod-like fragment of ovate and cylindrical shape with length 10-12 cm and major diameter 5-6 cm (Fig. 3 a). The surface is slightly rough, and its fresh fracture shows the granulated well cemented rock. The cross section markedly reveals the zonation with a clear peripheral part (3-5 mm) and dark center.

Fig. 3. Phosphatized debris of ichnofauna: a – *Thalassinoides* Ehrenberg, b – *Ophiomorpha* Lundgren, c – cross section

In our opinion, this is a fragment of a burrow nucleus of a crayfishlike decapoda of *Thalassinoides* Ehrenberg ichnogenus, which can be inferred from the condition of the surface, absence of a constructed wall and its size. The cylindrical shape can be an indication that the fossil is a part of a vertical "mine" (the terminology is borrowed from *Yanin, Baraboshkin, 2013*); and the size would infer *Th. suevicus* type II (Reith) species, described in (Monaco, Giannetti, 2002) and some other works.

The cylindrical fragment is the fine grained sandstone, with predominant quartz content (90%) and phosphate cement. The cement filling of the intergranular space is different according to the area. In the edge zone the cement shows only contour filling, and there are many void pores. This results in the lighter colour of this zone (Fig. 4a). The cement content in the rock does not exceed 8-10%. In the transition zone, the ratio of debris and phosphate is about the same; and in the center the amount of cement exceeds the volume of debris. (Fig. 4b). This fragment can be classified as a sandy phosphorite. The increase in the decrystalisation degree of the phosphate towards central zones is typical for diagenetic structures.

The structures of the second type are dark reddish and black. These are fragments of pipe-like (or cone-like) debris with diameter from 1 to 2.5 cm and length up to 6 cm with a specific hummocky surface, some fragments are branched (Fig. 3b). They also feature a zonal structure with darker peripheral parts compared to central areas (Fig.3c). The outer phosphorite shell is more rigid compared to the inner part, which is subject to destruction and gradual emptying of material due to weak cementation, so the pipe is a semi-hollow channel from its edge.

We believe that the phosphorite features of the second type are cores of the decapod burrows – *Ophiomorpha* Lundgren genus with a characteristic ophiomorphic sculpture in the form of knobbles on the outer surface. The wall is composed of rounded or oval rock grains; the structure is like a tube constructed with a flat inner surface. One of the fragments has a Y-shaped branching at the edge. Since the principal feature for distinguishing between

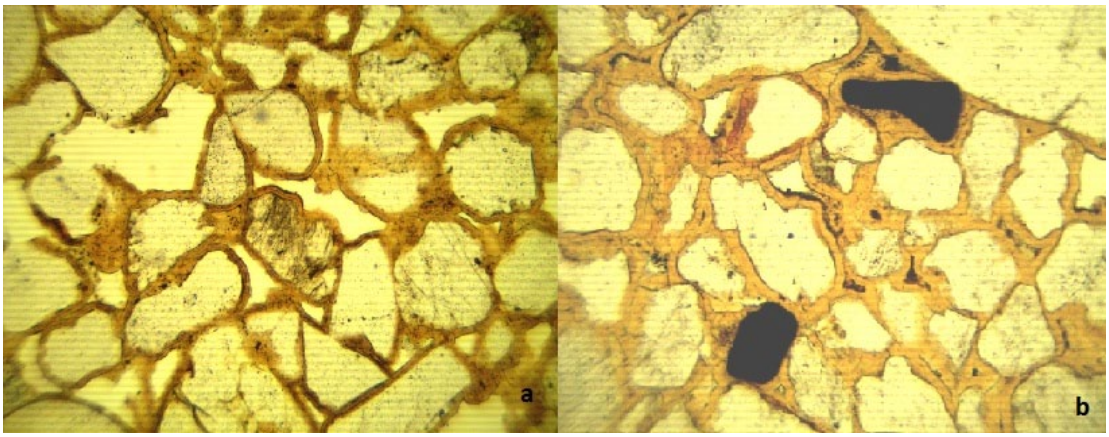

Fig. 4. Cement filling of the intergranular space: a- periphery, b - central zone. Thin section, PPL, 10x10. Frame length is 1 mm

species is the diameter of the burrow, which indicates the size of the animals (Vyalov, 1966), the described forms can be attributed to the species *O. nodosa* Lundgren (outer diameter range 1.5-3.3 cm). After the analysis of W. Häntzschel (Häntzschel, 1952), the ophiomorphs are considered as dwelling pipes of burrowing Decapoda. A specific sculpture of the walls was probably formed as a result of their lining with balls of sedimentation material.

The structures of the second type (compared to the first) have certain differences in the distribution and nature of phosphate material. They also feature a zonal structure, but different from the former case. The outer shell, 1-3 mm thick, is formed with amorphous phosphate with tiny debris of phytoorganics and quartz grains. Phosphates make up 60-70%, sometimes up to 80% of the bulk. The substance has globular structure. Possibly, phosphates were removed from the sediments into the burrows and precipitated on the walls, permeated with organic matter. The inner part of the burrow is clogged with fine-grained quartz sandstone with glauconite and phosphate cement with contour and basal type filling (Fig. 5).

known earlier within the Middle Dnieper area. The animals constructed a system of void ducts in the well ventilated middle ichnofossil layer with depth up to 60 cm (as can be inferred from the diameter of *Thalassinoides*). Although crayfish burrows can be present in any formation, it is generally thought, that they are more specific for the littoral and shallow water environments (Singh et al., 2008).

The modern burrow builders as analogs of the described fauna could be prawns – the representatives of the Callianassa genus, which permanently reside in excavated burrows. They feed on small organisms and detritus with the use of a filtration system. Modern Callianassidae reside in warm ocean waters, massively occupying areas from littoral to bathyal zones (Yanin, Baraboshkin, 2013).

Taking into account marked traces of secondary deposition (chipped edges, eroded surface etc) and the fact that the described ichnofossils do not belong to any species attributed by G.A. Radkevich as Eocene fauna, we believe that these fragments are probably of Cretaceous age. An indirect indication of this can be the bones and teeth of Cretaceous

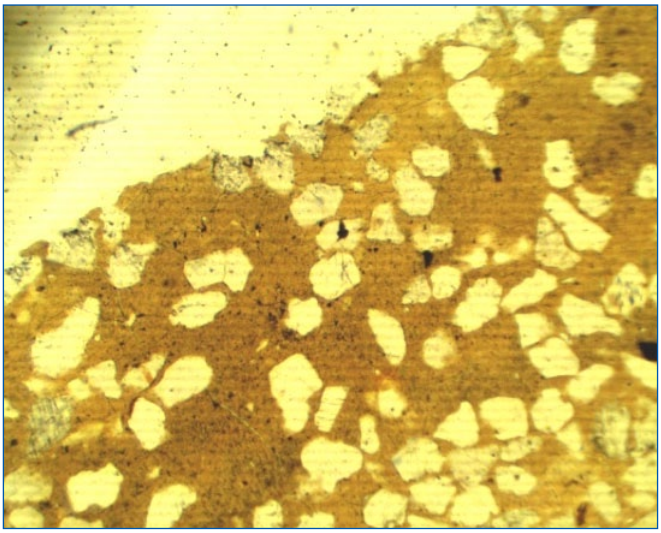

Fig. 5. A burrow with phosphate walls. Thin section, PPL, 4x10. Frame length is 2.5 mm

The burrows of both types are passively (gravitationally) filled. According to the appearance, the representatives of both genera differ essentially, although, according to some researchers, the shape of the burrows mostly depends on the nutrition, rather than on the substrate type, and is related to the specific features of the species (Griffis, Suchanek, 1991). Others (Yanin, Baraboshkin, 2013) note that according to the substrate nature a change of *Ophiomorpha* morphological patterns into *Thalassinoides* may occur.

The described burrows are interpreted as domichnia: dwelling places of fossil fauna. They were not

vertebrates, found in the same basal layer, in particular, ichthyosaurus genus *Platypterygius* sp. (Sokolov and Makarenko, 1983; Kyselevych, Ogienko, 2018), and a phosphate concretion with ammonite remnants (pers. com. Ogienko O. S., Mitrokhin A.V.). Since the top of the Cretaceous outcrop (Genichevsky horizon, $\mathbf{K_2}\boldsymbol{km}$) is represented by a layer of writing chalk stone and marls, it can be inferred that the final stages of the existence of a marine basin were periodically marked with the "hardground" features, as specific structures, caused by the interruptions in the sedimentation, which are well abundant in Cretaceous

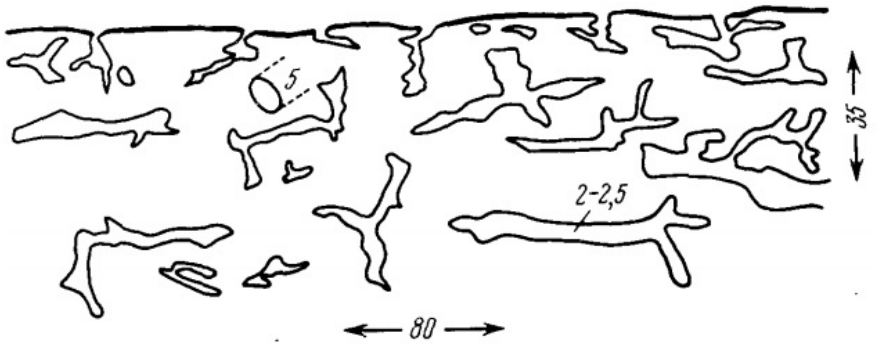

Fig. 6. "Hardground" at the contact of Maastricht and Danian, Aksyyirtau cross section, Mangyshlak. Numbers are dimensions (cm) by (Naydin et al., 1986)

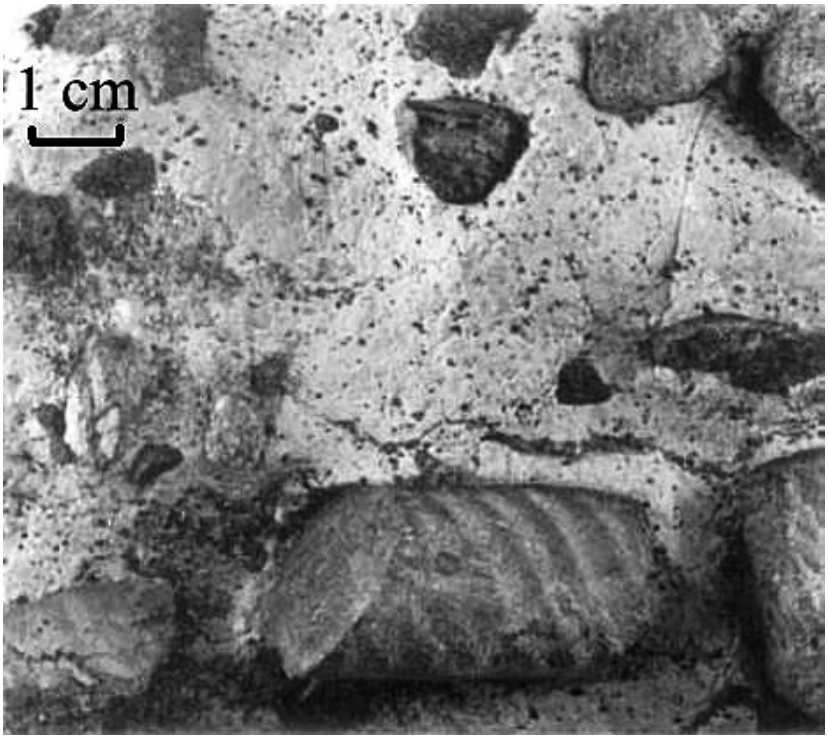

Fig.7. Phosphate nodules and phosphatised ichnofossils. The limestone hardground. Specimen 10 cm across. Mid-Cretaceous, French Alps by (Tusker M.E., 2003)

rocks of the East European platform and its frames (Fig. 6, 7). These surfaces are formed on the bottom of a sea basin with a predominantly carbonate sedimentation, when the steady sedimentation process is interrupted. Mild calcareous muds undergo gradual contraction and lithification in this environment down to the depth from 5-8 cm to several dozens of cm, and the sea bottom becomes a hard surface, suitable as a habitat for various sessile and free benthic organisms (their remnants were documented in the outcrops of Melanchin Potik gulley, Fig. 2). A ramified system of Thalassinoides burrows is characteristic for the mature stage of the hardground (Naydin, 1986).

Subsequently, a rapid shallowing of the basin took place, and the change of the facial environment resulted in the crayfish burrows filling with sand. Later on the sandstone with phosphate cement formed in the process of diagenetic transformation. This assumption is supportedfavorized by the zonality of these features, which is observable both visually and in thin sections.

Besides phosphatized ichnofauna debris, the basal level contains black odd-shaped nodules and micro concretions with sizes 2-5 mm, composed of amorphous phosphate minerals. They contain a considerable amount of microscopic fossils of presumably phytoorganic nature and fragments of undeterrmined groups (no studies have been performed yet). Microfossils, which have preserved the initial composition, are semi-transparent, red-brownish and black-brown. The remaining part of the fossils is phosphatized. Fig. 8 shows, that phytomaterial was redistributed and squeezed into peripheral parts of concretions during their growth (a dark ring on the

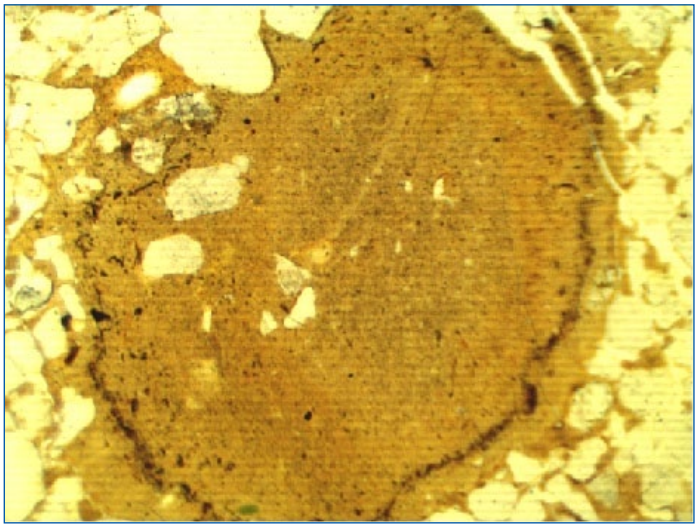

Fig. 8. Phosphorite micro concretion with phyto organics, squeezed towards periphery. Thin section, PPL, 4x10. Frame length a=2.5 mm.

photo under small magnification). From the fact that the phosphate material is not completely crystallized, and that some microfossils have preserved their initial composition, we infer that these structures are the youngest, that is they belong to the Early Eocene.

Conclusions. The burrows of *Thalassinoides* and *Ophiomorpha* are referred to as domichnia – dwelling structures; they are widely represented, especially in Cretaceous deposits of the East European platform. They are built mostly by Crustaceans, which is supported by data from many sources, although they were not described earlier for the Upper Cretaceous and Eocene sequences in the Middle Dniepr area.

In spite of a rather wide range of environmental conditions where such dwelling structures can be found, their most frequent occurrence is in the shallow water facies.

Together with phosphatized fragments of ichnofossils (which is described), the basal horizon of the Kanivska suite contains younger phosphorite structures, represented by concretions of irregular shapes and microconcretions, the formation of which was triggered by the presence of agglomerations of microfauna remains.

The age of redeposited phosphatized fragments of ichnofauna in the basal horizon of Eocene is Late Cretaceous, although the sedimentation conditions and the age of fauna of the phosphorite concretions of the basal horizon and lower strata of Kaniv suite still is questionable.

Further findings of the Cretaceous biota in the Eocene basal level can provide additional information about the paleofacial environment, persisting during the prolonged period of progressive degradation of the marine basin in the Late Cretaceous.

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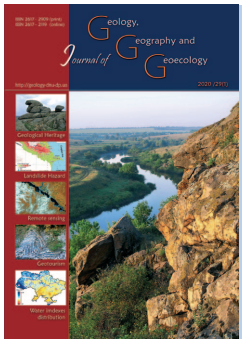

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Gradation and geochemistry of the Fenced Lagoon sediments (Bandar Anzali) with regard to source rock and tectonic location

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Abstract. The location of the Fenced Lagoon in the urban basin of Bandar Anzali, which should be considered due to its impact on the lives of the people of the region in terms of the conservation of the wetland and its environmental issues, and, on the other hand, the potential of this area to be introduced as a geotourism center determine the need to investigate the area's sedimentology and geochemistry. Therefore, to study sedimentary and geochemical properties of the Fenced Lagoon sediments located in Bandar Anzali, 33 samples were taken in the form of 6 cores and 12 grabs, and basic sedimentation tests and heavy metals measurement were carried out on them .Studies show that the sediments range from sand to clay in terms of gradation and have mainly coastal-river origin. The sediments of this lake are classified into four sedimentary types: Muddy Sand, Slightly Gravelly Muddy Sand, Sand and Slightly Gravelly Sand, and sand is the main component of all of these sediments. The most abundant sedimentary types belong to Muddy Sand and Sand and the least abundant sedimentary types belong to Slightly Gravelly Muddy Sand and Slightly Gravely Sand. The nature of the source rock is derived from acidic to intermediate combination and in general, sedimentary rocks of the area under study are within the continental arch islands and, to a lesser extent, the active continental margin.

Keywords: Anzali port, sediment, sedimentary geochemistry, measurement of metals, origin, tectonic location

Градація і геохімія відкладів огороджених лагун (Бендер Ензелі) виходячи зі співвідношення напрямків знесення вихідних порід і тектонічного положення

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Анотація. Розташування огородженої лагуни у міському басейні Бандар-Анзалі має розглядатися через вплив на життя людей регіону з точки зору збереження водно-болотних угідь та через призму екологічних питань, а з іншого боку, потенціал використання цієї території як центру геотуризму визначає необхідність дослідження седиментології та геохімії району. Тому для вивчення осадових та геохімічних властивостей осадів огородженої лагуни, розташованих у Бандар-Анзалі, було взято 33 зразки у вигляді 6 проб з керну та 12 з жолонки, а основні випробування на седиментацію та вимірювання важких металів були проведені на них за допомогою XRF (рентгено-флюористичного аналізу). Дослідження показують, що осади варіюються від піску до глини за гранулометричним складом та мають переважно прибережно-річкове походження. Осади цього озера класифікуються на чотири осадові типи: мулистий пісок, слабогравійний мулистий пісок, пісок і слабогравійний пісок, і пісок є основною складовою всіх цих осадів. Найбільш поширені осадові типи належать до мулисто-піщаного та піщаного, а найменш поширені осадові типи належать до слабогравійного мулистого піску та слабогравійного. Характер породи-джерела походить від кислих до проміжних комбінацій і, як правило, осадові породи досліджуваної території знаходяться в межах континентальних дугових островів і, в меншій мірі, активної континентальної окраїни.

Ключові слова: порт Анзалі, осад, осадова геохімія, вимірювання металів, походження, тектонічне положення

Introduction. Coastal wetlands provide a wide range of natural services that are socially valuable (Gönenç and Wolflin, 2005), including fishing, tourism and even storm control (Abigail et al., 2009). Maintaining these valuable environments depends on precise study and recognition. Obviously, their economic productivity and maintenance are impossible environmentally without the recognition and study of

the wetlands (Abdollahi,2010). The southern Caspian basin also has several wetlands that require studies from different perspectives.

The Caspian Sea and its rapid fluctuations at sea level during the Holocene have been the subject of many studies over the past two decades (Lahijani et al., 2009, Leroy et al., 2011 Kakroodi et al., 2012b, NaderiBeni et al., 2013a, NaderiBeni et al., 2013b). The Caspian Basin, after separating from the open sea, became a lake at the time of Pliocene, and from then on, a series of tectonic activities, fluctuations in water levels, wave effects and their flows, and rivers, have shaped the present state of its morphology (NaderiBeni et al., 2014). Climate is the most important reason for changes in the water level of the Caspian Sea (Kroonenberg et al., 2007, NaderiBeni et al., 2013a, Leroy et al., 2013). These fluctuations at sea level have different impacts on costal evolution and relatively on coastal deposits (NaderiBeni et al., 2013b).

Changes in the level of Caspian Sea waters may result from a factor or a combination of factors, such as climate change, tectonic processes, and human activity. Obviously, any change on the Caspian Sea has a direct impact on its marginal wetlands and the performance of river systems. Changes in such habitats will have a direct impact on the morphology and animal life and even the coastal economy. Moreover, considering that wetlands are usually influenced by sea and river forces, and changes in the dynamics of seas and rivers affect them, recognizing these effects and various anomalies in heavy elements when they enter the wetland and are deposited there are very important both ecologically and economically (Ranjbar, 2012). The sediments of wetlands are the main components of our environment and an important source of cadmium, organic and chemical substances that can either result from natural processes and erosion or be created by human intervention. In addition, coastal wetlands play an important role in trapping river sediments and nutrients and reducing their transmission to seas. Of course, the pattern of human activities in the use of land, such as agriculture and urban planning and the way of land use have made a lot of changes in this important issue (Bruland et al. 2010). Wetlands also play an effective role in preventing flood occurrence and act as a sedimentary slab (Kazanci et al., 2004). Since climate change and human interventions have caused many of the country's wetlands to dry out, if wetlands are studied comprehensively and properly, this environmental catastrophe can be controlled largely and the destructive effects of this process can be minimized.

Due to the environmental importance of this wetland and the Anzali area in general, various studies have been carried out in this area in recent years. For instance, Kowsari carried out semi-detailed explorations in the area in relation to titanium in the region in 1991. Shahrabi published a book on the seas and lakes of Iran in 1994 in which the significance of this wetland is also mentioned. A compilation report of the studies on water resources of the SefidRoud basin was prepared in 2001 by Gilan Regional Water Company. Other studies in this area include the geological map of Bandar-e-Anzali, prepared by Mousavi (2001) and Khabaznia et al. (2005) to better understand this water basin. Then, to complete them, Kheiri (2005) presented a report on remote sensing of the Bandar Anzali plate with special attention to the marine geology and morphology of the Caspian region. Karim Khani (2007), prepared a report on the sedimentology and sedimentary geochemistry of the sea plate of Bandar Anzali, and the latest research in this area was carried out by Ms. Hazer Meshar (2015), as a doctorate dissertation, which has not been published yet.

Despite the presence of the Fenced Lagoon inside the city of Anzali and its impact on the lives of residents around it, no comprehensive study has been carried out so far on the sedimentology of this area. Therefore, this study seeks to achieve this goal.

Geographical location and sampling points. The Fenced Lagoon (fenced lagoon) is about 240 meters in length and in the broadest place 40 meters wide at latitude 41 47 855 N and longitude 36 51 52 E and is located in the southeast of Anzali wetland and in the north of the fire department of Ghazian district and in the city of Anzali. The elevation of the lake is 24 m from the sea level, the area of the lake is 29,353 m^2 and its perimeter is 1,137 m. This area is located in the 1:100,000 Anzali rectangular maps. In the past, this wetland was part of the Caspian Sea drainage basin, which was running to the Anzali wetland through a water slab. Surface waters and seasonal and winter rainwaters flowed into the pond after crossing various areas. At present and in the summer, its water content decreases, which somewhat plays the role of the drainage of the area. The wetland is surrounded by residential houses and private estates.

For this research, after collecting the data and office studies, the wetland area was first determined using aerial photos and satellite imagery using ArcGIS software. Then the sampling points were determined according to the extent of the wetland (Fig. 1).

Materials and methods. Sampling at the surface of the wetland was carried out based on previous findings

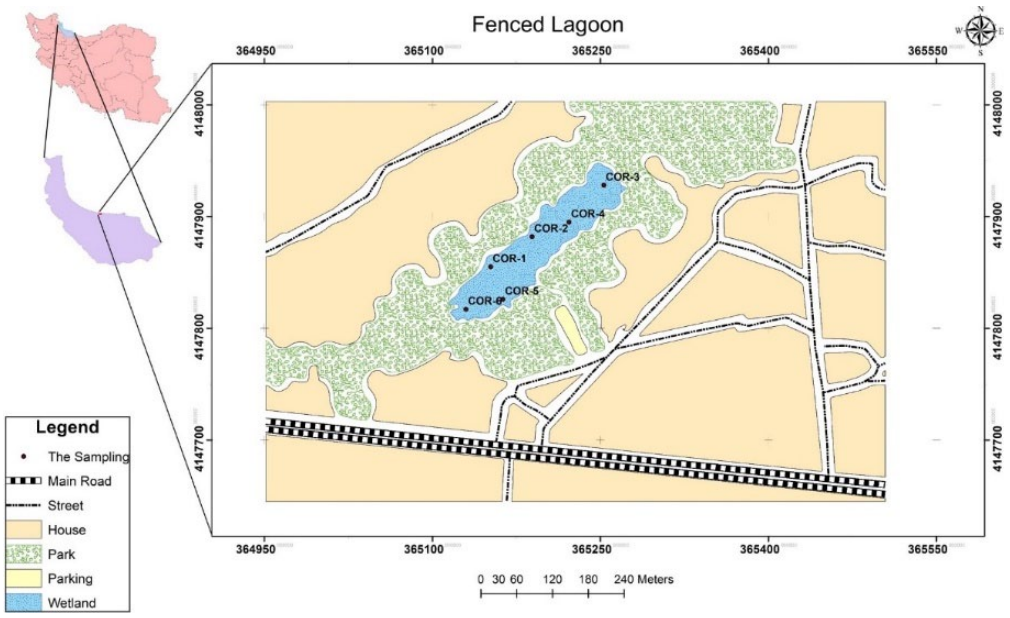

Fig. 1. Geographical location of the Fenced Lagoon and the sampling points

and data, which consisted of 33 specimens in the form of six cores, the cores were taken by polyethylene pipes, and 12 samples of the deposits in the wetland floor taken by the grab (Fig. 2).

Samples preparation. After transferring the specimens to the laboratory and freezing them, the sedimentary cores were separated from the polyethylene tubes by a stone milling machine, so that half of the core thickness was still in the tube. At this point, care must be taken to prevent the contact of metal blade of the milling machine to the cores (Fig. 3).

The specimens inside each core were separated according to colour change and sedimentation and were accumulated and numbered in individual containers. Experiments performed on the samples included gradation, hydrometry, XRF and ICP. There are several methods for measuring the diameter of the grains (Harami,2006). Dry sieve method was used in this study. After drying, the samples were weighed and dried through sieving and were graded by the shaker (Anderson,2004). The results of gradation were used to obtain the statistical factors and the comprehensive Folk (1980) drawing method was used for the particles' sedimentology such as sorting, tilting and stretching, and the population of suspension, mutation and deflection of sediments, as well as their turning point were calculated using a cumulative diagram. Then, the frequency percentage chart of the particles

Fig. 2. Coring the wetland using polyethylene pipes, and packing and recording the cores (left), and sampling by grab (right)

Fig. 3. Cutting of polyethylene pipes by means of milling machine (above) and sedimentary cores after cutting (below)

was plotted using GRADISTAT software (Blott&Pye, 2001). In the following, using Folk's (1954) method, four facial types were identified and using Rockwork software, facies columns were depicted based on the depth and this information was used to interpret and comment the sedimentary environment and their vertical and lateral changes. For gradation of clay and salt particles (below 63 microns) the hydrometric method is the best method in which the particles' diameter is obtained according to Stokes's law (Faiznia, 2008). Hydrometric experiments were carried out on 3 cores and 2 crop samples, then parameters such as creep rate, time, particle diameter and ultimately transition and cumulative percentages were calculated and diagrams were plotted based on the cumulative percentage and particle diameter in F and the results were analyzed.

After the sedimentation steps, a geochemical method was used for to analyze the samples and determine the forming oxides and to identify the minerals in the sediments. Many geochemical methods, despite the high resolution, are very time consuming and cause the waste of the sediment. Therefore, in this research, the non-destructive XRF method was used (Jansen et al., 1998; Ro¨hl and Abrams, 2000). This method is widely used in the Dutch Texel Research Institute for measuring the intensity of heavy elements (Bahr et al., 2005).

For this purpose, all 45 samples were sent to the laboratory of the Geological Survey and Mineral Exploration of Iran and the elements in the samples were analyzed. Then, using the multivariate graphs, the origin of the wetland sediments was obtained.

Discussion. ***Gradation studies.*** Grain size is one of the most important characteristics of sedimentary particles that is affected by their transfer and sedimentation (Folk & Ward, 1957). Therefore, analyzing particle size and shape gives us important clues about the origin of sediment, transport history and sedimentation conditions. Since the obtained results may not be directly comparable using different methods, and the analysis of the obtained data by using more than one method may be difficult (Pye, 1994), the obtained data and the results of 6 cores and 12 samples of grab were investigated in this research using GRADISTAT software. By determining the percentage of particles with different diameters in the described method, the sediment was named according to the Folk method (1954). Despite the low percentage of gravel in samples, since the abundance of coarse grains in sediments, even to a negligible amount, is valuable for interpreting the energy and the type of the environment (Harami, 2004), it was considered in the sediments' classification and environment determination. According to the Folk method (1954), the sediments of this lake were divided into four sedimentary types including Muddy Sand, Slightly Gravelly Muddy Sand, Sand, Slightly Gravelly Sand, and sand is the main component of all these sediments. The most abundant sedimentary types belong to Muddy Sand and Sand and the least abundant sedimentary types belong to Slightly Gravelly Muddy Sand and Slightly Gravelly Sand. The frequency of Muddy Sand is mainly seen in surface sediments up to the depth of 100 cm, while the facies type of Slightly Gravelly Muddy Sand is related to greater depths and both facies are more abundant in the north and northeast parts of the lake. By moving to the south and southwest regions of the lake, the two facies of Sand and Muddy Sand become more abundant (Fig. 4). The size of sediment particles increases as the depth decreases from northeast to southwest. Alternate layers of sand - mud and sand horizons containing shellfish represent the periods of

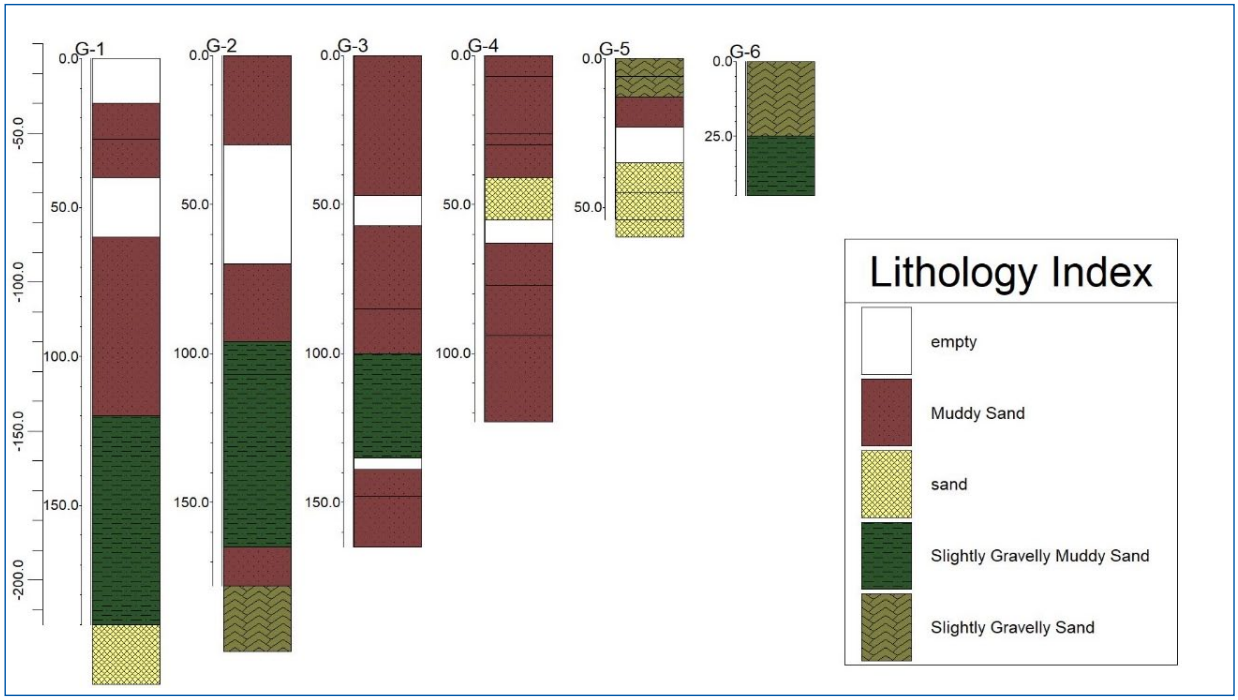

Fig. 4. Stratigraphic column of Fenced Lagoon Sediments

relaxation of the lagoon and its relationship with the sea (Ghazban, 2010).

The range of elongation in the sediments of the studied basin is between 0.63 and 1. In other words, the elongation of sediments in different cores varies from very broad to broad, medium and stretched, which is more toward broader grains indicating that the curve trail (silt, clay and gravel) has a better alignment than the middle part of the curve (Faiz Nia, 2008). In most of the rivers with bed load, it is shown that with better alignment downwards, the cumulative curve elongation increases (Harami, 2004). The majority of the samples in the basin have bad to moderate alignment (between 0.5 to 1.7). This situation usually represents the flow turbulence that is probably due to the arrival of seasonal flow of rivers into the basin (Paseban & Mahbubi, 2012). The range of tilting variations in the studied sediments varies between -0.6 and 0.3. Of these, only six samples taken with the grab have positive tilting and the rest have negative tilting. Positive tilting indicates a greater frequency of fine-grained sediments, possibly due to the presence of these particles between coarser-grained sediments (Paseban & Mahbubi, 2012). Of course, the turbulence of the feeding currents of the area, erosion and crushing of coarse-grained sediments, and unstable grains that lead to the production of smaller sediments, are also the causes of positive tilting (Rice, 1999). Negative tilting also means an increase in coarse-grained particles, which can be seen on shores where the reciprocating waves are active and fine particles are removed (Faiz Nia, 2008).

Gradation changes in this basin, including changes in grain size and changes in statistical parameters such as sorting and rounding and flattening can indicate the intensity of changes in the feeding currents of the area and lithological changes in the region. Non-continuous changes in the particles' size indicate the role of subordinate feeding branches in supplying sediment in this basin.

Geochemical studies. One of the most reliable methods to identify the source rocks and separate sediments is the use of geochemical data in the separation of the main and secondary elements. Many researchers have carried out geochemical studies to determine the origin of sediments in the wetlands, their water quality, as well as the pollutants contained in them (Amini, 2012). In the meantime, the volume of studies carried out on Anzali wetlands and its surrounding wetlands is remarkable because of its importance as an international wetland (Khzaiei, 2012).

Swamps and bays of the Caspian margin are formed under three main processes of longitudinal transmission of coastal sediment, elevation of the Caspian Sea and anticline-syncline structures (Leontiev et al., 1977), and are considered the environment of the land-to-sea transition. These environments, which are semi-closed with sandy slabs or structural complications, provide a relatively low-energy environment for sedimentation (Leeder, 1982), thus in addition to being influenced by the marine environment, they are affected by the catchment area and surrounding shores as well.

In general, geochemical data of the main and secondary elements can be used for chemical classification of rocks, determination of the prevailing weathering conditions of sedimentary rocks, separation of adult sediments from immature, determination of the source rock and the main tectonic position of igneous rocks and some sedimentary rocks (Rollinson, 1993). The study of the main elements is often limited to 10 elements, Ca, Na, K, P, Ti, Al, Fe, Mn, Mg and Si, which are conventionally expressed as oxidation in XRF chemical decomposition. Controlling processes of the elements in sedimentary rocks can be studied using the normalization diagrams similar to the spider diagrams (Rollinson, 1993).

The main part of the Caspian coastline is covered with delta, river and coastal sediments of the present day (Agha Nabati, 2006). The present sediments of the study area include the granitoid complex remains between the hardened sediments attributed to continental - sea climates of the Quaternary (Alavi, 1996). Based on geochemical similarities and previous studies ((Nazari, et al, 1995), this granitoid is comparable to Lahijan granites. This unit itself is located on older sediments, including sedimentary-deltaic facies of the sub-intertidal zone of the upper Triassic, lower Jurassic to early Cretaceous, deposited in various tectonic climates. The most ancient rocks in the area under study are also a row of destructive rocks, sandy shale and thin to middle layer sandy argilfaceae of olive green, which can be considered equal to the upper part of the Mila Formation or the middle section of the Lalun Formation (Alavi,1996). Before examining the results of the geochemistry on the commonly used charts and their interpretation, it is necessary to analyze the statistical processing of the decomposition of the main and secondary elements of the cores. As shown in the table, the mean SiO_2 content of the Fenced Lagoon sediments (61.37%) is approximately equal to the mean SiO_2 content of the continental crust (Talor&McLenan, 1985; SiO_2= 64/8). Moreover, the mean CaO content of the wetland sediment (1.4%) is about twice as much as the CaO content of the upper crust (4.19), which indicates a high amount of fine stones and carbonate cement, causing a relative reduction in SiO_2 and Al_2O_3 percentage. The amount of K_2O and Na_2O (1.55 on average) is higher than that of the continental crust, which can indicate the presence of feldspar in the samples. A higher percentage of Fe_2O_3 and MgO oxides, as compared to the upper continental crust, may also represent mafic minerals.

Since Al_2O_3 is almost unchanged during weathering, diagenesis and transformation, it can be used as an appropriate factor for comparison with other major elements. Therefore, in order to investigate the geochemical position of the main and rare elements in the sand and mud sediments of the Fenced Lagoon, the frequency diagrams of the oxides of the main elements have been used against Al_2O_3 (Afarin, 2012). The changes trends of the oxides of the main and trace elements against Al_2O_3 indicate that the sediments under study can be classified into two general groups of sand and mud. In Figure 5, the relationship between Al_2O_3 and K_2O, Fe_2O_3, MgO, TiO_2 and SiO_2 is positive and it does not show a significant relationship with MnO, CaO, Na_2O, K_2O and P_2O_5. The positive relationship between Al_2O_3 and Fe_2O_3 and K_2O can be due to the presence of these elements in clay and mica minerals (Mclennan et al., 1993; Jin et al., 2006). Furthermore, K_2O can represent a rich aluminum phase, especially illite, or concentration of potassium minerals in samples (Lee, 1999; Das et al, 2006). Since the amount of clay in stone background is low in sand samples, the K_2O content is probably related to clay minerals found in shale specimens. The positive association of Al_2O_3 and SiO_2 indicates the presence of feldspar and mica and clay minerals. Increasing TiO_2 with Al_2O_3 indicates the association of TiO_2 or phyllosilicates, especially illite (Dabard, 1990). High percentage of CaO indicates that the samples can contain carbonate, and calcite, in particular. A relatively high proportion of K_2O / Na_2O (especially in shale) can be attributed to the presence of albicagmatic plagioclase, feldspar potassium of mica and illite (Pettijohn et al., 1963, Mclennan et al., 1993, Nath et al., 2000).

The main elements during weathering, transport and diagenesis can be used to determine the degree of maturation of sediments (Maclennen, 1993). A low amount of Na_2O in the studied sandstone can be attributed to their high maturity. In addition, the SiO_2 / Al_2O_3 ratio is also an indicator used to determine maturity. This amount increases during weathering, transport and re-cycling as a result of quartz increase over unstable parts such as feldspar and rocky parts. A greater proportion of 5 to 6 in sediments and sedimentary rocks represents the high maturity of sediment or rock. (Roser et al., 1996) The average of this fraction in the studied samples is less than one, which indicates the immaturity of these sediments; this is also characterized by high Na_2O content.

Source Rock. Geochemistry of sediments can play an important role in determining the source and mother rock and climatic conditions of sediments. The analysis of secondary elements, as well as major oxides such as Al_2O_3 and TiO_2, is very important for

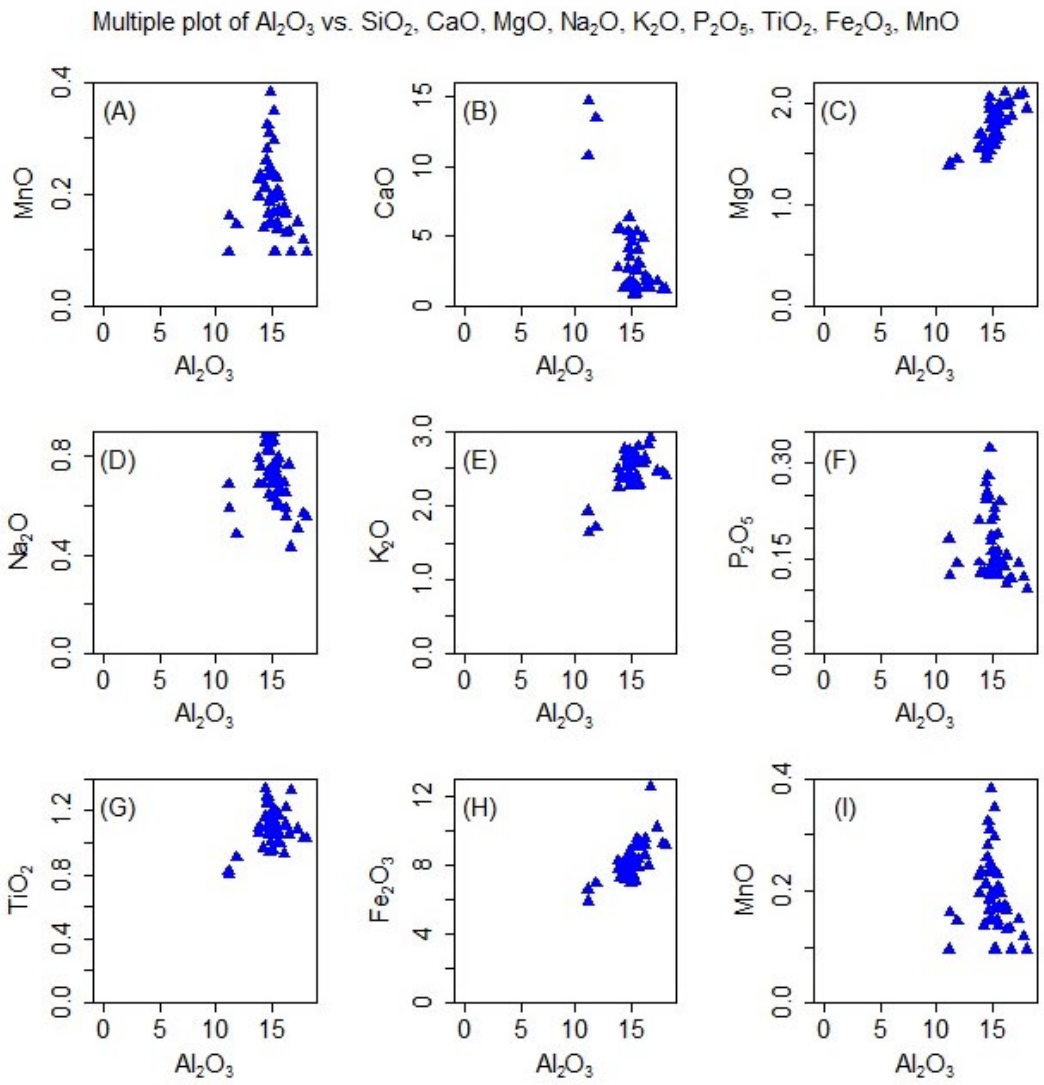

Fig. 5. Chart of changes of some of the oxides of the main and secondary elements against the weight percent of Al2O3 in order to study the geochemical status of the main and rare elements in the Fenced Lagoon sediments (Harker, 1909)

the interpretation of sediments (Katemaunzanga and Gunter, 2009; Maslov et al., 2011). For example, trace elements such as barium, lanthanum, vanadium, zirconium in sediments provide researchers with important information about mother rock of the sediments, and using different techniques such as the use of triangular and dual diagrams can provide useful information on wetlands (Lak, 2015).

In this regard, many classifications can reveal the origin of deposits. For example, Maynard et al., 1982; Bhatia, 1983; Bhatia & Crook, 1986; Roser&Korsch, 1986 ; the methodology used for this study is presented by Roser&Korsch (1988), which helps us recognize four kinds of sediments origins in four different zones including mafic, intermediate, felsic and depositional quartz. These diagrams are obtained from the total oxides of Ti, Al, Fe, Mg, Ca, Na and K. The advantage of using this method is that one can ignore the percentage of biogenic SiO_2 and CaO and consider the percentage of the oxide of other elements against Al_2O_3 while using these diagrams to determine the source (Roser&Korsch, 1986).

With respect to (Fig. 6), the obtained samples show a gradual transition from mafic to intermediate igneous origin. Samples containing shale are well plotted in mafic zone (Roser&Korsch 1988). It seems that the ratio of Al_2O_3 / TiO_2 in shale is similar to that of source rocks and can therefore be used as an indicator of origin. (Hayashi, 1997). Hayashi et al insist that a ratio of above 21 could indicate the felsic origin. This average in our research was between 16.93 and 20.67, which could indicate the origin of the combination of mafic to intermediate.

It should be added that the distribution of metal elements in sediments around the Caspian Sea region suggests that, in some cases, such as barium, their concentration is more than the amount in the ground, which indicates their entry through human activities, although most of them are supplied through destructive deposits of the watershed (Lahijani, 2002). Com-

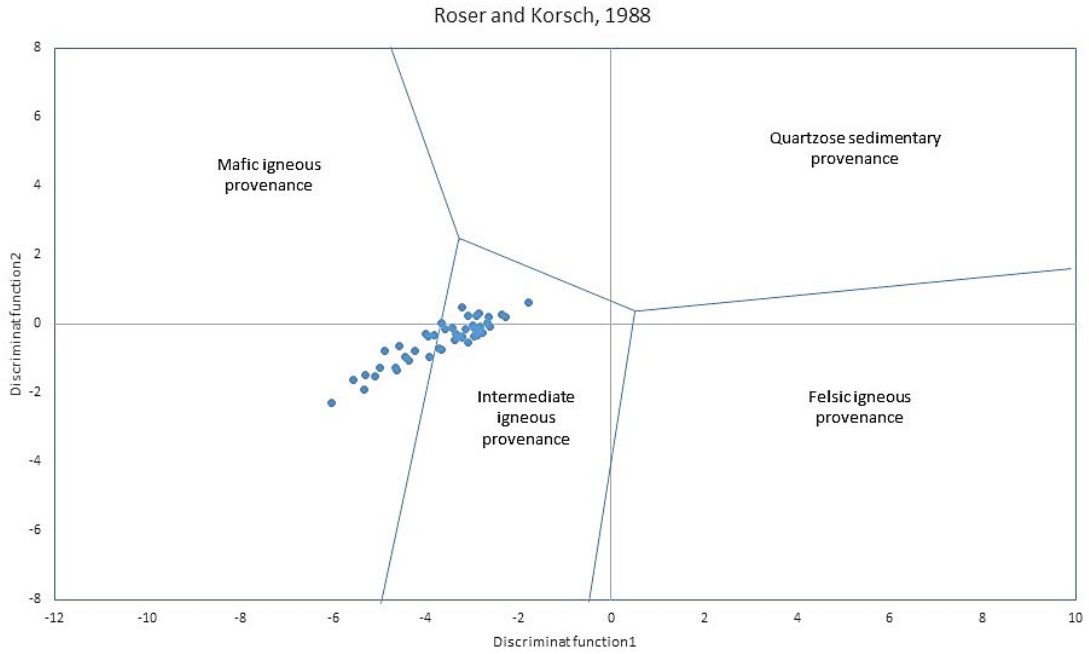

Fig. 6. Locating the samples taken from the Fenced Lagoon on the chart Roser&Korsch (1988)

Discriminant function I = –1.773 TiO_2 + 0.607 Al2O_3 + 0.76 Fe_2O_3(total) –1.5 MgO + 0.616 CaO + 0.509 Na_2O – 1.224 K_2O – 9.09;

Discriminant function II = 0.445 TiO_2 + 0.07 Al_2O_3 – 0.25 Fe_2O_3(total) – 1.142 MgO + 0.438 CaO + 1.475 Na_2O + 1.426 K_2O – 6.861.

parison of metal composition of surface sediments with deep sediments of the same area in terms of chemical composition can indicate the geochemical background of the region (Karageorgis et al., 2006. Buccolieri et al., 2006. Muller, 1979. Adams et al., 1992).

Tectonic Location. Determination of tectonic location is influenced by factors such as sedimentation, diagenesis and initial composition of sediment (Pettijohn et al., 1987; Bhatia, 1983; Chamley, 1990). Therefore, the main elements of the sand can be used to determine their tectonic position (Bhatia, 1983; Von Eynatten, 2003; Armstrong-Altrin &Verma 2005; Al-Juboury et al., 2009;Sahraeyan & Bahrami, 2012 As shown in Fig. 7, based on changes in the values of the main elements, the cranial rocks of oceanic arch islands,, continental arch islands, active continental margin, and passive margin can be separated from each other. In the Roser & Korsch (1986) diagram, major oxides of SiO_2, Al_2O_3, Na_2O and K_2O are used to determine the long-standing tectonic location of sediments. With regard to Fig. 7, it appears that the Fenced Lagoon sands are more oriented to the continental arch islands. The reason for the displacement of the samples in relation to the determined limits can be the presence of Fe_2O_3 and MgO oxides. The presence of some Al_2O_3 can be due to the presence of particles containing iron and magnesium phyllosilicates.

In general, the summary of the graphs used to study the tectonic position of sedimentary rocks suggests that the sediments of the studied area are located in the continental arch islands and, to a lesser extent, in the active continental margin. The existence of a stable tectonics in the region has resulted in relatively regular geochemical data accumulation (Adabi, 2011). Therefore, with regard to petrographic and tectonic-stratigraphic evidence of the sediments in the region it can be concluded that these sediments have been deposited near the source. Geochemical study of surface sediments of the region indicates that there is a good correlation between frequency of elements and gradation and mineralogy in some elements. In fact, the destructive origin of sediments is the main contributor to the distribution of elements, especially heavy metals in the bed, and the anomaly of the concentration of the elements is mainly dependent on the mud blasters and the penetration of groundwater from the bed (Glazovski et al,. 1991, Brusilovskii and Turuchkina 1974).

Conclusion. Sedimentary and geochemical studies of destructive deposits of the Fenced Lagoon were carried out to identify the source rock and tectonic location and the following results were obtained. Sediments of this lake were divided into four sedimentary types including Muddy Sand, Slightly Gravelly Muddy Sand, Sand, and Slightly Gravelly Sand, and sand is the main component of all these sediments.

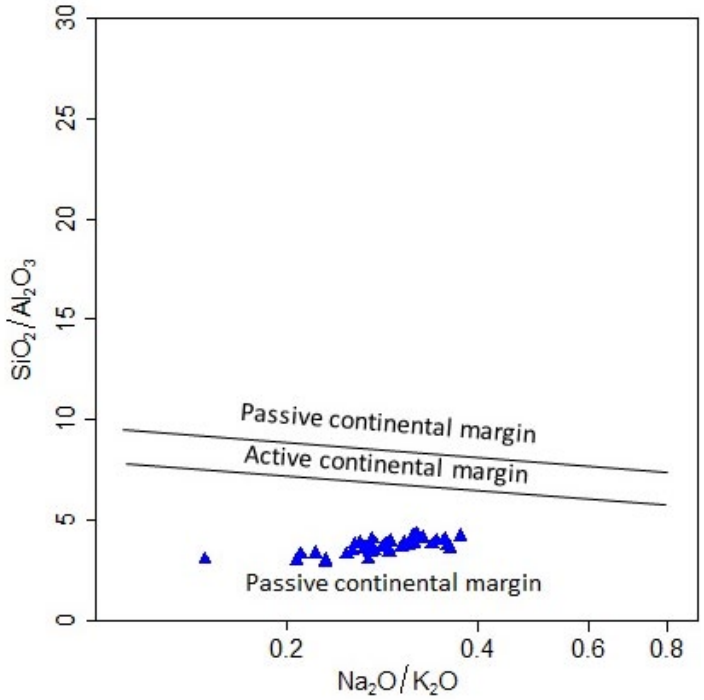

Fig. 7. The composition diagram of the main elements of the Fenced Lagoon sediments to determine the tectonic location of the deposits. Bhatia, 1983; Roser&Korsch, 1986

The most abundant sedimentary types belong to Muddy Sand and Sand and the least abundant sedimentary types belong to Slightly Gravelly Muddy Sand and Slightly Gravelly Sand. The frequency of Muddy Sand is mainly seen in surface sediments up to the depth of 100 cm, while the facies type of Slightly Gravelly Muddy Sand is related to grater depths and both facies are more abundant in the north and northeast parts of the lake. By moving to the south and southwest regions of the lake, the two facies of Sand and Muddy Sand become more abundant. The size of sediment particles increases as the depth decreases from northeast to southwest. Alternate layers of sand - mud and sand horizons containing shellfish represent the periods of relaxation of the lagoon and its relationship with the sea (Ghazban, 2010). The changes in trends of the oxides of the main and trace elements against Al_2O_3 indicate that the sediments under study can be classified into two general groups of sand and mud. A review of the charts to determine the nature of the origin rock suggests that the sediment samples of the Fenced Lagoon fall into different ranges of mafic and felsic origin rock, that is, they have acidic to intermediate combination.

The survey of the total graphs used to study the tectonic position of the sediments indicates that the sediments of the studied area are located in the continental arch islands, and to a lesser extent, the active continental margin.

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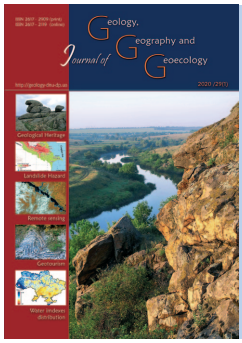

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The analysis of time series of river water mineralization in the Dnipro basin with the use of theoretical laws of random variables distribution

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Abstract. The analysis of current scientific work on the use of statistical methods in hydrochemical research has shown that this approach is sufficiently substantial, both in Ukraine and abroad. The purpose of this work is to determine the main statistical parameters and to research the possibility of applying theoretical laws of distribution to the time series of water mineralization.This research presents the results of the application of standard statistical methods of hydrometeorological information processing for data on water mineralization at 28 gauges of the Dnipro basin (within Ukraine) for the period from 1990 to 2015. The dynamics of the obtained statistical parameters (long-term annual average, coefficients of variation, asymmetry and autocorrelation) within the Dnipro basin in Ukraine has been analyzed. The average annual values of mineralization vary substantially within the studied part of the Dnipro basin - in the northern part the maximum value of the annual average mineralization is 447 mg/l, as it moves to the south, the mineralization increases and in the sub-basin of the Middle Dnipro it reaches a maximum of 971 mg/l; the highest values are observed in the south (sub-basin of the Lower Dnipro), where they can reach extremely high values for particular small rivers (the Solon River - Novopavlivka village, 3356 mg / l). The long-term variability of mineralization in the rivers of the studied area is insignificant, and the autocorrelation coefficients of the mineralization series are quite high, in most cases they are significant and tend to decrease from the sub-basin of the Prypyat' river in the north to the sub-basin of the Lower Dnipro river in the south. Within the framework of the presented research, the possibility of using theoretical distribution curves known in hydrology to describe the series of river mineralization, using the example of the Dnipro basin, has also been analyzed. Using Pearson's fitting criterion, the Pearson type III distributions and the three-parameter distributions by S.M.Krytsky and M.F.Menkel have been verified on their correspondence with the empirical series of mineralization. As a result, it was found that in 85% of cases the Pearson type III distribution can be used, and the three-parameter by S.M.Krytsky and M.F.Menkel can be used in 60% of cases.

Keywords: mineralization, statistical parameters, distribution laws.

Аналіз часових рядів мінералізації води річок у басейні Дніпра з використанням теоретичних законів розподілу випадкових величин

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Анотація. Аналіз сучасних наукових робіт щодо використання статистичних методів у гідрохімічних дослідженнях показав, що такий підхід достатньо обґрунтований, як в Україні, так і за кордоном. Мета даної роботи – визначити основні статистичні параметри та дослідити можливість застосування теоретичних законів розподілу до часових рядів мінералізації. В представленому дослідженні наведені результати застосування стандартних статистичних методів обробки гідрометеорологічної інформації для даних спостережень за мінералізацією води на 28 постах басейну Дніпра (у межах України) за період з 1990 по 2015 роки. Проаналізовано динаміку отриманих статистичних параметрів (середніх багаторічних значень, коефіцієнтів варіації, асиметрії та автокореляції) в межах басейну Дніпра на території України. Середні річні значення мінералізації суттєво змінюються в межах досліджуваної частини басейну Дніпра - у північній частині максимальне значення середньобагаторічної мінералізації дорівнює 447 мг/л, із просуванням на південь мінералізація збільшується, і вже у суббасейні Середнього Дніпра її максимум досягає 971 мг/л; найбільші значення спостерігаються на півдні (суббасейн Нижнього Дніпра), де можуть досягати екстремально високих значень для окремих малих річок (р. Солона – с. Новопавлівка, 3356 мг/л). Багаторічна мінливість мінералізації в річках досліджуваної території незначна, а коефіцієнти автокореляції рядів мінералізації доволі високі, у

більшості випадків вони є значущими та мають тенденцію до зменшення від суббасейну Прип'яті на півночі до суббасейну Нижнього Дніпра - на півдні. В рамках представленого дослідження також проаналізовано можливість застосування відомих у гідрології теоретичних кривих розподілу для опису рядів мінералізації річок, на прикладі басейну Дніпра. З використанням критерію згоди Пірсона, перевірено розподіли Пірсона III типу та трипараметричний С.М. Крицького і М.Ф. Менкеля на їх відповідність емпіричним рядам мінералізації. В результаті виявлено, що у 85 % випадків можна використовувати розподіл Пірсона III типу, а трипараметричний С.М. Крицького і М.Ф. Менкеля – у 60 % випадків.

Ключові слова: мінералізація, статистичні параметри, закони розподілу

Introduction. Hydrochemical indicators of river water and, in particular, mineralization, are formed under the influence of natural and anthropogenic factors, due to the complex processes that occur during the daily, seasonal, annual and secular periods. The influence of each factor on the formation of mineralization cannot be taken into account unambiguously, so this process can be considered stochastic or probabilistic. In this case, taking into consideration that the samples of hydrochemical characteristics are random variables, there is a basis for the use of mathematical statistics in the study of the processes of formation of hydrochemical parameters of rivers.

This approach is used in Ukraine by scientists of the Ukrainian Hydrometeorological Research Institute (Kovalchuk et al., 2008; Osadchiy and Kovalchuk, 2013), in particular, to divide the magnitude of hydrochemical concentrations into natural and anthropogenic components based on theoretical distribution laws. In the foreign literature such an example can be found in the work of Chinese scientists (Yang and Jian-Ying, 2017), who investigated the possibility of using empirical distribution curves to analyze the concentration of chemicals in the water runoff of the river in different phases of water and for values of probability. The use of multidimensional statistical analysis by the scientists of different countries is also noteworthy, for example, for the geochemical assessment of groundwater quality in Côte d'Ivoire (Guler et al., 2002), or the use of the principal component method for the study of the territory salinity in Spain (Morell et al., 1996). Among the recent works the studies by scientists from India on the hydrochemical composition of groundwater in different parts of the country (Reghunath et al., 2002; Umarani et al., 2019) using cluster and factor analysis are also worth noting.

The purpose of this work is to determine the main statistical parameters and to research the possibility of applying theoretical laws of distribution to the time series of water mineralization of rivers in the Dnieper basin (within Ukraine).

Output data. The research was carried out on the basis of data from the State Surface Water Survey, carried out by the State agencies for water resources management of the Civil Protection Department of the Ministry of Emergency Situations of Ukraine. For determination of statistical regularities and distribution laws, the data of mineralization observations at 28 gauges of the Dnieper basin (Fig. 1) for the period from 1990 to 2015 has been selected (1990-2015, Shchorichni dani). The boundary of the study area of the Dnieper basin coincides with the state border between Ukraine and Belarus and Ukraine and Russia.

Research methods. When performing hydrological calculations, one of the main tasks is to determine the probabilistic properties of a random variable on the basis of distribution laws. Each random distribution law is a mathematical function that fully describes a random variable from a probabilistic point of view. In practice, it is not necessary to consider the law of distribution as a mathematical expression, it is sufficient to indicate individual numerical characteristics that reflect its main features (1997, Rukovodstvo).

Specific statistical methods have been developed to estimate statistical parameters on a sample basis. The method of statistical moments is the most universal, it is not related to any theoretical law of distribution. In hydrological calculations methods of determining statistical parameters based on certain distribution laws are also used. These methods include the highest-likelihood method, the calculation formulas of which are derived from a three-parameter gamma distribution, and a graph-analytic method that uses theoretical distribution laws (most often Pearson III and log-normal).

The number of statistical parameters used in a theoretical distribution law should not be large. The world experience shows that in calculating runoff, the most optimal in terms of practical application are those theoretical laws of distribution, which require two or three statistical parameters for description – such as mathematical expectation, dispersion and the coefficient of variation dependent on it, distribution asymmetry characteristics.

In modern hydrometeorology, as a rule, the three most common methods of determining statistical parameters are used – method of moments, method of greatest plausibility and graph-analytical method. The calculations are performed on the basis of hydrological series (Hopchenko et al., 2014; Shkolnyi et al., 1999),

but in this research it is proposed to use time series of mineralization as the initial data.

Results and their analysis. The authors have obtained statistical characteristics for the series of measured mineralization values for the long-term period from 1990 to 2015 with the help of the software "StokStat 1.2 - Statistics for hydrology" (http://www.geodigital.ru/soft_hydr), such as: the average value of the series of total mineralization and relative average squared deviation of arithmetical mean value σ; coefficient of variation C_v; the C_s asymmetry coefficient of C_s/C_v ratio, as well as the autocorrelation coefficient (Table 1).

The analysis of Table 1 shows that the length of the series of river water mineralization in the subbasin of the Prypyat' varies from 132 (the Ubort' –Perga village) to 185 values (the Styr – Lutsk). Average values of ions over a multi-year period range from 368 mg/l (the Stokhid – urban settlement Liubeshiv) to 442 mg/l (the Styr – Lutsk), accurate to the average value calculating from 1.08% to 1.60%; maximum deviations are noted in the gauge of the Ubort'–Perga village with the value = 339 mg/l at σ = 3.17%, as well as at the gauge the Uzh – Korosten city, where = 232 mg/l at σ = 2.05%. In most gauges, the value of C_v is 0.14-0.19, and in the gauges of the Uzh – Korosten city and the Ubort'–Perga village it is 0.26 and 0.36 respectively. The C_s value varies from 0.57 to 1.15, the C_s/C_v ratio ranges from 4.0 to 4.4.

For the Desna subbasin, the length of the series ranges from 97 (the Seim – Mutin village) to 204 values (the Desna – Chernihiv). Average values of ion sums within for a multi-year period range from 300 mg/l (the Snov – Shchors village) to 447 mg/l (the Seim –Mutin village), with the accuracy of calculating of the average value of σ from 1.06% to 2.11%. The C_v value makes 0.15-0.23. The value of C_s varies from 0.37 to 0.30, the ratio varies from 2.4 to 1.6.

The diagrams in the Fig. 2 represent a more evident characteristic of the distribution of statistical parameters of mineralization within the basins. Thus, in the Prypyat' basin (Fig. 2a), the average value of mineralization tends to decrease towards the west, where the upper river is, to the southeast, towards the Uzh basin. Naturally, the dynamics of the coefficients of variation have the opposite direction - the highest values are characteristics of the basins of the Ubort' and the Uzh. The number of samples varies slightly by

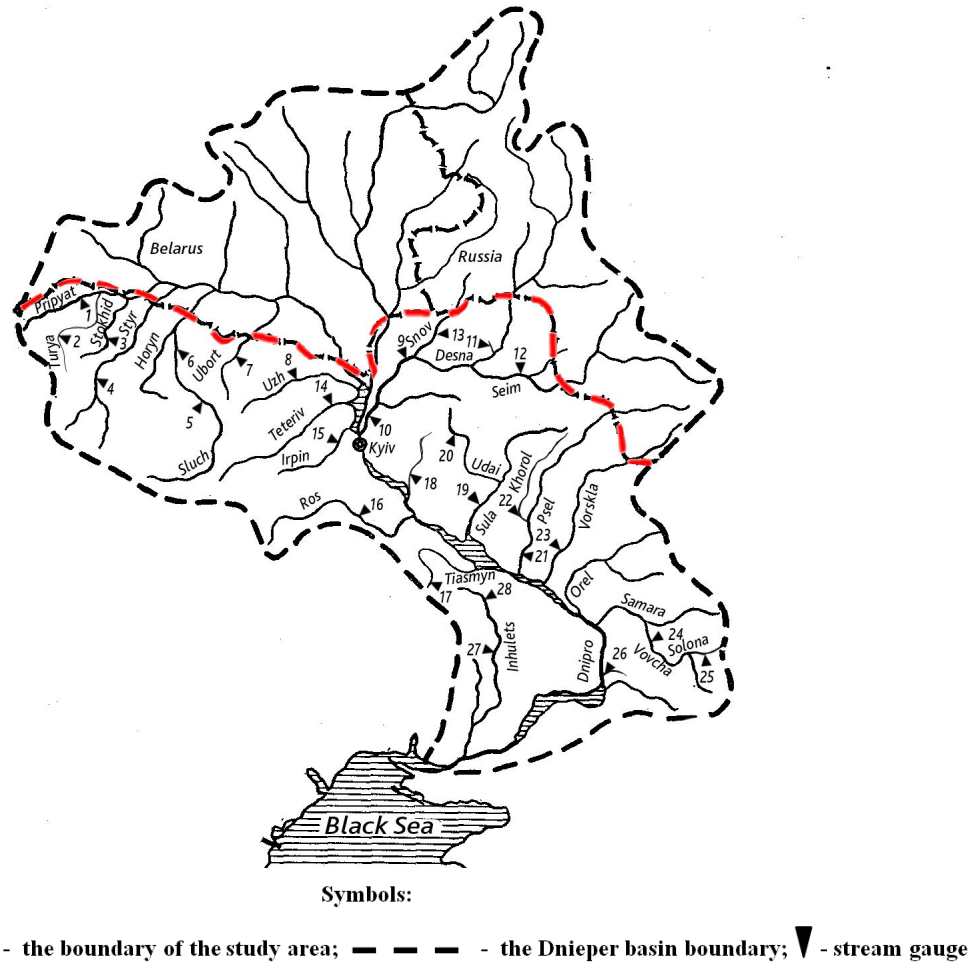
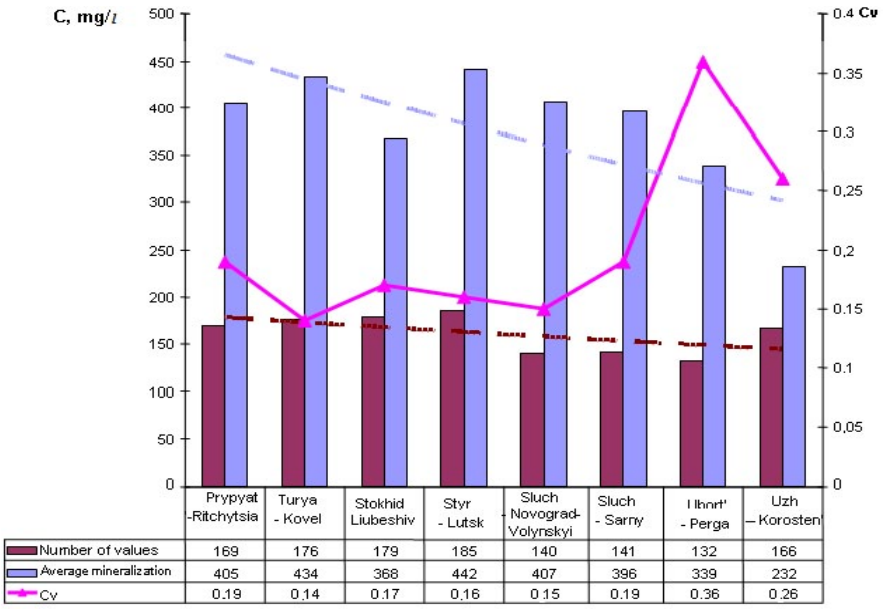


Fig. 1. Map-diagram of the observation gauge locations in the Dnipro basin (within Ukraine), mineralization data of which has been used in the research

Table 1. Statistical characteristics of the general mineralization series of water bodies in the Dnipro river basin for the period 1990-2015.

№ of gauge on the map	River-gauge	Number of values *n*	Period average value $\overline{C}$, mg/l	Coefficient of variation C_v	Asymmetry coefficient C_s	C_s/C_v	relative average squared - deviation of arithmetical mean value $\sigma = \frac{100\tilde{N}_v}{\sqrt{n}}$	auto-correlation coefficient r(1)
Subbasin of the Prypyat' river								
1	The Prypyat'- Ritchytsia village	169	405	0.19	0.71	3.7	1.48	0.36
2	The Turya – Kovel city	176	434	0.14	-0.57	-4.0	1.08	0.45
3	The Stokhid – urban settlement Liubeshiv	179	368	0.17	-0.06	-0.4	1.26	0.47
4	The Styr – Lutsk city	185	442	0.16	0.012	0.07	1.19	0.28
5	The Sluch - Novograd-Volynskyi city	140	407	0.15	-0.14	-0.9	1.28	0.51
6	The Sluch - Sarny	141	396	0.19	0.24	1.3	1.60	0.50
7	The Ubort'- Perga village	132	339	0.36	-0.04	-0.1	3.17	0.66
8	The Uzh – Korosten' city	166	232	0.26	1.15	4.4	2.05	0.19
	Average	**161**	**378**	**0.20**	**0.16**	**0.51**	**1.64**	**0.43**
Subbasin of the Desna river								
9	The Desna – Chernigiv city	204	372	0.15	-0.37	-2.4	1.06	0.38
10	The Desna –Litky village	189	374	0.16	-0.23	-1.5	1.15	0.33
11	The Golovesnia – Pokoshechi village	120	398	0.23	-0.05	-0.2	2.11	0.46
12	The Seim –Mutyn village	97	447	0.19	0.00	0	1.93	0.08
13	The Snov –Shchors village	110	300	0.19	0.30	1.6	1.76	0.19
	Average	**144**	**378**	**0.18**	**-0.07**	**-0.50**	**1.60**	**0.29**
Subbasin of the Middle Dnipro								
14	The Teteriv –Ivankiv village	92	373	0.18	1.21	7.1	1.85	0.26
15	The Irpin - Gostomel village (Mostyshche village)	171	476	0.13	-0.03	-0.2	0.99	0.21
16	The Ros' – Korsun'-Shevchenkivskyi city	92	531	0.13	-0.20	-1.5	1.35	0.24
17	The Tiasmyn –Velyka Yabkunivka village	105	699	0.20	0.14	0.7	1.91	0.29
18	The Trubizh – Pereryaslav-Khmelnytskyi city	179	610	0.12	-0.06	-0.5	0.90	0.09
19	The Sula – Lubny	177	807	0.19	0.72	3.8	1.43	0.31
20	The Udai – Pryluky city	87	831	0.18	-0.32	-1.8	1.91	0.01
21	The Psel – village Zapsillia	101	712	0.17	-0.03	-0.2	1.66	0.01
22	The Khorol – Myrgorod city	106	971	0.25	1.06	4.3	2.34	0.46
23	The Vorskla – Kobeliaky city	168	785	0.18	0.34	1.9	1.41	0.08
	Average	**128**	**680**	**0.17**	**0.28**	**1.36**	**1.58**	**0.20**
Subbasin of the Lower Dnipro								
24	The Vovcha – urban settlement Vasylkivka	170	3305.0	0.15	-0.31	-2.04	1.17	0.33
25	The Solona – Novopavlivka village	159	3356.0	0.18	-0.19	-1.06	1.43	0.33
26	The Mokra Moskovka – Zaporizhia city	172	1377.0	0.26	0.79	3.04	1.98	0.28
27	The Ingulets –Sadove village	103	357	0.11	5.00	45.45	1.08	0.06
28	The Ingulets – Kryvyi Rih city	171	1524.8	0.35	0.96	2.74	2.68	0.43
	Average	**155**	**1984**	**0.21**	**1.25**	**9.63**	**1.67**	**0.29**
Average for sub-basins		**145**	**772**	**0.19**	**0.36**	**2.26**	**1.61**	**0.29**
Average for the Dnieper River		**144**	**479**	**0.19**	**0.13**	**0.46**	**1.61**	**0.30**

a)



b)

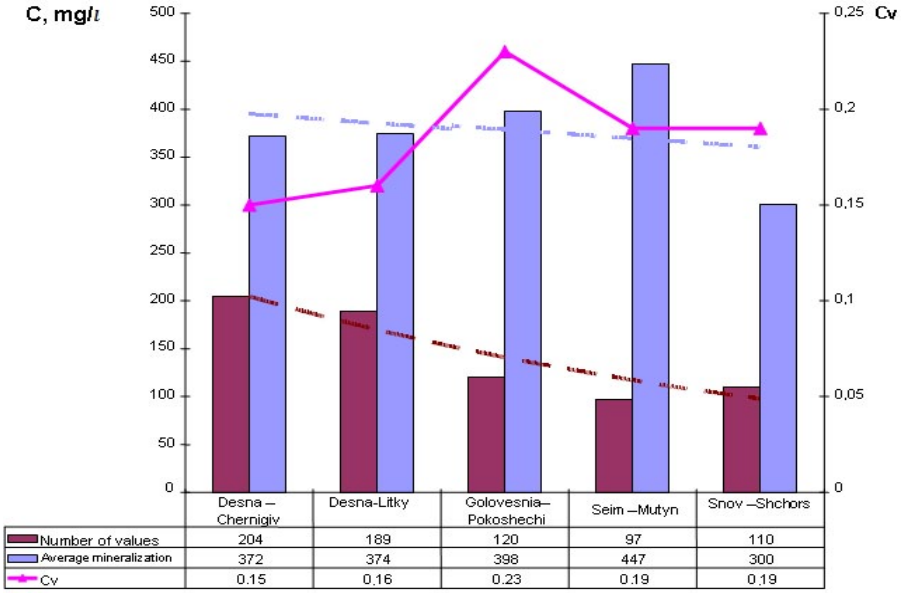


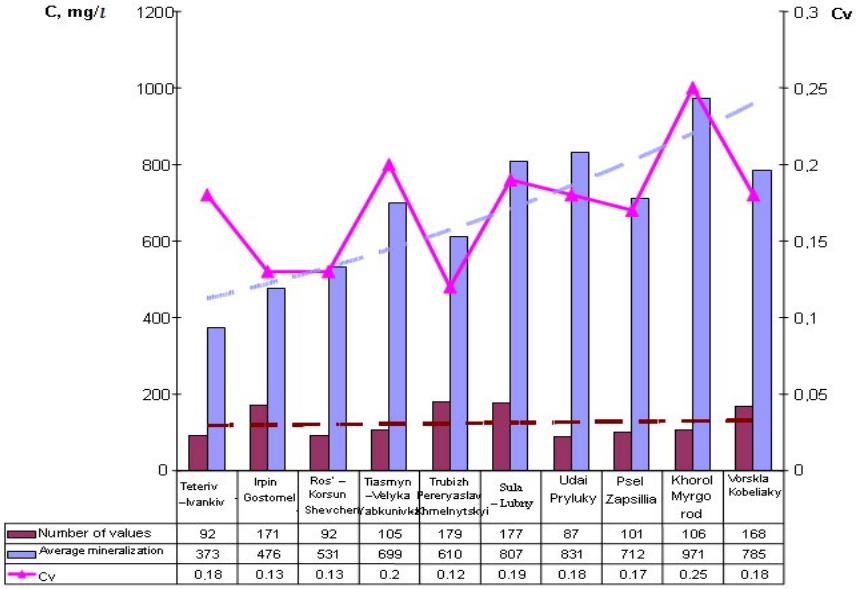
Fig. 2. Diagrams of statistical parameters of water mineralization in the Prypyat' (a) and the Desna (b) river basins.

the pool. In the Desna basin the situation is different - mineralization does not change substantially across the territory, with some deviations in the Seim river basin; the number of samples decreases remarkably from the Desna to the Seim, and the coefficient of variation increases (Fig. 2b).

In the subbasin of the Middle Dnieper the length of mineralization series changes from 87 (the Udai – Pryluky city) to 179 values (the Trubizh - Pereyaslav-Khmelnytskyi). The average values of the total sum of ions for the investigated period increase from the west to the south east from 373 mg/l (the Teteriv – urban settlement Ivankiv) up to 971 mg/l (the Khorol – Myrgorod), with the fluctuation of relative standard deviation σ from 0.9 % to 2.34% (Table 1, Fig. 3a).

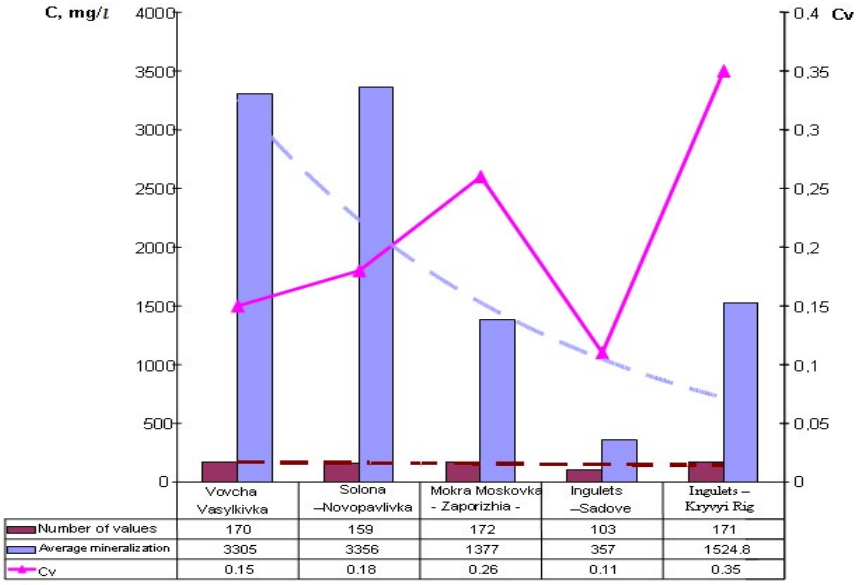
At the gauge of the Irpin – urban settlement Gostomel, the Trubizh - Pereyaslav-Khmelnytskyi city and the Ros - Korsun-Shevchenkivskyi city the values C_v equal 0.12-0.13; at the gauges of the Teteriv – urban settlement Ivankiv, the Sula – Lubny city, the Udai – Pryluky city, the Psel - Zapsillia village and the Vorskla – Kobeliaky city, the values of C_v fluctuate between 0.17-0.19; the highest values of C_v are marked along the cross-sections of the Tiasmyn - Velyka Yablunivka village and the Khorol - Myrgorod city and make respectively 0.20 and 0.25 (Fig. 3a), so that there is a slight tendency to increase in the same direction as mineralization values. The values of asymmetry coefficients C_s vary at the most wide range - from -0.03 (the Irpin – urban settlement Hostomel

a)



	Teteriv –Ivankiv	Irpin Gostomel	Ros' – Korsun Shevchen	Tiasmyn –Velyka Dabkunivka	Trubizh Pereryaslav Khmelnytskyi	Sula – Lubny	Udai Pryluky	Psel Zapsillia	Khorol Myrgorod	Vorskla Kobeliaky
Number of values	92	171	92	105	179	177	87	101	106	168
Average mineralization	373	476	531	699	610	807	831	712	971	785
Cv	0.18	0.13	0.13	0.2	0.12	0.19	0.18	0.17	0.25	0.18

b)



	Vovcha Vasylkivka	Solona –Novopavlivka	Mokra Moskovka - Zaporizhia -	Ingulets –Sadove	Ingulets – Kryvyi Rig
Number of values	170	159	172	103	171
Average mineralization	3305	3356	1377	357	1524.8
Cv	0.15	0.18	0.26	0.11	0.35

Fig. 3. Diagrams of statistical parameters of water mineralization in the subbasins of Middle (a) and Lower Dnipro (b).

and the Psel –Zapsillia village) to 1.21 (the Teteriv – urban settlement Ivankiv), and the C_s/C_v ratio varies accordingly from -0.2 to 7.1.

Considering the subbasin of the Lower Dnipro, it can be noted that the length of the series of mineralization observations here ranges from 159 (the Solona – Novopavlivka village) to 172 values (the Mokra Moskovka – Zaporizhia city), and only at the Ingulets point - Sadove village it makes 103 values. The average values of the sum of ions vary from 3356 mg/l (the Solona – Novopavlivka village) to 357 mg/l (the Ingulets – Sadove village) over the perennial period, with the accuracy of the average value σ 1.08% - 2.68% (Table. 1, Fig. 3b), i.e. there was a decrease in mineralization from the northeast to the southwest.

The C_v values for the series of mineralization of the Lower Dnipro rivers vary from 0.11 - 0.35; the value of C_s ranges from -0.31 to 0.96, with the exception of the Ingulets – Sadove village, where the asymmetry coefficient is 5.00; the C_s/C_v ratio varies from -2.04 to 3.04, and for the Ingulets point - Sadove village reaches 45.45. Such a significant difference in all indicators for the Ingulets – Sadove village can be explained by the influence of the Dnipro waters, which flow down the river channel 75 km upstream (Khilchevskyi et al., 2012).

Table 1 also shows the average values of statistical characteristics for sub-basins and their averaged values for all basins. In this case, the average mineralization for a basin is equal to 772 mg/l, but this value will not be correct, because the small and

medium-sized rivers of the sub-basin of the Lower Dnipro have an average mineralization of 1984 mg/l, which is a feature of the small rivers of the Black Sea and Azov Sea region, but it does not correspond to the mineralization of the Dnipro itself in its lower flow. This situation can be explained by a small influence of the inflow of rivers of the Lower Dnipro on the runoff of the Dnipro River. Therefore, the average values of these rivers can be ignored in calculations, and the average mineralization of the Dnipro River can be calculated using its large tributaries in the upper and middle parts of the basin. Thus, the average mineralization for the Dnipro River (within Ukraine) can be accepted at the level of 479 mg/l , the average value of C_v is 0.19; the C_s / C_v ratio can be averaged as 0.5 and the autocorrelation coefficient is 0.30. The obtained values correspond well with the data on the mineralization of the main rivers of Ukraine presented in the paper (Khilchevskyi et al., 2018), where, according to the authors' calculations, the average mineralization of the Dnipro River is 488 mg/l, and the mineralization of the Black Sea and Azov region rivers is at the level of 2200 mg/l .

The analysis of the dynamics of variability and the autocorrelation coefficients throughout the Dnipro basin (within Ukraine) are also of interest. As well illustrated in the Fig.4, the variation of mineralization within the considered territory is insignificant, the correlation coefficient of the trend line is not significant. On the other hand, the autocorrelation coefficients have a significant tendency to decrease from the subbasin of the Prypyat' to the Lower Dnipro.

The second stage of the research was checking of the series of general mineralization for compliance with the Pearson type III distributions and the three-parameter distributions by S.M.Krytsky and M.F.Menkel, the results of which are presented in the Table 2.

The analysis of the Table 2 shows that the series of mineralization during the study period at all the investigated gauge in the subbasin of the Prypyat' River, except for the gauge the Ubort' – Perga village, correspond to the the Pearson type III distributions and the three-parameter distributions by S.M.Krytsky and M.F.Menkel according to the fitting criterion $\chi^2(\alpha,\nu)$ at $\alpha = 0.05$ and $\nu = 7$. The series of mineralization of the Ubort' gauge – Perga village does not comply with any of the studied distribution laws. This can be explained by the fact that this series has the highest temporal variability and the highest autocorrelation coefficient, that is, the internal regulation of the series is not well described by the selected distribution laws.

In the subbasin of the Desna, the mineralization series at all the investigated gauges correspond to the Pearson type III distribution law and the three-parameter distribution by S.M.Krytsky and M.F.Menkel according to the fitting criterion $\chi^2(\alpha,\nu)$ at $\alpha = 0.05$ and $\nu = 7$, apart from the Golovesnia gauges – Pokoshychi village and the Snov – Shchors village, where the values $\chi^2 > \chi^2(\alpha,\nu)$, that is the series of mineralization during the studied period do not correspond to the law of distribution by S.M.Krytsky and M.F.Menkel (Table 2).

In the subbasin of the Middle Dnipro, the series of mineralization during the studied period correspond

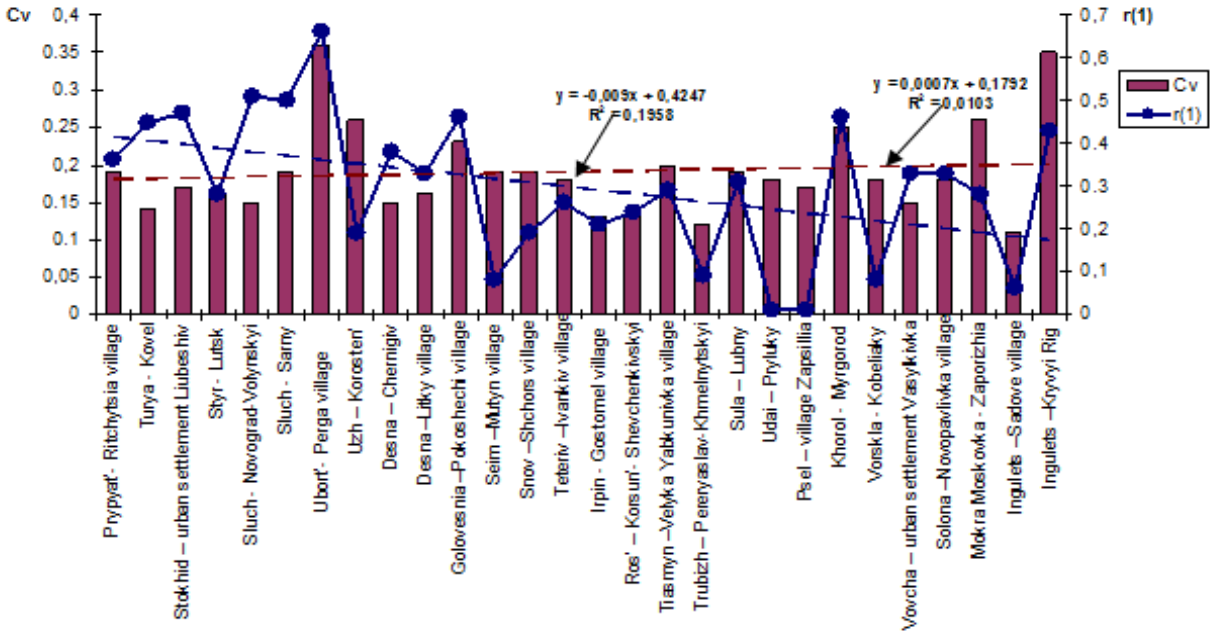


Fig. 4. Dynamics of variability and autocorrelation of river water mineralization series in the Dnipro basin.

Table 2. Check of the series of general mineralization of water bodies in the Dnieper river basin for 1990-2015 for compliance with Pearson type III distribution law and three-parameter distributions by S.M.Krytsky and M.F. Menke

№ of gauge on the map	River- stream gauge	$\chi^2(\alpha,\nu)$	Pearson type III distribution		distribution by S.M.Krytsky and M.F.Menkel	
			χ^2	compliance	χ^2	compliance
Subbasin of the Prypyat' river						
1	The Prypyat'- Ritchytsia village	12.6	12.5	compliant	12.5	compliant
2	The Turya – Kovel city	12.6	7.8	compliant	7.9	compliant
3	The Stokhid – urban settlement Liubeshiv	12.6	9.8	compliant	10.4	compliant
4	The Styr – Lutsk city	12.6	7.5	compliant	10.1	compliant
5	The Sluch - Novograd-Volynskyi city	12.6	12.3	compliant	10.1	compliant
6	The Sluch – Sarny	12.6	8.1	compliant	9.6	compliant
7	The Ubort'- Perga village	12.6	17.7	not compliant	15.8	not compliant
8	The Uzh – Korosten' city	12.6	7.1	compliant	11.5	compliant
Subbasin of the Dnieper river						
9	The Desna – Chernigiv city	12.6	7.1	compliant	7.4	compliant
10	The Desna –Litky village	12.6	7.4	compliant	11.1	compliant
11	The Golovesnia –Pokoshechi village	12.6	8.8	compliant	35.2	not compliant
12	The Seim –Mutyn village	12.6	8.7	compliant	12.4	compliant
13	The Snov –Shchors village	12.6	5.3	compliant	13.1	not compliant
Subbasin of the Middle Dnieper						
14	The Teteriv –Ivankiv village	12.6	13.2	not compliant	16.9	not compliant
15	The Irpin - Gostomel village (Mostyshche village)	12.6	5.90	compliant	11.7	compliant
16	The Ros' – Korsun'-Shevchenkivskyi city	12.6	9.30	compliant	20.2	not compliant
17	The Tiasmyn –Velyka Yabkunivka village	12.6	7.48	compliant	15.5	not compliant
18	The Trubizh – Pereryaslav-Khmelnytskyi city	12.6	10.2	compliant	18.8	not compliant
19	The Sula – Lubny city	12.6	15.5	not compliant	14.4	not compliant
20	The Udai – Pryluky city	12.6	3.92	compliant	6.68	compliant
21	The Psel – village Zapsillia	12.6	2.86	compliant	12.96	not compliant
22	The Khorol – Myrgorod city	12.6	4.0	compliant	4.25	compliant
23	The Vorskla – Kobeliaky city	12.6	12.1	compliant	4.9	not compliant
Subbasin of the Lower Dnipro						
24	The Vovcha – urban settlement Vasylkivka	12.6	9.7	compliant	5.9	compliant
25	The Solona –Novopavlivka village	12.6	3.45	compliant	3.96	compliant
26	The Mokra Moskovka – Zaporizhia city	12.6	7.65	compliant	12.3	compliant
27	The Ingulets –Sadove village	12.6	8.9	compliant	20.7	not compliant
28	The Ingulets – Kryvyi Rih city	12.6	15.37	not compliant	15.49	not compliant

to the Pearson III type distribution law at all gauges except the Teteriv gauges – urban settlements Ivankiv and the Sula – Lubny city, and the three-parameter distribution by S.M.Krytsky and M.F.Menkel in three cross sections (the Irpin – urban settlement Gostomel (Mostyshche village), the Udai - Pryluky city and the Khorol – Myrgorod city) according to the fitting criterion $\chi^2(\alpha,\nu)$ at $\alpha = 0.05$ and $\nu = 7$ only within the cross section (Table 2).

To sum up: for the cross sections the Irpin – urban settlement Gostomel (Mostyshche village), the Udai - Pryluky city and the Khorol - Myrhorod city the series of mineralization correspond to both distribution laws, for other gauges it is possible to

use Pearson III type distribution law for calculations, which is determined by the condition $\chi^2 < \chi^2(\alpha,\nu)$, for the gauge of the Teteriv – urban settlement Ivankiv the series of mineralization do not correspond to any of the studied distribution laws (the Table 2).

In the subbasin of the Lower Dnipro, the series of mineralization at the three investigated gauges correspond to the Pearson type III distribution law and the three-parameter distribution by S.M.Krytsky and M.F.Minkel by the fitting criterion $\chi^2(\alpha,\nu)$ at $\alpha = 0.05$ and $\nu = 7$. At the gauge of the Ingulets River – Sadove village the series of mineralization correspond only to the Pearson III type distribution law, at the gauge of Ingulets – Kryvyi Rih the series do not correspond to any distribution law, which can be explained by significant anthropogenic loads and peak emissions of the mine waters of the Kryvyi Rih iron ore basin (the Table 2).

Conclusions.

• As a result of a standard statistical processing (using the methods of moments and maximum likelihood), the statistical characteristics of the series of measured values of mineralization of water bodies of the Dnipro basin for the period from 1990 to 2015 have been determined.

• The average annual values of mineralization vary substantially within the studied part of the Dnipro basin within Ukraine. Thus, in the northern part (subbasins of the Prypyat' and the Desna) the average long-term mineralization fluctuates from 232 mg/l to 447 mg/l, and as it moves to the south, mineralization increases and in the subbasin of the Middle Dnipro it changes in the range from 373 mg/l to 971 mg/l; the highest values are observed in the south, in the subbasin of the Lower Dnipro, where they fluctuate from 357 mg/l (the Ingulets - Sadove village) to extremely high values of 3356 mg/l (the Solona - Novopavlivka village).

• The obtained data are consistent with the data (Khilchevskyi et al., 2018) on the spatial changes of the water mineralization of the rivers of Ukraine, in particular for the Dnipro basin, which indicates the statistical stability of the average long-term mineralization.

• The long-term variability of mineralization in the rivers of the studied territory is insignificant, the values of the coefficients of variation C_v vary in the Dnipro basin within Ukraine in the range from 0.11 to 0.3 and do not have a signified trend.

• The asymmetry of the mineralization series is sufficiently signified, and the corresponding coefficients vary over a wide range from -0.03 to 5.00.

• The autocorrelation in the mineralization series is quite high and the coefficients r(1) are in most cases significant; in general within the basin there is a decrease of the autocorrelation coefficients from the north to the south.

• Within the framework of the presented research, the possibility of using theoretical distribution curves known in hydrology to describe river mineralization has been analyzed. In terms of the Dnieper basin, using the Pearson fitting criterion χ^2, the type III Pearson distributions and the three-parameter by S.M. Krytsky and M.F.Menkel have been checked for their correspondence with the empirical series of mineralization. As a result, it was found that in 85% of cases the Pearson type III distribution can be used, whereas the three-parameter by S.M.Krytsky and M.F.Menkel in 60% of cases.

• The obtained results make it possible to use theoretical curves to determine the mineralization values of different probability of exceedance, but for the final conclusions it is necessary to continue the study using more source of initial information.

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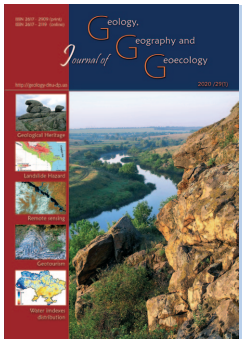

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The geographical prerequisites for the identification and prevention of dangerous geomorphological processes in the mountain geosystems of the Alpine-Himalayan belt (on the example of the Major Caucasus of Azerbaijan)

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Abstract. Destructive natural phenomena are a serious, sometimes unsolvable, regional and local environmental and socioeconomic problem. This paper presents the results of a comprehensive analysis of materials from long-term geomorphological studies in the mountainous areas on the example of the Major Caucasus of Azerbaijan. The dangerous geomorphological processes on the example of the Major Caucasus of Azerbaijan were investigated in detail using large-scale maps, satellite imagery and aerial photography. Geomorphological maps were drawn (map of mudflow hazard and map of landslide hazard in the Azerbaijani part of the Major Caucasus). The research determined the dangerous zones where landslides could cover 65–70% of the total area and outlined the zones and regularities of spread of various types of mudflow origination sites. The analysis of the manifestations of most active (with catastrophic consequences) destructive natural processes and the morphotectonic structure of the studied area showed that the their occurrence and maximum intensity was confined to the weakest plexuses of mountains – intersections of faults and fractures of various directions and orders. A technique for assessing the eco-geomorphological risk to prevent dangerous natural phenomena was offered. The technique is based on the detection of zones with intensive geomorphological processes, which are often not dangerous separately, but could have catastrophic consequences together. The results obtained during the assessment of the effect of natural and man-caused factors on the stability of montane ecosystems may be used to forecast dangerous natural phenomena and to research geodynamical dangerous geomorphological process not only in Azerbaijan, but also in other regions of the Alpine-Himalayan orogenic belt. The obtained results can be used to plan and perform economic activities, determine and minimize the hazards and risks of occurrence of dangerous natural phenomena, and forecast such phenomena in the future.

Keywords: hazardous geomorphological processes, Alpine-Himalayan montane system, geomorphology, tectonics, dangerous exogenous processes.

Географічні передумови ідентифікації та запобігання небезпечним геоморфологічним процесам у гірських геосистемах Альпійсько-Гімалайського поясу (на прикладі Великого Кавказу Азербайджану)

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Анотація. Деструктивні природні явища являють собою серйозну, іноді нездійсненну, регіональну і місцеву екологічну і соціально-економічну проблему. У даній статті на прикладі Великого Кавказу Азербайджану представлені результати комплексного аналізу матеріалів багаторічних геоморфологічних досліджень в гірських районах. Небезпечні геоморфологічні процеси на прикладі Великого Кавказу Азербайджану були детально вивчені з використанням великомасштабних карт, супутникових знімків і аерофотознімання. Були складені геоморфологічні карти (карта селевої небезпеки і карта зсувної небезпеки в азербайджанській частині Великого Кавказу). В ході дослідження були визначені небезпечні зони, в яких зсуви можуть покривати 65-70% загальної площі, а також окреслені зони і закономірності поширення різних типів місць виникнення селів. Аналіз проявів найбільш активних (з катастрофічними наслідками) руйнівних природних процесів і морфотектонічної будови досліджуваної території показав, що їх виникнення і максимальна інтенсивність обмежувалися найбільш слабкими сплетеннями гір - перетинами розломів різних напрямків. Запропоновано методику оцінки екогеоморфологічного ризику для запобігання небезпечних природних явищ. Методика заснована на виявленні зон з інтенсивними геоморфологічними процесами, які окремо часто не представляють небезпеки, але разом можуть мати катастрофічні наслідки. Результати, отримані в ході оцінки впливу природних і техногенних факторів на стійкість гірських екосистем, можуть бути використані

для прогнозування небезпечних природних явищ та дослідження геодинамічно небезпечних геоморфологічних процесів не тільки в Азербайджані, але і в інших регіонах Альпійсько-Гімалайського орогенного пояса. Отримані результати можуть бути використані для планування і здійснення господарської діяльності, визначення і зведення до мінімуму небезпек і ризиків виникнення небезпечних природних явищ та прогнозування таких явищ в майбутньому.

Ключові слова: небезпечні геоморфологічні процеси, Альпійсько-Гімалайський гірська система, геоморфологія, тектоніка, небезпечні екзогенні процеси.

Introduction. Over recent decades have seen a trend of increasingly intensive involvement of mountainous areas in human economic activities, which include mass construction and expansion of settlements, motorways and railroads, pipelines, agricultural and industrial facilities, construction of Olympic facilities, sanatoriums, hotels, holiday centers, etc. This causes intensive degradation of the natural resource potential of mountainous and piedmont territories, which are viewed as a means of achieving economic goals. The geo-systems of such regions lose their stability to external impacts, which increases the probability of dangerous destructive natural phenomena occurring (Alizade and Tarikhazer, 2010, 2015; Gotvansky, 2010; Mazur, 2004; Jansky, 2006; Spengler et al., 2016). Human activity combined with climate change have a direct effect on the formation and development of destructive natural phenomena, such as mudflows, screes, landslides, avalanches, desertification, etc. (Mazur, 2004; Jansky, 2006; Kang et al., 2004; Anakhaev et al., 2016; Lioubimtseva, 2009).These phenomena are especially dangerous for settled territories of mountainous and piedmont regions, since they completely destroy the infrastructure, buildings, and structures and cause deaths and considerable financial loss. Such territories include Central Asian countries, including the Azerbaijan Republic.

Destructive natural phenomena against the backdrop of urbanization, expansion of agricultural lands and industry in mountainous and piedmont regions of Azerbaijan, the sudden occurrence of said phenomena, their unpredictability, and close relation to geological, geomorphological, and other geodynamic processes are a serious, sometimes unsolvable, regional and local environmental and socioeconomic problem, the consequences whereof have a negative effect on the development of the entire country. The most dangerous, common, and destructive ones are landslides and mudflows (Anakhaev et al., 2016; van den Eeckhaut et al., 2007; Petrascheck and Hazard, 2003; Yafiazova, 2009; Seversky et al., 2010; Lee et al., 2008).

In order to solve a series of problems facing mountainous areas, specialists direct their efforts to the detection and anticipation of the causes of spread and development of current destructive natural processes. This will help to solve many practical and economic problems, prevent dangerous natural phenomena and their consequences caused by a catastrophic transformation of natural geo-systems, and minimize the risk of damage therefrom. Therefore, the development of a technique for assessing the risk to montane systems from adverse natural and man-caused processes (geo-ecological assessment) is a national priority. Such risk assessment methods should take into account multiple natural and man-caused factors, the combination whereof facilitates the development of these dangerous processes and phenomena. The dynamic of these processes and phenomena can be traced in the geo-dynamically active area of the Major Caucasus of Azerbaijan, most of which is part of zones with a high level of general eco-dynamic hazard that are exposed to several intensive dangerous terrain-formation processes and a probability of catastrophic manifestation of some of them. Therefore, studying the regularities in the connection between the endogenous and exogenous components of the terrain, i.e. the comparison of the terrain morphology in mountainous regions to Alpine orogeny in the system, which causes dangerous geodynamic processes, is a relevant task of structural geomorphology and morphostructural analysis. Therefore, the purpose of this research was to investigate the dynamic of these processes and phenomena, which required determining the main factors and trends in the development of terrain.

Methods and materials. Researchers of different countries have developed and continue to develop techniques for preventing landslides, which calculate the risks of occurrence of this or that phenomenon in territories with different natural conditions (Petrascheck and Hazard, 2003; Yafiazova, 2009; Seversky et al., 2010; Lee et al., 2008; Schlögel et al., 2015; Duong et al., 2013; Ardizzone et al., 2002; Baynes et al., 2002; Brardinoni et al., 2003; Corominas et al., 2014; Malamud et al., 2004; Singhroy and Molch, 2004; Abu-Zeid et al., 2003; Inaba, 2003; Mills, 2003; Paramonov, 2005).

After analyzing a number of techniques used to assess the landslide hazards (Seversky et al., 2010; Lee, 2006; Bobrovich, 2008; Schlögel et al., 2015; Duong et al., 2013; Ardizzone et al., 2002; Baynes et al., 2002; Brardinoni et al., 2003; Corominas et al., 2015; Malamud et al., 2004; Singhroy and Molch,

2004), the conclusion was made that most of them had their flaws. Deterministic methods of analysis (Bobrovich, 2008) based on estimated values of stability coefficients often show results that do not correspond to reality due to the lack of initial engineering and geological data. Techniques based on probability and statistics methods (geodynamic potential method, regression analysis method) (Lee et al., 2006; Duong et al., 2013), the idea behind which is the determination of the probability of landslide occurrence based on the probability of an impact of landslide-formation factors, are very labor-intensive and require complicated mathematical treatment. The landslide rhythm analysis technique (Yafiazova, 2009; Seversky et al., 2010; Bobrovich, 2008; Baynes et al., 2002), which is based on the detection of the periodicity of landslide occurrence and its relation to precipitation intensity and other meteorological parameters, is complicated by a lack of representative observations and the complexity of treatment of raw data. Remote sensing techniques are more practical. Such techniques enable determining the morphological indicators of landslide development to draw 1:5000 maps of density and probable occurrence of landslides (Ardizzone et al., 2002; Baynes et al., 2002; Brardinoni et al., 2003; Corominas et al., 2015; Malamud et al., 2004; Singhroy and Molch, 2004).

This research used a technique of landslide susceptibility of the territory (Duong et al., 2013), which is considered more appropriate for the territory of the Major Caucasus of Azerbaijan. It is expedient to indicate the main factors that cause the activation of said processes: geological structure, slope, thickness of potentially landslide-dangerous sediments, landscape, etc. The main criterion that allows regarding this or that factor as a landslide hazard is the shape of distribution of discovered landslides by the information classes of the factor under consideration. The standard deviation of the distribution of discovered landslides by the information classes of the factor under consideration is the basis for determining its weight w_j; at that, the weights of all *(n)* assessed factors are normalized so that their sum is 1:

$$w_j = 1 - \frac{\sigma_j}{\sum_{j=1}^{n} \sigma_j} \quad (1)$$

where σ_j is the standard deviation of the distribution of discovered landslides by the information classes of factor *j*.

The weights of information classes x_{ij} are normalized as regard to the number of detected landslides so that the sum for each factor is 1:

$$x_{ij} = \frac{\text{number of detected landslides in this information class}}{\text{number of detected landslides in the entire studied territory}} \quad (2)$$

The method for zoning the landslide susceptibility of the territory consists in the following. An integrated index *H* is calculated for each elementary plot of the studied:

$$H = \sum_{i,j=1}^{n} w_j x_{ij}, \quad (3)$$

where *H* is the integrated landslide susceptibility index, dimensionless; w_j is the weight of factor *j*; x_{ij} is the weight of class *i* of factor *j*.

This research uses a comprehensive technique of landslide susceptibility of the territory: structural morphotectonics, seismicity, climate, hydrogeological conditions, exogenous geomorphologic processes that facilitate landslide formation, vegetation, nature of engineering and economic activities in the studied regions, etc. (Gotvansky, 2010).

Researchers in various countries (Abu-Zeid and Furlanis, 2003; Huang, 2003; Inaba, 2003; Mills, 2003), including post-Soviet countries that are exposed to mudflow phenomena (Yafiazova, 2009; Seversky et al., 2010; Chernomorets, 2003;), are actively studying said phenomena, with a view to preventing them, minimizing their consequences, and developing means of protection therefrom. Mudflow phenomena have been investigated from different perspectives: the regional peculiarities of their occurrence or general territorial regularities of their spread; mudflow-forming processes as a result of the impact of water flows with friable debris; specific mudflow-forming factors or certain types of mudflows, etc. (Yafiazova, 2009; Seversky et al., 2010).

The most practical and sufficiently informative technique is aerial photography followed by photogrammetric treatment of aerial photographs of mudflow-hazardous regions with a scale of 1:2000-1:5000 (Chernomorets, 2003; Seversky et al., 2010; Paramonov, 2005). It enables covering the entire studied district; it can also be used when planning the socioeconomic development of regions, outlining "risk zones", distributing resources, planning measures aimed at minimizing damage, making long-term forecasts, and analyzing mudflow phenomena. Several studies (Alizade and Tarikhazer, 2010, 2015) determined the mapping criteria, optimal scale and legend of maps, depending on the hierarchic level of the investigation of the region and the landscape conditions of the manifestation of the processes. It was found that the optimal scale for the detection and anticipation of natural destructive phenomena in the montane geo-systems of the Major Caucasus of

Azerbaijan, as well as local morphogenesis processes, was 1:100000.

Mapping on a 1:100000 scale, by the example of mudflows, allows for additional monitoring of the state of the mudflow origination site, mudflow channel, and impact area of mudflows. This scale enables covering the entire mudflow basin, which allows using it as a basis for modeling the mudflow process along the entire mudflow channel and monitoring the entire mudflow basin comprehensively.

While analyzing the materials, the conclusion was made that much depends on the stability of terrain objects to the impact of both natural and, primarily, man-caused factors. Therefore, in newly developed regions, it is necessary to pay special attention to the detection of zones of risk or intensive geomorphological processes, which are often not dangerous separately, but could have catastrophic consequences together.

The information framework of this research included materials of long-term geomorphological studies in the mountainous regions of the Major Caucasus of Azerbaijan. The dangerous geomorphological processes of the Major Caucasus of Azerbaijan were investigated in detail using large-scale maps, satellite imagery and aerial photography (1986-2018) with the ArcGIS software package (Hydrology, Statial, Analyst, 3D Analyst, etc.). Geomorphological maps were drawn.

The types of dangerous morphogenesis processes (main, accompanying, and secondary) and their intensity index, expressed in percentage of the areal extent of the process in a certain exo-geomorphological region, were compared to those of other processes.

Results. The results of the morphotectonic interpretation of the materials of structural and geomorphological decoding of satellite imagery and aerial photography materials of Major Caucasus and adjacent territories were analyzed to determine the geo-dynamically active borders of morphostructures, their spatial arrangement, and interrelation.

Endodynamic factors

The studied region has a complex morphotectonic structure. It is characterized by extensive overthrust masses, magma and mud volcanos, frequently changing bearing of trend of large morphostructures (Fig.1), active seismotectonic and neotectonic processes, clear differentiation of exogenous processes, etc.

The territory of Azerbaijan is an area of collision of the East European Craton and the Arabian Platform. The current morphotectonic frame of this region was formed by the subduction of the Meso-Tethys oceanic crust under the Anatolian-Iranian Platform (to the Late Cretaceous) and the collision of the Transcaucasian continental crust under the Scythian Platform with the Anatolian-Iranian crust under the Transcaucasian Platform. At that, various morphotectonic processes

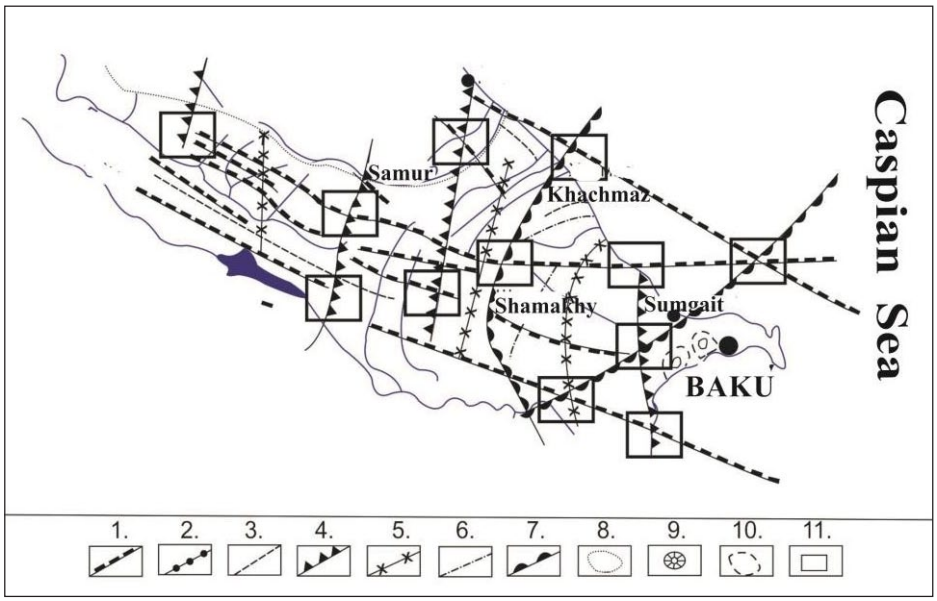

Fig. 1. Schematic map of morphotectonic intensity in Major Caucasus and adjacent territories (Alizade, 2004)

Lineaments that correspond to longitudinal (general-Small-Caucasus) faults (overthrust and upthrust): 1 – Regional deep faults that limit large longitudinal orogenic-block terraces; 2 – Local faults that correspond to the borders of longitudinal orogenic-block morphostructures; 3 – Fractures that determine the details of morphostructures.

Lineaments that correspond to longitudinal (anti-Caucasus) faults (overthrust and upthrust): 4 – Regional deep faults that тlimit longitudinal megablocks; 5 – Local faults that correspond to the borders of longitudinal block segments; 6 – Fractures; 7 – Large interregional diagonal volcanic centers; 10 – Ring structures (tectonic and volcanic). 11 – Geo-dynamically intense fields.

created a complex area that features the results of rifting and orogeny. Intensive, but differentiated horizontal and resulting vertical tectonic movements created rootless montane structures of the Major Caucasus.

The differentiation of compressions within the studied region caused the formation of imbricated and brachiform morphostructures, while the intensive formation of multiple disjunctive and folded dislocations caused the encroachment of surface rock plates on one another, which resulted in the formation of large surface overthrust masses, olistostromes, olistoliths, etc., which radically changed the morphology of this region's terrain (Alizade, 2004; Alizade and Tarikhazer, 2010, 2015).

Fault tectonics plays a major role in the enhanced tangential compression and extension of geoblocks during the formation of the current terrain of the Major Caucasus of Azerbaijan. The mountain terrain is especially complex and mosaic at the intersections of faults and fractures of various directions and orders. Large block morphostructures and their internal differentiation in fracture areas creates a complex and dynamic horizontal and vertical differentiation of the territory. This is seen from the fact that the intensive exogenous processes in these regions are almost always confined to weakened and endogenously fractured parts of the Earth's crust, i.e. zones of fractures, and are caused by block tectonics and limited to them (Alizade and Tarikhazer, 2010, 2015; Tarikhazer, 2006; Tarikhazer, 2010; Tarikhazer, 2013). It was found that virtually all large river valleys in orogenic regions are confined to complex and multi-order grids of lineaments – fractures.

In Azerbaijan, the most geo-dynamically active and dangerous geo-systems are those of the Major Caucasus, which is a large and complex mega anticlinorium, comprised mostly of Mesozoic, Paleogene, and Neogene sediment rocks and Quaternary sediments along river valleys, intermountain basins, and flat surfaces of rangelines.

In the Major Caucasus, endodynamically active ranges alternate with massive plateaus, large intermountain and intramontane basins, and high-mountain glaciers. The mountainous terrain is heavily affected by old and new erosion, which formed a dense network of multiple deep and narrow river valleys and rifts running in different directions. In general, the Major Caucasus is a highly mobile geotectonic area and one of the main seismically active belts on the Earth. The total range of new elevations in the Major Caucasus of Azerbaijan near the mountains of Bazardyzy, Shahdagh, and Tufandag over the Pliocene-Quaternary period exceeds 3600 m.

Despite the diversity of the structural zones that constitute the joint elevation, together they form a regularly arranged divergent horst-anticlinal structure, which is divided into a series of longitudinal block segments by large longitudinal lineaments. Eastern Caucasus, located to the east of the Transcaucasian longitudinal elevation, is divided from the periclinal submersion zone – the Southeastern Caucasus – by the large Western Caspian deem joint.

Exodynamic factors

The geological structure in combination with endodynamic processes that occur in the studied territory are one of the main factors that cause exodynamic processes. It is worth noting that the intensity of these processes largely depends on the geotectonic activity of separate blocks and disjunctive faults. For instance, most river valleys, large cliffs, and edges of terrain terraces are confined to the heterogenic multi-order grid of fractures.

The territory of Azerbaijan that is located in the geo-dynamically active zone is characterized by a high potential probability of occurrence of dangerous endo- and exo-geomorphologic processes. In the mountain regions of the Major Caucasus of Azerbaijan, these processes are primarily caused by intensive neotectonic and differentiated neotectonic movements, typical for the new Alpine-Himalayan orogenic belt, peculiarities of the morphological structure (distinct longitudinal and altitudinal zonation of morphostructures), climate, surface runoff, etc. An indirect but equally important effect on the intensity of development and stabilization of processes comes from vegetation – its floristic composition and plant cover. The lithological factor also has a significant impact. Man-caused processes have a dual effect: stabilizing at the local level (for instance, in case of forestation of hillslopes), but destabilizing during the development of regions (Gotvansky, 2010; Mazur, 2004; Jansky, 2006; Spengler et al., 2016; Kang et al., 2004; Lioubimtseva, 2009; Kuzmin, 2014).

For instance, mudflows, etc. are not subject to the latter. In general, most active catastrophic exogenous processes in the studied area are confined to steeper hillslopes of the Major Caucasus.

The most dangerous exo-geomorphological processes are dominant mostly in high-mountain zones – absolute altitude of 2200 m and higher. These include avalanches, landslides, rockslides, mudflows, etc.

Avalanches are intensive in the Central Caucasus, but in the eastern part of the Major Caucasus, this intensity decreases. The origination sites of avalanches are cirques, narrow erosion cuts, etc. The

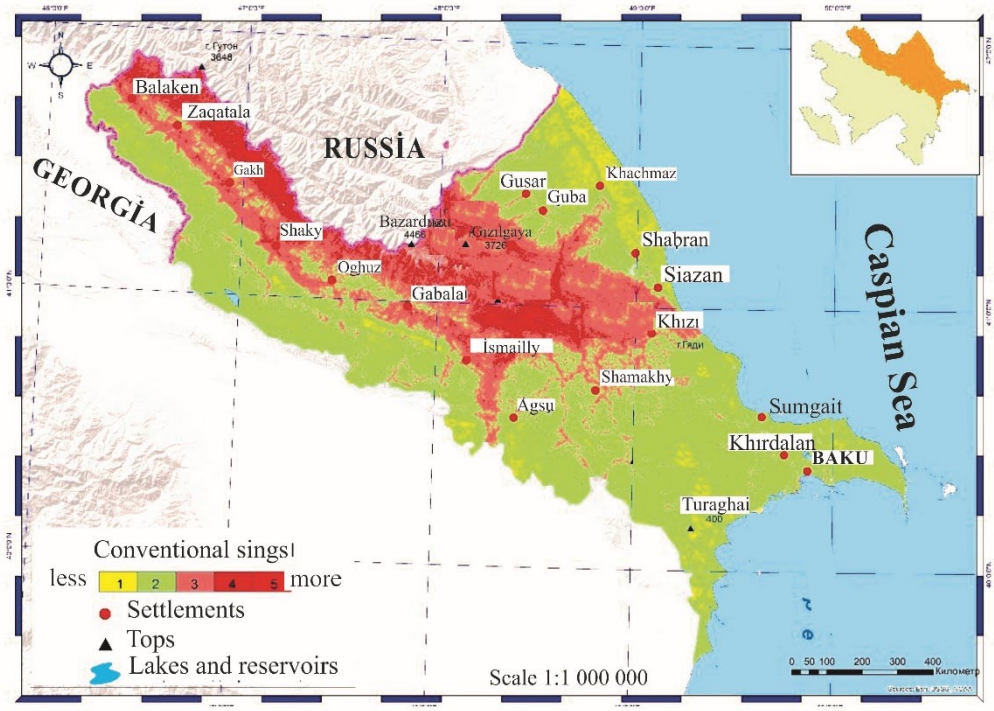

Fig. 2. Map of landslide hazard in the territory of Major Caucasus (in points) (compiled by Tarikhazer, 2018).

5 points – highly intensive territories with active landslide processes (landslide occurrence probable in 65-70% of the territory);
4 points – intensive territories with active landslide processes (landslide occurrence probable in 50-65% of the territory);
3 points – moderately intensive territories with intensive landslide processes (landslide occurrence probable in 30-50% of the territory);
2 points – territories with relatively weak landslide processes;
1 point – territories without landslide processes.

latter are often exposed to channeled avalanches, which are encountered most frequently and are very devastating. Their speed reaches dozens of meters per second, their pressure on a fixed obstacle ranges from dozens to more than a hundred tons per square meter. Avalanches mostly occur at altitudes of 2500-3000 m and higher. The consequences of snow avalanches, which destroy slopes, carry friable debris along avalanche channels, and deposit it at the foothills in the form of avalanche cones, are often found near Bazardyzy Mountain, Shahdagh Mountain, Gyzylgaya Mountain, Tufandag Mountain, etc. On the slopes of the Main and Flanking Caucasus ranges, avalanches occur suddenly, destroy buildings, roads, and may cause death.

Dangerous gravitational processes that occur at all altitudes of terrain in Azerbaijan's mountains include landslides, rockslides, and screes.

High ranges, deep valleys, current tectonic mobility, and frequent earthquakes – all this is typical for the Major Caucasus. It creates a considerable potential for gravitational movements of large masses downhill. Ancient landslides are also frequent.

The results obtained during the research were used to draw a schematic map of landslide hazard in the territory of Major Caucasus (Fig. 2). The parameters of landslide occurrence include the level of landslide activity, seismic activity of the area, man-caused effect, level of vegetation degradation, erosion stratification, lithological composition of constituent rocks, and landslide dynamics.

Landslides are frequently encountered within the Gusar inclined plain, where they occur in both loose and primary deposits and are mostly confined to valley sides. Their spatial development is associated with the outcroppings of Tertiary deposits in the basins of Velvelichay River, Gudiyalchay River, Garachay River, Agchay River, and Chagajugchay River.

In the Major Caucasus, landslides occur at virtually all altitudes, but mostly in medium-altitude mountains. On the southern slope of the Main Caucasus Range, between rivers Mazymchay and Goychay, landslides occur at altitudes from 1300 m to 3000 m. Here they occur in clay-marl rock masses and are caused, alongside other factors, by active faults and cleavage of rocks. Landslides primarily occur on side branches, which are characterized by steep slopes and clay composition, where significant humidification causes genetic types of landslides, such as tectonic-gravitational block slides, tearing, and mudflows (Yafiazova, 2009; Seversky et al., 2010; Lee et al., 2008; Schlögel et al., 2015; Duong, 2013).

In the high-mountain area of the southern slope of the Major Caucasus, landslides occur at the springhead of Shinchay River, on the slopes of some side branches near the Gdym mountain pass, on the slopes of Kazhal Mountain, Gotur Mountain, Peygyambyarbulag Mountain, and other mountains. In this case, tectonic faults play the major role in the development of landslide processes. Landslides also occur on the northern and southern slopes of the Flanking Range, on the southern slope of the Main Caucasus Range, in the basins of Gusarchay River, Gudiyalchay River, and Velvelichay River, and along the upper reaches of Garachay River, Jimichay River, etc. (Fig. 3, 4).

Fig. 3. Landslip processes in Laza village on Major Caucasus

Fig. 4. Landslide processes in Sudur village on Major Caucasus

Rock-falls occupy a lot of space in the mountainous territory of Azerbaijan. They mostly occur in the high-mountain and medium-mountain areas of the Major Caucasus, especially on the slopes of the Flanking Range with its steep step-shaped slopes and the southern slope of the Main Caucasus Range, in the valleys of Velvelichay River, Gilgilchay River, Tugchay River, Sumqayit River, Kurmukchay River, Kishchay River, Talachay River, Belokanchay River, and others. Large rock-falls occur in the foothills of the Shahdag, Gyzylgaya, Buduq, Girdag, and other plateaus. Rock-falls cover the Gusarchay River bed between Shahdagh Mountain and Gyzylgaya Mountain (Tarikhazer, 2010; Alizade and Tarikhazer, 2010, 2015).

Rock-falls that participate in mudflow formation occur within the high-mountain areas of basins of Kurmukchay River, Gusarchay River, Tikanlychay River, Velvelichay River and others (Fig. 5).

The slopes of trough valleys and cirques within the watershed of the northern slope of the Main Caucasian Range are unstable and exposed to rock-falls and landslides. Large rock-fall and landslide masses are typical for the slopes of trough valleys of Tufan, Kurve, Garanlyg, and others.

In the Major Caucasus, landslide slopes are typically encountered in the high-mountain parts of valleys of Gusarchay River, Gudiyalchay River, Velvelichay River, and Jimichay River, as well as in parts that cut into the synclinal plateau of the Shahdagh-Gyzylgaya rock mass. In the Shahdagh, Gyzylgaya, and Buduq high synclinal plateaus, the denudation part of landslide slopes is confined to cliffs and overhangs of gravitational and tectonic origin, and zones of altitudinal movement of certain limestone blocks along fault lines. The height of cliffs ranges from several dozens of meters to 500–600 m. The accumulative part of slopes occupies a similarly large area and frames the foothills of northern and southern slopes 6-8 km wide. Certain large limestone rocks several hundred m^3 in volume move for 12–13 km. These deposits often fill the beds of longitudinal valleys (upper reaches of Gusarchay River) and accumulate at the foothills of the opposite slope. Vast deluvial deposits with an undulating and hummocky terrain were created by the rock-fall and landslide material at the southern wall of Shahdagh and Gyzylgaya mountains — at the left edge of the Shakhnabadchay River valley, Ateshgah area, and the left edge of the Tskhoamush valley (left tributary of Gudiyalchay River), Guzuntakhta-Kechaldag area on the northern slope of Shahdagh Mountain, and the Mykhtekian-Dyaligay area at the northern edge of the Gyzylgaya and Buduq plateaus (Tarikhazer, 2006, 2010, 2013).

Mudflows are common in the territory of Azerbaijan. In terms of solid particles (silt,crushed stone, rocks) in the flow, mudflows are divided into structural (mud-and-stone), stone, and mud.

Fig. 5. Mudflow material in channel of river Velvelichay

In the Major Caucasus, mudflow processes are encountered in all landscape and geomorphological zones – from low-mountain areas to high-mountain ones. Many highly populated settlements located in the basins of mudflow rivers are constantly exposed to the threat of mudflows. Mudflows are extremely devastating due to their hydrodynamic properties. They flow in waves, disable hydraulic facilities, destroy bridges, roads, and settlements, cause huge economic damage, and are often accompanied by human losses. For instance, a mudflow (Kishchay River basin) damaged the town of Shaki and caused human losses in 1997. Villages and cities exposed to the mudflow hazard are located near places where rivers run into piedmont areas – Balakan, Zaqatala, Shaki, Qakh, Oghuz, Gabala, Shabran, and others. Devastating mudflows occurred in the basins of Kurmukchay River (2002), Girdimanchay River (2011), Agsuchay River (2013), and others (Fig. 6).

Mudflow rivers in the Major Caucasus include Kishchay River (its largest mudflow tributary is Damarchik River), Shinchay River (including its tributaries – Shikhgaflan River and Babachay River), Kurmukchay River (including its tributaries – Bulanygsu River, Agbulaq River, Khamamchay River, Kunakhaysu, Agsuchay), Gumbash, Lyakit, Zeyzid, Gamzalicha Qatexchay, Talachay, Mukhakhchay, Mazymchay, Damiraparanchay, Dashagyl, Tikanlychay, Goychay, Gusarchay River, Velvelichay River, Gudiyalchay River, Atachay River, Devechichay River, upper reaches of the Sumgait River, and many others. Mudflow rivers in southeastern Caucasus include Tugchay River, Takhtakerpu River, Dzheyrankechmez River, and others. Other areas exposed to mudflows are the blind creeks and gullies in the Adjinour-Djeyranchol piedmont area, Gobustan, and others.

Discussion. The research discovered an intensifying occurrence of destructive natural phenomena in the studied mountainous regions of the Major Caucasus of Azerbaijan, which is caused by an increasing effect of endo- and exogenous factors. Montane ecosystems, especially in Central Asian regions, are incredibly fragile and require an understanding of the entire complex of interconnected factors and processes that cause this fragility (Alizade and Tarikhazer, 2010, 2015; Gotvansky, 2010). The analysis of the factors that affect the development of dangerous natural phenomena found that besides commonly known causes that were described by other researchers (Budagov, 1993), an important role is played by the geomorphological factor, in particular, their confinement to the weakest plexuses of mountains – intersections of faults and fractures of various directions and orders.

Due to the complex interaction of natural and man-caused factors that cause the development of dangerous geodynamic processes in mountainous regions, it is very difficult to determine the specific role that each of these processes plays. Therefore, these processes should be considered in combination when forecasting the risk of occurrence of dangerous natural phenomena. This approach, which takes into consideration the entire set of factors, was taken to draw the schematic maps of landslide and mudflow hazard areas.

It is also worth noting that besides the geomorphological factors, which are the main cause of dangerous natural phenomena, climatic factors also play a significant role. In most cases, they serve as the catalyst of these phenomena and a factor that can upset the natural balance. Considering the fact that in the last decades, the average annual precipitation, evaporation, and surface runoff levels have increased in the high latitudes of the northern hemisphere due to earlier snowmelt caused by global warming (Lioubimtseva, 2009), this factor could not be ignored.

The technique of landslide susceptibility of

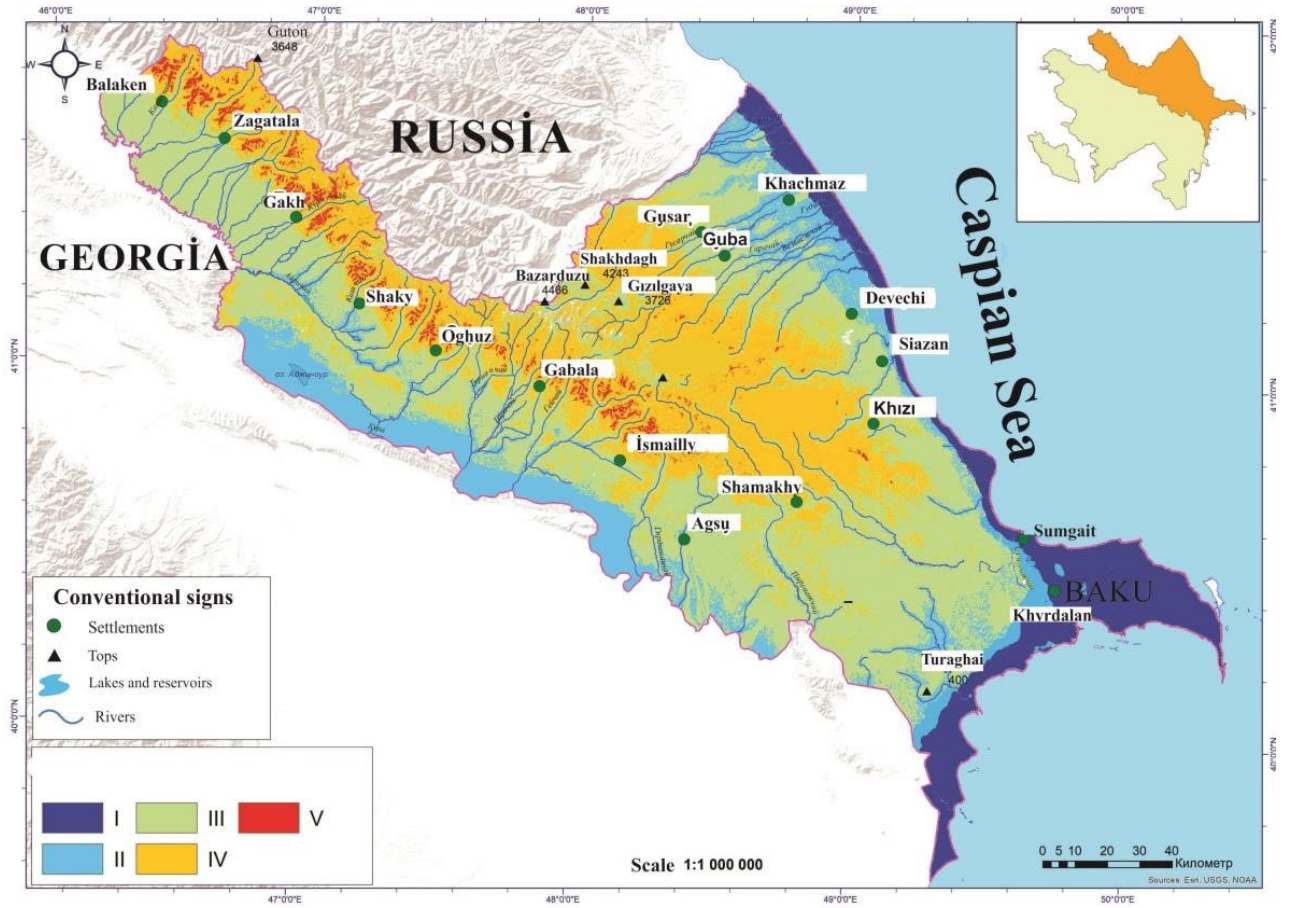

Fig. 6. Map of mudflow hazard in the Azerbaijani part of the Major Caucasus (compiled by Tarikhazer, 2018).

Territories, where there are no mudflow processes - I point.
Territories with potential mudflow hazard - II points.
Territories with a weak mudflow hazard (once in 5-10 years is possible 1 strong mudflow) - III points.
Territories with an average mudflow hazard (once in 3-5 years is possible 1 strong mudflow) - IV points.
Territories with high mudflow hazard (once in 2-3 years is possible 1 strong mudflow) - V points

the territory enabled taking into account not only the geomorphological and climatic factors, but also a number of other factors that participate in the occurrence, development, and manifestation of dangerous natural phenomena, such as the intensity of the studied phenomenon, the seismic activity of the area, manmade influence, erosion stratification, lithological composition of rocks, and the dynamic of the process.

The effect of human activities on the occurrence and development of dangerous geomorphological phenomena was proven once again. It was found that deforestation, overgrazing, and steep slopes in the mountainous regions of Major Caucasus in Azerbaijan created prerequisites for the occurrence of mudflows with scree, landslide, and rock-fall materials. Similar to other mountainous regions of Central Asia, excessive manmade influence triggers dangerous destructive natural phenomena (Kang et al., 2004; Anakhaev et al., 2016; Lioubimtseva, 2009). The consequences of various manmade influences are especially dangerous in regions that are undergoing intensive development. In areas with minimum natural process intensity, which are territories with increased risk, even the smallest intrusion might have catastrophic consequences (Seversky et al., 2010).

Presently, mountainous regions of Azerbaijan are exposed to active human activities: construction of tourist and recreation facilities, roads, canals and other line structures, deforestation, etc. All this can increase the amount of catastrophic consequences for the infrastructure and the population. Therefore, a top-priority task that can help to prevent economic and human loss is the organization of monitoring, with a view to collecting information and data that could allow detecting and anticipating destructive natural phenomena in Alpine-Himalayan montane geosystems.

Conclusion. The obtained results allow analyzing in detail the factors that facilitate the occurrence of dangerous natural phenomena in the mountainous regions of the Major Caucasus of Azerbaijan. Similar

to all orogenic zones, these areas are characterized by an increasing rate of dangerous destructive natural phenomena, which is caused by an increased effect of both natural and man-caused factors. The analysis of the manifestations of most active (with catastrophic consequences) destructive natural processes and the morphotectonic structure of the studied area showed that the their occurrence and maximum intensity was confined to the weakest plexuses of mountains – intersections of faults and fractures of various directions and orders.

The analysis of large-scale maps, satellite images, and aerial photographs of the territory of Azerbaijan made from 1986 to 2018 determined the main geomorphological processes in specific regions of the country and their main causes. In such areas as the Shahdagh-Gyzylgaya rock mass, the Main Watershed Range, the Gonagkend-Khaltan intramontane basins, and others, the main geomorphological processes are earthquakes, landslides, screes, rock-falls, and snow avalanches; in the Gusar inclined plain – landslides, rock-falls, screes, and erosion processes; in the Samur-Devechi depression – eolation and abrasion; in the Absheron Peninsula – earthquakes, landslides, gullies, arroyos, eolation, and abrasion.

Due to the complex interaction of natural and man-caused factors that cause the development of dangerous geodynamic processes in mountainous regions, it is very difficult to determine the specific role that each of these processes plays. Therefore, these processes were considered in combination when predicting the risk of occurrence of dangerous natural phenomena. This approach toon into consideration the entire set of factors, such as the intensity of the studied phenomenon, the seismic activity of the area, manmade influence, erosion stratification, lithological composition of rocks, and the dynamic of the process. Obtained data were used to draw the schematic maps of landslide and mudflow hazard areas and to outline the areas where they are most likely to occur.

The studied region was zoned in terms of landslide hazards according to a five-point system. The most intensive geosystems included territories where landslides could cover 65–70% of the total area. Such territories include medium-mountain and low-mountain zones of the Major Caucasus, the basins of Velvelichay River, Girdimanchay River, Gilgilchay River, Atachay River, Pirsaatchay River, etc. The research found that the main factor that caused the emergence of new mudflow origination sites was favorable lithological conditions that facilitate denudation and exposure of slopes.

The most intensive landslide processes (with up to catastrophic consequences) in the Major Caucasus occur in the low- and medium-mountain areas (basins of Sumgait River, Gusarchay, Gudiyalchay River, Devechichay River, Gilgilchay River, Atachay River, Kishchay River, Damiraparanchay River, Girdimanchay River, Shinchay River, etc.). Here, they are confined to argillaceous outcroppings of various age: in covering deposits, Jurassic, Cretaceous, and Tertiary clay and slate, as well as in Paleogene, Neogene, and Quaternary deposits.

Obtained results were also used to draw the schematic maps of mudflow hazard areas and to outline the most vulnerable areas with prerequisites for the occurrence of mudflows with scree, landslide, and rock-fall materials. These areas are mostly confined to nival-subnival, mountain-meadow, and, partly, mountain-forest landscape belts. They include scree, rock-fall, and landslide areas with alluvial cones of friable debris, accumulated in the foothills of southern and southwestern steep slopes and cliffs. Active mudflow origination sites in the nival-subnival belt are developed in the area of Akhvay Mountain (springhead of Bulanygsu River), Garagay Mountain (springhead of Shinchay River), and others; in the mountain-meadow belt, they are developed in the area of Garaguzey Mountain (springhead of Gaynarchay River), Kishchay River basin, etc.; in the mountain-forest belt, they are developed in the area of Kish village (Kishchay River basin), Shinchay River basin, the northern slope of Yarpuzbassar Mountain near Ilisu village, etc. Their main causes are the geomorphological structure and lithological composition of rocks, deforestation, overgrazing, and manmade influence.

The step-by-step method used to assess the effect of factors on the stability of montane geosystems provides for more accurate a detection of morphodynamic stress within separate montane geosystems and allows forecasting the development of dangerous geodynamic processes.

The scientific and methodological approach and the results obtained during the assessment of the effect of natural and man-caused factors on the stability of montane geosystems by the example of the Major Caucasus of Azerbaijan may be used to study geo-dynamically dangerous geomorphological processes in other regions of the Alpine-Himalayan orogenic belt, especially in France, Austria, Italy, Balkan countries, Switzerland, Georgia, Tajikistan, Kyrgyzstan, and other countries.

The obtained results can be used to plan and perform economic activities, determine and minimize the hazards and risks of occurrence of dangerous natural phenomena, and forecast such phenomena in the future.

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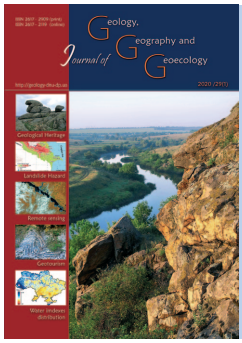

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Mineralogical studies of amphibolite outcrops within the Kryvyi Rih Basin

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Abstract. This study explores the mineralogical composition of the material of samples extracted from the outcrops of amphibolites located within the Kryvyi Rih Basin. Amphibolites of the Novokryvorizka suite of the Kryvorizka series are located in the area of Rodina mine of the Kryvyi Rih Iron Ore Enterprise (KRIOE) on the right bank of the Saksahan river, where the amphibolites crop out as an interrupted line. Over the recent years, industrial and geological tourism has been actively developing not only within Kryvyi Rih, but also in Ukraine in general. The Kryvyi Rih Basin has many objects which deserve the status of unique geological observation sites. One such site has amphibolites of the Novokryvorizka series, which rarely outcrop to the surface. Such an object is interesting and useful not only for interested tourists, but especially for geology students as an example of rocks that have been formed out of effusive eruption products during the geological process such as regional metamorphism. No other examples of their exposure have been observed in the area. The studied outcrops are unique, but recently, their reduction has been observed due to the poor level of their preservation. The relevance of this study is conditioned by necessity of conducting geological evaluation of the amphibolite outcrops with a view to the future use of this object for development of industrial and geological tourism within the Kryvyi Rih Basin. We studied all possible outcrops of the amphibolites within the surveyed territory, and analyzed the results of the previous studies on the topic. We developed a schematic image of the outcrops with consideration of their thicknesses. The mineralogical composition of all outcrops of the amphibolites was studied for further determination of the exact age of the amphibolites and opportunity of providing the amphibolite outcrops with the status of unique observation sites. For achieving the goal, we used the following methods of study: geological survey, selection of representative petrographic samples of the amphibolites, mineralogical and petrographic analyses, generalization of results of field and laboratory studies.

Key words: Ukrainian Shield, Kryvyi Rih Basin, geological tourism, outcrops of amphibolites.

Мінералогічні дослідження виходів амфіболітів в межах Криворізького басейну

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Анотація. Дана робота присвячена мінералогічному вивченню матеріалу проб, відібраних з відслонень амфіболітів, що розташовані в межах Криворізького басейну. Амфіболіти новокриворізької світи криворізької серії знаходяться в районі шахти «Родіна» Криворізького залізорудного комбінату (КЗРК) на правому березі річки Саксагань, де переривчастою смугою виходять на поверхню. В останні роки активно розвивається промисловий і геологічний туризм в межах не тільки Кривого Рогу, а й в Україні в цілому. В межах Криворізького басейну існує багато об'єктів, що заслуговують на статус геологічної унікальної точки спостереження. Одним з таких є амфіболіти новокриворізької серії, які рідко виходять на земну поверхню для спостережень. Такий об'єкт є цікавим і корисним не тільки для зацікавлених туристів, а й особливо для студентів-геологів у якості прикладу гірських порід, що утворились з ефузивів при такому геологічному процесі як динамотермальний метаморфізм. Інших прикладів наочності в межах Криворізького басейну не спостерігається. Досліджене відслонення є унікальним, але останнім часом спостерігається його скорочення у зв'язку з низькою збереженістю виходів амфіболітів. Актуальність даної роботи обумовлена необхідністю проведення геологічної оцінки виходів амфіболітів для подальшої можливості використання цього об'єкту для розвитку промислового і геологічного туризму в межах Криворізького басейну. Досліджено всі можливі виходи амфіболітів в межах вивченої території, проаналізовано результати попередніх досліджень з даної теми. Побудоване схематичне зображення їх відслонень з урахуванням потужностей. Вивчено мінеральний склад всіх виходів амфіболітів з метою подальшого визначення точного віку амфіболітів та можливості присвоєння виходам амфіболітів статусу унікальної точки спостереження. Для досягнення поставленої мети використовувались наступні методи досліджень:

виконання геолого-зйомних робіт, відбір представницьких петрографічних проб амфіболітів, виконання мінералогічних і петрографічних досліджень, узагальнення результатів польових та лабораторних досліджень.

Ключові слова: Український щит, Криворізький басейн, геологічний туризм, відслонення амфіболітів.

Introduction. One of the most interesting geological objects of the Ukrainian Shield is the Kryvyi Rih Structure. This is explained not only by the localization of unique reserves of iron ores below the ground, but also by a specific structure determined by the history of the geological development of the region, which reflects all the main stages of formation of the Ukrainian Shield.

According to the modern point of view, the Kryvyi Rih Structure is a complex geological structure developed by metal-volcanic-sedimentary of the Upper Archean, Lower, Middle and the Upper Proterozoic and Cenozoic Periods (Stepanuk,e.a., 2011). The structure includes deposits of the Kryvorizka series made up of Novokryvorizka, Skeliuvatska, Saksahanska, Hdantsivska and Hleiuvatska suites (Akimenko, et. al., 1957; Belevtsev, et. al., 1991).

The Novokryvorizka suite has been studied most substantially within the Saksahan and South iron ore regions of the Kryvyi Rih Basin, where it is embedded with angular and stratigraphic unconformity on the Konkska series. In its basal part, amphibolites, products of regional metamorphism of the covering basalts, are dominant. The initial effusive nature of the amphibolites is indicated by the presence of lensed amygdules of quartz in their structure (Gritsay, e. a., 1975). In the upward direction along the section of the suite, there is an increase in content of metaclastolites – quartz-chlorite, sericite-quartz-chlorite, quartz-sericite-chlorite (area of manifestation of green schist facies of metamorphism) or quartz-bimicaceous, quartz-hornblende-biotite (areas of epidote-amphibolite facies) of the schists. In a small amount, the upper section of the suite contains feldspar-quartz meta-sandstones and meta-gritstones with chlorite, quartz-chlorite cement, formed by interlayers of 1-2 m thickness, and also schist meta-conglomerates. Within the central part of the Saksahan iron ore region, where the deposit of the Rodina Mine is located, the thickness of the suite equals 150-200 m.

The Skeliuvatska suite is conformably embedded on the Novokryvorizka suite. It contains rocks of three subsuites: lower, middle, and the upper. Total thickness of the suite ranges from 40-50 to 340-360 m.

The Saksahanska suite is a productive iron ore thickness of the basin, and is embedded on the Skeliuvatska suite. Its complete section includes seven iron ore and seven schist horizons. The horizons range in number and thickness along the Kryvorizka Structure. The most complete section is within the deposit of the V. I. Lenin Mine. There, its thickness reaches 1,300 m. In the section of the suite of the deposit of the Rodina Mine, the seventh schist and seventh ferriferous horizons are absent. By petrographic content of the stratigraphic horizons, the Saksahanska suite is divided into the lower, middle, and lower subsuites.

The terminating part of the Kryvorizka series is the Hdanivska suite which is embedded with angular and stratigraphic unconformity on the rocks of the Saksahanska suite. Its structure comprises sericite-plagioclase-quartz-chlorite, graphite-sericite-quart-chlorite schists, oligomictic meta-sandstones and meta-conglomerate-breccia (green schist facies) or quartz-plagioclase-biotite, staurolite-andalusite-quartz-biotite, graphite-quartz-micaceous, quartz-biotite-hornblende schists, biotite, hornblende-biotite quartzites, and also ferriferous quartzites of different composition, initially clastogenic metamorphosed rich iron ores (products of rewashing of the weathering rind of the ferriferous rocks of the Saksahanska suite), quartz-carbonate rocks and dolomite marbles. The average thickness of the suite within the Inhulets iron ore district is 30-50 m, Saksahan and South districts – 700-1,000 m, North district – up to 2,000-2,500 m, does not exceed 1,500 m on average.

Rocks of the Hleiuvatska suite form the central part of the Kryvorizka Structure. The structure of the suite comprises polymictic meta-conglomerates, quartz-fieldspar and fieldspar-quartzitic metasandstones, quartz-biotite, plagioclase-quartz-biotite, garnet-quartz-biotite, garnet-hornblende-quartz-biotite schists and shists of other composition. The total thickness of the suite in the northern part of Saksahan and Northern iron ore districts is up to 2,000-2,500 m. Towards the north, this parameter significantly decreases, the suite outcrops in the south part of the Saksahansk district, and the suite is absent within the Southern and Inhuletsk districts.

According to earlier researchers (Stepanuk,et. al., 2011), outcrops of amphibolites occur also in the area of the Inhulets River, east of Rahmanivka village. They are dark-grey with greenish tone, and of fine-average grained structured texture. According to the mineral composition, they differ: amphibole represented by actinolite and hornblende, - 45-55%, acid plagioclase – 30-50%, quartz – up to 10%, biotite and chlorite – up to 5%, rarely – epidote and carbonate. Accessory minerals are represented by zircon,

apatite, ilmenite, tourmaline, rutile, and leucoxene. In these amphibolites, pyrite and pyrrhotite ore minerals rarely occur. According to the result of study of the age of the zircon in these amphibolites (Stepanuk, e. a., 2011), it was determined that they belong to the Konsk series (Paranko, e.a., 2007).

The objective of this paper was conditioned by active development of industrial tourism (Samoylenko, Dubytska, 2012) within the Kryvyi Rih Basin. The amphibolites of the Kryvorizka suite are unique as a geological object (Nesterovskyy,Krynutska, 2006), especially for Geology students as an example of rocks formed from effusive eruption products during regional metamorphism. Unfortunately, recently as a result of abandoning of this territory, low level of maintenance, the outcrops of amphibolites have lost their esthetic attractiveness. The study was performed in scope of the scientific topic (Gritsay, 2017) ordered by the open joint stock company Kryvyi Rih Iron Ore Enterprise.

Analysis of previous studies. The amphibolites within the Ukrainian Shield have been researched in several stages (Sukach, 2015). The first stage of studying the amphibolites was conducted by I. S. Usenko in 1940s, when the general picture of their distribution and peculiarities of composition was described. The second stage occurred after the 1950s, when complex scientific-research studies were conducted. According to the latter, the main areas of distribution of amphibolites within the Ukrainian Shield were designated and documented. The third stage was related to the studies of geochronology and geologic-formational orientation, which resulted in the obtaining of data on the age of the amphibolites (Sukach, 2015).

The amphibolites of the Novokryvorizka suite within the Kryvorizkyi Basin are exposed in natural outcrops on the slopes of the Inhulets and Saksahan rivers and slopes of the ravines which fall into these rivers. In the northern part of the Kryvbas, on the right slope of the Saksahan, natural outcrops with amphibolites of the Novokryvorizka suite are known, which border with concessions of the M. V. Frunze and Yuvileina mines. In the northern part of the Kryvbas, these amphibolites are exposed in outcrops on the left slope of the Inhulets River near the Quarry of the Northern Mining and Processing Enterprise and on the left slope of the Inhulets River near Lativka village.

There are several technogenic outcrops of amphibolites of the Novokryvorizka suite in the mine workings of quarries and mines. The most representative of them is located on the eastern capital pit side of the Quarry of the Inhulets Mining and Processing Enterprise.

Studies on the outcrops of amphibolites as a geological relic were performed by different organizations at different periods (Gritsay, 2017; Manyuk Vad., Manyuk Vol., 2011; Manyuk Vol., Manyuk Vad., 2018). The studies were conducted for clarifying the petrographic composition, area of distribution, coordinates of location and possibility of preserving the amphibolite outcrops as a geological relic (Manyuk Vol. V., Manyuk Vad. V., 2018). The study by Manyuk Vol. V., Manyuk Vad. V., 2018 provided information regarding relationship between amphibolites and spilite-keratophyre formation, where the amphibolites are the products of metasomatic transformation of paleotypic basalts or spilites. In their study, these scientists proved that the amphibolites are derivatives of the basalts of an ancient volcano, which is unique for the Kryvyi Rih Basin.

Methods of field surveys. The examined outcrops of amphibolites in the administrative aspect are located in the Saksahan districts of Kryvyi Rih, 500 m east of the Rodina Mine (Kryvbaszalizrudkom PJSC).

The outcrops of amphibolites are located on the steep slope above the Saksahan River. The outcrop was accurately examined (Fig. 1). According to the data of observations made by the authors, the amphibolite outcrops occurred only on the slope of the river as a narrow strip (around 97 m) of separate outcrops overgrown by bushes, trees and covered by shifted fractures of loams and soil-plant layer. Currently, the area of the outcrops of amphibolites is 12,500 m^2 (1.25 ha). Outcrops of the amphibolites are designated by two poles marked on Fig. 1.

According to the field identification, the rocks which formed the outcrops are represented by amphibolites of dark grey to black colour with green tone. The instrumental connection of the points of sampling was made using a GPS navigator. Macroscopic study included geological description of the outcrops and their schematic framing, macroscopic characteristic of rocks, formation of geological objects. We identified and macroscopically studied all the local outcrops of rocks and measured their sizes (length, width, height). It was determined that the amphibolite outcrops are not systematic, the size of the largest outcrop is around 9 x 2 m (Fig. 2a), all the rest are of much smaller size.

The amphibolites are characterized by different extent of schistosity, fracturing and hypergenic alteration (Fig. 2b). They are practically ubiquitously overlain by loess-like loams and soil-vegetative cover.

As a result of geological surveys, a schematic image of the amphibolite outcrops was developed (Fig. 3). The image was developed with consideration

Fig. 1. Location of the points of observation of the amphibolite outcrops.
Modern outcrops of amphibolites, marked by points "Pole 1" and "Pole 2"
A-1, A-2 … A-11 – points of extraction of the samples

of the layers of outcrops that are visible on the earth surface.

Microscopic studies (diagnostic of minerals, quantitative mineralogical calculations in standard preparations, microphotography) were undertaken in the laboratories of the Geology and Applied Mineralogy Department of the Kryvyi Rih National University using the standard methods with serial petrographic and mineralogic microscopes (NU, POLAM, MP-4, MP-6).

Mineralogical and petrographic composition of amphibolites. Within each of the local amphibolite outcrops, ordinary petrographic samples were extracted, the total number of which was 11. In the laboratories of the Kryvyi Rih National University, we performed cutting of the selected samples, out of which lumps of 6 x 9 cm were prepared for the following mineralogical studies (Fig. 4).

Out of the material of each sample, transparent and polished thin sections were prepared for microscopic mineralogical studies in the standard preparations and for performing quantitative mineralogical calculations, clarification of the textures and structures of the amphibolites and the pattern of spatial interrelation of the minerals. In correspondence to the obtained data, in structural and texture aspects,

а б

Fig. 2. Outcrops of amphibolites around the Saksahan River
a – amphibolite outcrop of maximum size (9 x 2 m);
b – schisted, fractured, intensely weathered amphibolites (1.1 x 0.8 m).

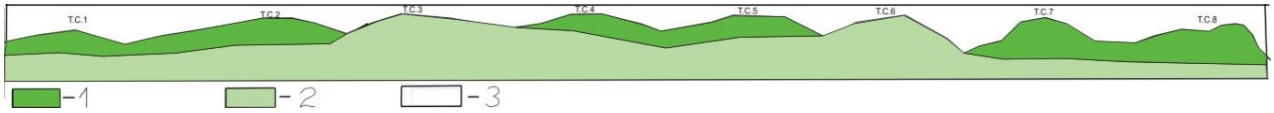


Fig. 3. Schematic image of amphibolites within the studied area of the Kryvorizkyi Basin.
1 – chloritized amphibolites; 2 – unchanged amphibolites; 3 – vegetative cover;
OP1-…..-OP8 – observation points.

the examined amphibolites are characterized by non-homogeneity, which is manifested by schistosity and fracturing. Rarely manifestations of massif texture of amphibolites were observed. Their colour changes from dark grey, dark green to grey-green, brown-green. The amphibolites have obtained a brown tone from numerous transversal veinlets of iron hydroxides.

biotite crystals. Size of the crystals is 2 mm to 0.7 mm in length (Fig. 5, c, d). Most of them are represented by simple twins. Cleavage is perfect to prism.

Biotite occurs in the form of small (0.1-0.3 mm) flat plaque-like, scale-like crystals which have lower level of idiomorphism compared to plagioclase crystals (Fig. 6). Its content ranges 5 to 30 % vol.

a b

Fig. 4. Lumps of ordinary samples 8 (a) and 2 (b) of amphibolites.

According to the microscopic studies, it was determined that rock-forming minerals are hornblende, plagioclase, quartz and biotite.

Hornblende (Fig. 5a) is present in the composition of amphibolites in amount from 35 to 65% vol. Significant fluctuations of the content are related to the variability of the chemical composition of the initial basaltoids and amount of additional clastic material in the compound of the effusive products. It forms elongated flat plaque-like xenomorphic and hypidiomorphic crystals, the size of which is up to 1.5-2 mm at maximum measurement (Fig. 5, a, b). Sometimes simple twins occur.

The colour of the mineral is grey-green with a bluish tone, pleochroism is from blue-green on Ng to light yellow on Np. Cleavage is perfect to prism with the angle between the surfaces measuring 55°. The extinction angle is up to 15°. The weathered types of amphibolites were observed to have heightened fracturing of the crystals of the hornblende.

Plagioclase is represented by andesine-labradorite. Its content ranges from 30 to 60 %vol. It is present in the form of flat plaque-like crystals, the level of idiomorphism is slightly higher compared to the

The mineral is yellow-brown with pleochroism from dark brown on Ng to light yellow on Np. Cleavage is perfect to the pinacoid.

Chlorite is present as an epigenetic mineral which in the process of weathering replaced biotite (Fig. 6b). Its amount ranges from 0 to 10 %vol. It has inherited the size and shape of initial xenomorphic plastic individuals of biotite. The colour of the mineral is light green, pleochroism is low. Cleavage is perfect to pinacoid. The interference colours are different tones of grey.

Apart from the silicates, amphibolites contain a small amount of ore minerals represented by magnetite, goethite and martite.

Magnetite, usually, occurs as separate small additions of isometric shape of 00.1 mm to 0.05 mm size (Fig. 7a). Content of the mineral is around 0.1 % vol.

Martite product of weathering of magnetite is represented by xenomorphic aggregates which have morphologically inherited the forms of the initial magnetite. We observed hypergenic replacement of magnetite by goethite (Fig. 7b). The size of the magnetite ranges from 0.1 mm to 0.6 mm.

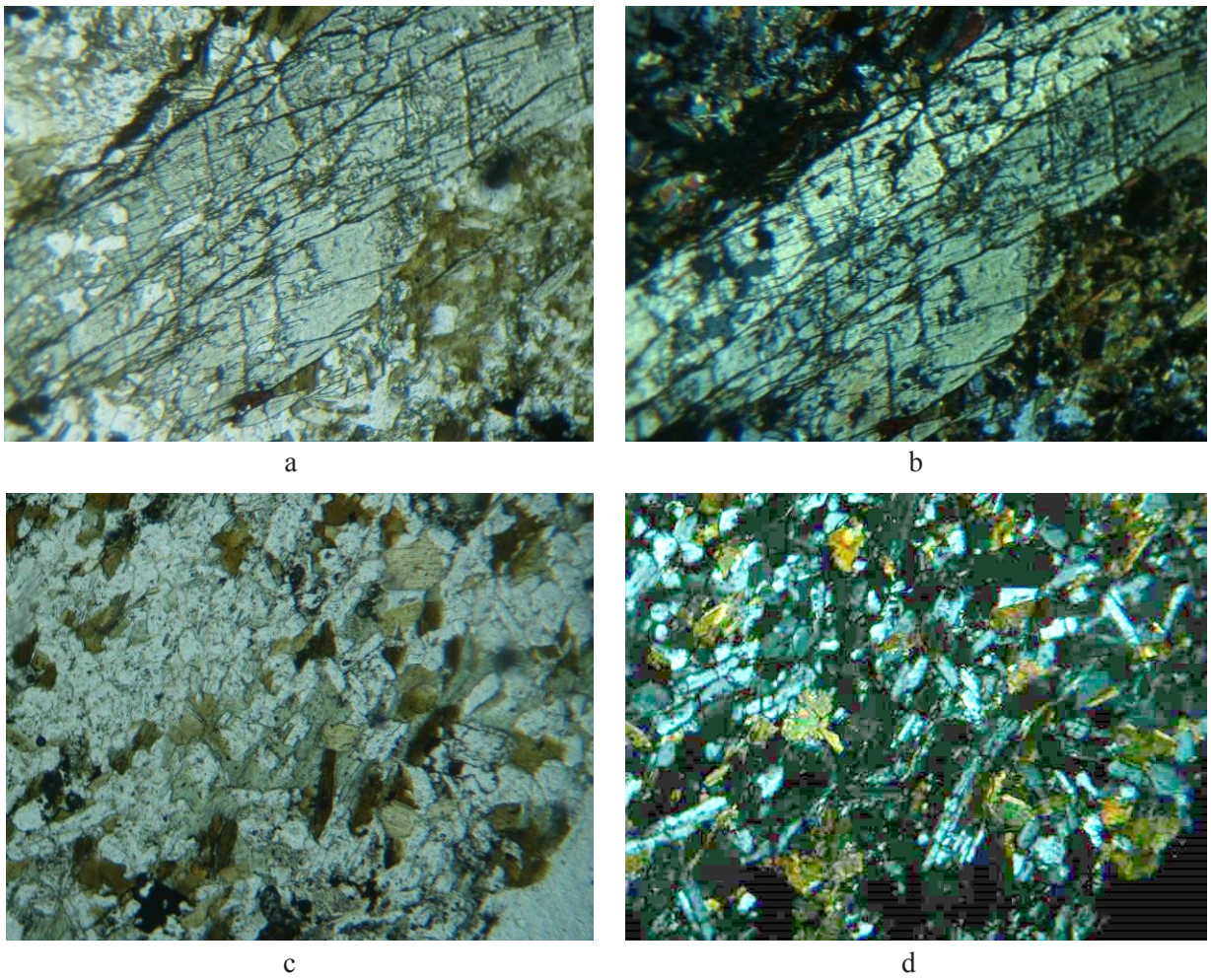


Fig. 5. Peculiarities of the structure and mineral composition of the amphibolites.
a-b – elongated large flat plaque-like crystals of the hornblende
c-d – flat plaque-like crystals of plagioclase (c – white; d – different tones of grey).

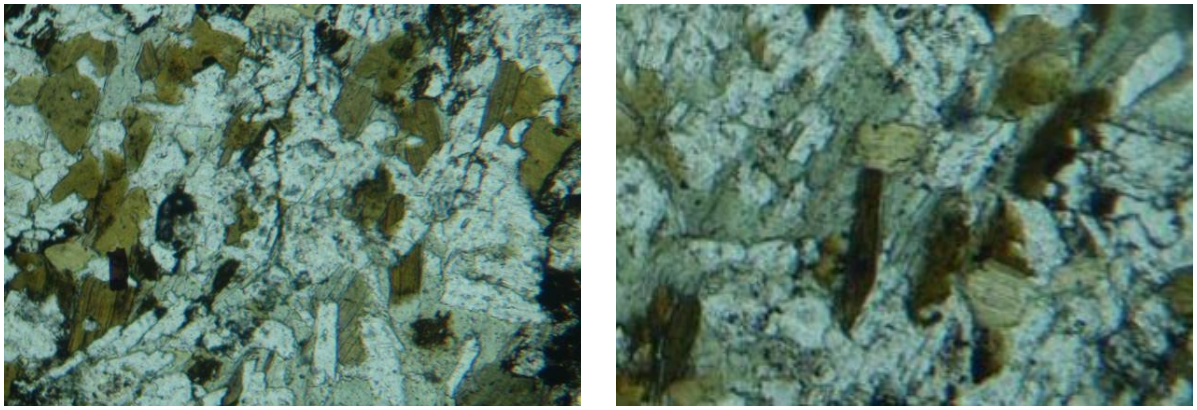
Goethite is present in the compound of amphibolites which were the most affected by weathering . It forms films along the fractures of the containing rocks, and also has metasomatically replaced all ferriferous minerals, mainly martite.

Results of the macro- and microscopic examinations of the materials of samples extracted from the outcrops confirm the stratigraphic confinement of these metabolites to the Novokryvorizka suite of the Kryvorizka series.

The uniqueness of the geological object. Currently, amphibolites have outcrops on the steep right slope of the Saksahan River in the form of a narrow, interrupted strip – this is a result of manifestation of shift of the loams and the soil-vegetation layer of the Quaternary period and sodisation, and overgrowing by shrubs and trees. The outcrops of amphibolites are represented by separate small rocky formations. The results of examinations of recent years indicate that the size of the amphibolite outcrops has a tendency towards reduction.

Furthermore, currently due to insufficient preservation of the relic, the continuity of the section of the Novokryvorizka suite has been lost. The upper parts of the fragmented outcrop are represented chiefly by weathered amphibolites; their slightly weathered or non-weathered types covered by shifted material and vegetation. Mineralogical, petrographic, geochemical variability of the section was not observed due to the non-systematic character of formation of outcrops of the rocks.

However, the outcrops have a certain scientific value determined by: 1) presence of several mineral types of amphibolites in the structure; 2) presence of layers and lenses of metaclastolites of different initial granulometric composition among them; 3) manifestation of vertical mineralogical zoning of the weathering rind – from intense hypergenically altered to initial amphibolites not affected by weathering; 4) textural non-homogeneity of amphibolites: manifestation of massif, layered, schisted, fractured, veinlet textures.



a b

Fig. 6. Shape of biotite crystals (brown) and chlorite (green) and peculiarities of their spatial interrelations with individuals of other crystals of amphibolites. Incident light; without analyzer; 50^x zoom.

The relic could be much more attractively displayed if the amphibolite outcrop site were cleared of vegetation, debris and intrusive manmade structures with the use of additional equipment. Currently private houses are located at the distance of around 100 m above the amphibolites; some of the houses are not inhabited and ruined. Near the houses (upper part of the slope), construction waste is deposited. Near the outcrops, there is a territory of the preventorium of the workers of the Rodina Mine, which is currently unused and under guard. Its premises are partly ruined, overgrown by shrubs and trees, and look unattractive. On the opposite, left slope of the river, there is a zone of a former park and a recreation house which borders it. The river near the suspension bridge, located south of the amphibolite outcrops, is completely overgrown by shrubs and its slopes have become swamped. Between the bridges, there is a stream pool of the river. During the summer, significant algae blooms occur. Therefore the esthetic attractiveness of the territory is low.

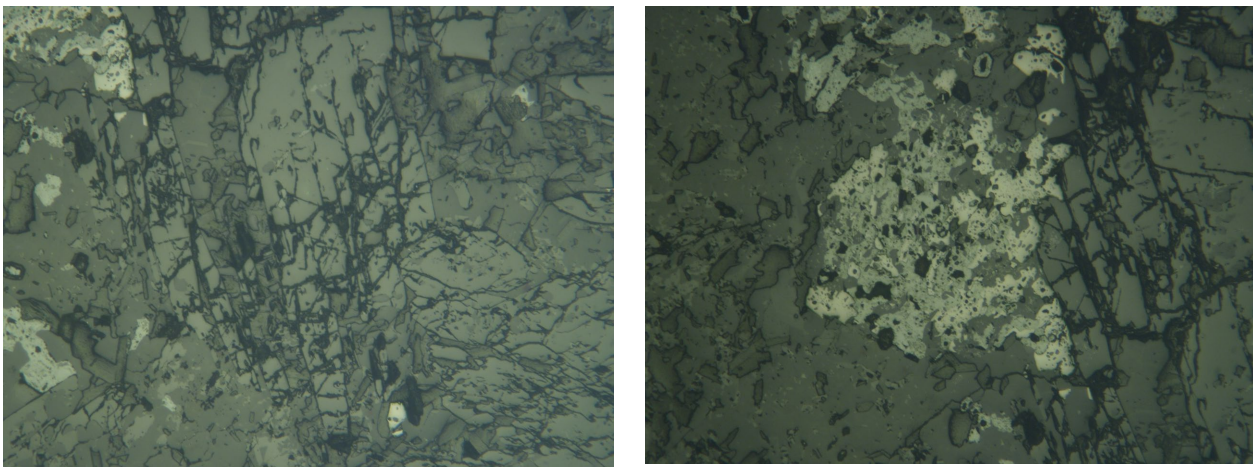
Conclusions.

1. Amphibolite outcrops are observed near the Rodina Mine of the Kryvbaszalizrudkom PJSC (Saksahan iron ore region of the Kryvyi Rih Basin).

2. Amphibolite outcrops are located on the western (right) slope of the Saksahan River in the form of a chain of small rocky outcrops of total length measuring 97 m. The size of the separate outcrops does not exceed a few meters. Maximum sizes of outcrops are up to 9 x 2 m.

3. According to the field observations, the amphibolites are characterized by non-homogeneity, which is manifested by schistosity, fracturing. Rarely, there was observed manifestation of massif texture of amphibolites. Their colour changes from dark grey, dark green to grey-green, brown-green. The brown tone of the amphibolites is caused by numerous transversal veinlets of iron hydroxides. Locally, presence of quartz was observed.

4. According to the data of microscopic studies, it was determined that rock-forming minerals are



a b

Fig. 7. Peculiarities of morphology of individuals and aggregates of ore minerals.

a – isometric crystal of magnetite (light grey); b –porous aggregate of martite (light grey) with manifestation of replacement with goethite (grey); Dark grey – silicates, black – pores. Reflected light; without analyzer; 75^x zoom.

hornblende, plagioclase, quartz and biotite. Ore minerals are represented by magnetite, martite and goethite.

5. The scientific significance of this study and the educational value of the amphibolites are limited due to their low preservation level, their insufficient level as a representative object of mineralogical, geochemical, petrographic studies, and local history observations. However, after performing necessary measures for clearing the territory from shrubs, construction wastes, etc, and taking into account both data obtained by the authors of this paper and results of the studies conducted earlier, more detailed study on amphibolites of the Kryvyi Rih Basin is needed.

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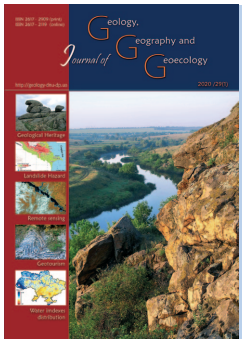

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Geoecological problems of decentralization (on Ternopol region materials)

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Abstract. The objective of the article is to study the essential geoecological problems of Ukrainian associated territorial communities. The necessity of implementation of effective environmental management, through introduction of an official responsible for improvement, ecology and sustainable development of the associated territorial communities in the administrative apparatus of communities is substantiated.The decentralization reform created a considerable potential for development of the local communities. The transmission of significant financial resources and powers provided the preconditions for the formation of competent associated communities. It was discovered during the study that despite of significant advantages of new administrative units, managerial approaches to the use and preservation of natural resources had not changed. Administration of forest, water, mineral and land resources is further carried out from the center. Practically no one cares about the main ecological problems, communities are drowning in wastes, using water polluted municipal waste with agrochemicals, and the last hectares of forests are being cut down and used as energy resources. In context of sustainable development, the priority issues to be solved for 38% of the communities in Ternopil region are the issues of an ecological nature the issues of an economic nature are priority for-34% of communities and the issue of the social nature – of 28% of comminities. In Ternopil region, as in one of the leaders in decentralization reform, 78% of community leaders consider high-quality water supply to be much more important than availability of cooperative or lighting of the streets. The most actual in regional communities are issues concerning sorting and utilization of wastes, lack of treatment facilities and an outdated drainage system.The article proposes amendments to the Article 19 of the Law of Ukraine «On Environmental Protection», regarding the extension of powers of village, settlement, city councils as well as associated territorial communities in the field of Environmental protection. The necessity of introduction the position of ecologist responsible for improvement, ecology and sustainable development of the community is substantiated. His duties are the following: monitoring of components of the environment; struggle with the illegal landfills, regulation of processes of economical nature management; optimization of land use; control of rational water use, preparation of a submission for the creation of new protected objects of local importance; creation of recreational and green zones.

Key words: environmental management, sustainable development, decentralization, associated territorial communities, environmental problems, position of ecologist.

Геоекологічні проблеми децентралізації (на матеріалах Тернопільської області)

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Анотація. У статті висвітлено основні геоекологічні проблеми об'єднаних територіальних громад України, обгрунтувано необхідність впровадження ефективного природоохоронного менеджменту, через запровадження в адміністративному апараті громад посадової особи відповідальної за благоустрій, екологію та сталий розвиток об'єднаної територіальної громади. Реформа децентралізації, створила значний потенціал для розвитку місцевих громад. Передача значних фінансових ресурсів та повноважень забезпечила передумови формування спроможних об'єднаних громад. У ході дослідження було виявлено, що попри значні переваги нових адміністративних одиниць, менеджерські підходи до використання та збереження природних ресурсів не змінилися. Управління лісовими, водними, мінеральними та земельними ресурсами і надалі здійснюється з центру. Основними екологічними проблемами практично ніхто не переймається, громади тонуть у відходах, вживають забруднену агрохімікатами та комунальними стоками воду, останні гектари лісів вирубуються та використовуються як енергетичний ресурс. В контексті сталого розвитку, першочерговими для вирішення у 38% громад Тернопільщини є питання екологічного характеру, у 34% – економічного характеру і у 28% – соціального характеру. В Тернопільській області, як одній із лідерів у реформі децентралізації, 78% керівників громад вважають якісне водопостачання набагато важливішим від наявності кооперативу чи освітлення вулиць. Найбільш актуальними в громадах краю, є проблеми пов'язані із сортуванням

та утилізацією відходів, відсутністю очисних споруд та застарілою системою водовідведення.У роботі запропоновано внесення змін до статті 19 Закону України «Про охорону навколишнього середовища», щодо розширення повноважень сільських, селищних, міських рад, а також об'єднаних територіальних громад, у галузі охорони навколишнього природного середовища. Обгрунтовано необхідність запровадження посади еколога – відповідального за благоустрій, екологію та сталий розвиток громади, із наступними посадовими обов'язками: моніторинг компонентів навколишнього середовища, боротьба із незаконними сміттєзвалищами, регулювання процесів ощадливого природокористування, оптимізація землекористування, контроль раціонального водокористування, підготовка подання на створення нових заповідних об'єктів місцевого значення, створення рекреаційних та зелених зон.

Ключові слова:природоохоронний менеджмент, сталий розвиток, децентралізація, об'єднані територіальні громади, екологічні проблеми, посада еколога.

Introduction. Ukrainian state reforming processes nowadays provide systemic changes in the principles of management of certain areas of public life causing conceptual managerial approaches to replace outdated methods of planned management. Thus, the basic principles of sustainable development concept should become priorities in shaping the new model of management of economic, social and natural resources.

Decentralization reform appears to be one of the effective reforms implemented in Ukraine. Decentralization is understood as transfer of powers and finances from the state power to local self-government bodies. Provisions of the European Charter of Local Self-Government and the world standards of public relations in this area form the basis of this policy. The focus on the balanced use of natural resource potential, the development of local infrastructure, the improvement of natural living conditions of the people, as well as the provision of services in the health, education and social relations can only be possible when the economic, natural and social subsystems are coordinated to ensure their conflict-free development.

The legal basis for a radical change in the governmental system and its territorial basis at all levels began to emerge in 2014. At the beginning of 2019 876 associated territorial communities (ATC) have already been established based on the Law of Ukraine «On Voluntary Association of Territorial Communities» (Legislation of Ukraine, 2015). These ATCs comprise 4010 former local councils with more than 9 million people. International experts consider such rates of inter-municipal consolidation to be very high (Decentralization, 2019).

The package of laws on extension of powers of local self-government bodies and optimization of the provision of administrative services allowed to delegate the necessary level of authority to the local self-government bodiesso they could provide basic administrative services. However, in our opinion, among legislative acts and bills, there is a lack of those regulainge legal relations in the environmental and ecological spheres. Today, despite the need to solve a number of economic and social problems, the environmental problems of citizens are the most important in most ATCs. They include a problem of collecting and utilizing solid household wastes, the problem of qualitative drinking water supply, sewage drainage and its removal, the problem of creating field-protective forest belts and green areas within settlements, and finally, the problem of optimizing land use for more efficient and diverse use of productive and unproductive land plots, as well as the problem of effective environmental education of people. Little attention is paid to solving these and other geoecological problems nowadays, since the ATC management structure lacks a position of manager for ecological development and improvement.

In this regard, the **purpose of the article** is to study the main environmental problems of the associated territorial communities of Ukraine and its individual regions; to substantiate the necessity to implement effective environmental management through the introduction an official responsible person in the communities' administrative apparatus for improvement, resolution of environmental problems and sustainable development of ATCs.

Review of the literature. Materials and methods of the study.A narrow circle of scientists is engaged in the study of problems of environmental and ecological management in the context of decentralization. Issues of this nature are often raised by public activists, newly elected community leaders and various international organizations that promote local self-government reform in Ukraine.Among the most recent scientific researches in the field of decentralization it should be noted the works of Ye. Khlobistov (2016), V. Matyukha, I. Bistryakova, D. Klinovy (2015). Land resources management in conditions of decentralization and geoecological problems of using land by combined territorial communities is covered in the publications of Tretyak A.M. (2015), Kostyshyn O. (2015), Kuzyk I. (2018) and a number of other specialists conducted. Problems of administrative-territorial reform of Ukraine and the formation of capable communities are engaged by L. Zastavetska (2015), Ya. Oliynyk (2016) and others. N.Kotenko and T. Illyashenko (2015), conducted researches in the field of fiscal decentralization and provision of public eco-

logical services. Economic mechanisms of nature management are analyzed in the works of V. Boronos, I. Sklyar, M. Kostel (2012). Decentralization in terms of managing sustainable development processes is considered in the studies of Bardhan P. (2002), Holden E., Linnerud K. and Banister D. (2014). The problem of decentralization and administrative ecology at the end of the XX century was considered by Brown P. (1987). Research in Tereshina M., Tambovceva T. and Khalafyan A. (2018) concerning the socio-economic potential of rural communities are relevant in the context of decentralization.

The theoretical and methodological basis of the research is the fundamental provisions of ecological management and auditing, geoecology, ecological and constructive geography, geographical native land and a number of legal acts of state importance. In preparation of the article the theoretical and applied developments of such domestic and foreign scientists, articles in periodical professional editions, stock materials of the State Statistics Service of Ukraine, resource and analytical center «Society and Environment», Department of Ecology and Natural Resources of the Ternopil Regional State Administration.

Materials for writing the article were the results of the ATC representatives' survey, on the relevance of environmental problems and the prospects for their solution in the context of decentralization reform. Polls of community representatives were conducted using questionnaires. The questionnaires were prepared in advance. The questions raised were of a closed and open type. Answers to the questionnaire were provided by community leaders or authorized persons (deputy, secretary). As part of the survey, 42 communities were interviewed. According to the results of the survey, charts were created (figures 2,3,4), that cover the results of the sociological research. The survey was conducted directly by the authors of the article, by the method of V. Verbets (Verbets, 2008).

The wide range of phenomena, processes and factors an alyzed in the article led to the necessity of using general scientific methods: statistical (analysis of the current state of decentralization reform, the number of existing ATCs and their financial and resource support), assessment (assessment of the main geoecological problems of territorial communities), descriptive (characteristic problems of waste management, watersupply and drainage, landuse by ATC), comparative (comparison of actual ecological and socio-economic problems in the context of the sustainable development of communities). Also, in the course of the study, special scientific methods were used: cartographic (mapping of the territory of Ukraine covered by the acting ATC), geoinformation, ecological-geographical analysis and others.

Resultsand their analysis. In Ukraine, the biggest amount of associated territorial communities is created in Dnipropetrovsk (63), Zhytomyr (56), Cherkasy (55) and Zaporizhzhya (49) oblasts. About 40 ATCs already operate in Volyn, Poltava, Ternopil, Khmelnytsky and Chernihiv oblasts. Outsiders in the decentralization reform are Kharkiv (17 ATCs), Kyiv (17 ATCs) and Zakarpattia (6 ATCs) oblasts (Decentralization, 2019).

The largest percentage, 45% of territories covered by the existing associated territorial communities

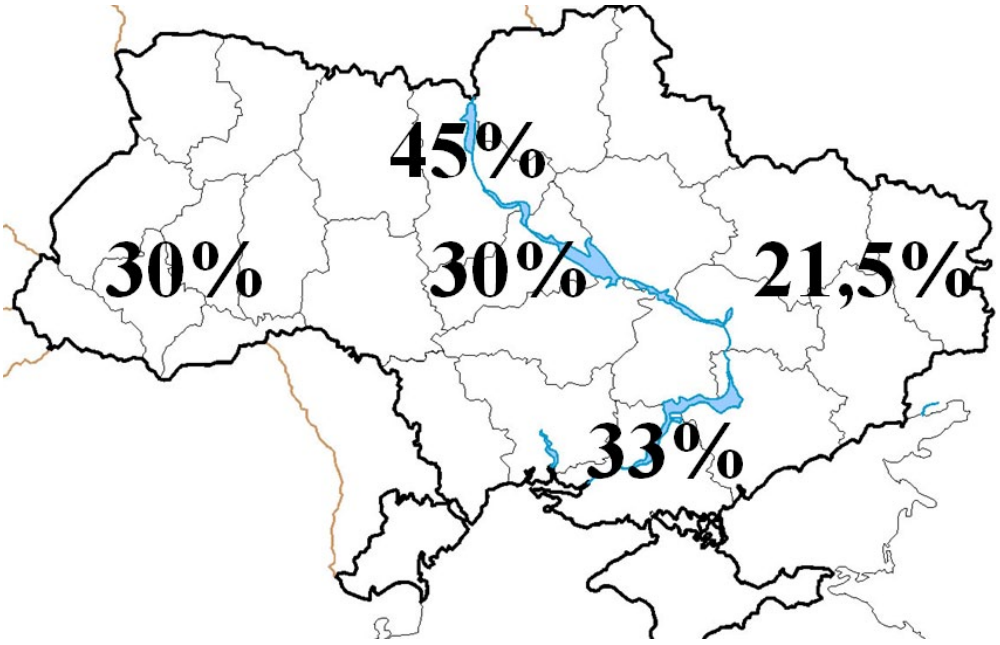

Fig. 1. Percentage of the territory of regions of Ukraine covered by operating ATCs

is observed in the northern region of our state since most of these administrative units were created in Zhytomyr, Volyn and Chernihiv oblasts (Fig. 1).

Southern (Odesa, Mykolayiv and Kherson) regions are ranked second with decentralized territories covering 33% of their total area; some 30% of the territory is now part of ATCs in the western and central regions. Yet only 21.5% of the territories are occupied by associated communities in the east of Ukraine, which is explained by the difficult economic situation in most settlements of the region and ongoing military actions.

ATCs operating with unresolved strategic issues in the field of ecological, social and economic development occupy about a third of the territory of Ukraine. While financial decentralization has been legally regulated in a certain way, with appropriate regulations and laws adopted, powers delegated to local communities and changes made to the budget code, no steps have been taken in the context of the environmental component of sustainable development, except for changes in environmental tax deductions. At the same time, for most ATCs, the issue of a safe environment remains the most urgent and calls for immediate solution.

As the part of the United States Agency for International Development project (USAID), the Global Communities «Decentralization brings better results and effectiveness», a survey was conducted among 75 ATCs in 7 oblasts of Ukraine (Dnipropetrovsk, Ivano-Frankivsk, Kharkiv, Kherson, Kirovograd, Ternopil and Mykolaiv). According to the results of the survey, the majority of respondents (representatives of ATCs) ranked environmental factors first among those influencing the quality of life in the communities. According to the interviewed persons, the following components are crucial to the quality of life in the territorial communities:

1. Cleanliness and availability of green recreation zones;

2. Road infrastructure (high quality roads with asphalt covering);

3. Illumination of streets.

The survey showed that problems with solid waste management, river cleanliness, ponds and lakes, and the problem of drainage (lack or unsuitability of sewage networks) are among the most acute ecological problems in 75 participating ATCs. Such issues as cemetery keeping and air quality were most successfully addressed in surveyed communities.

Being a participant in the «DOBRE» program, Ternopil region is one of the leaders in the number of ATCs created (42), 12 of which (Baikivtsi, Velyki Hayi, Vyshnivets, Husyatyn, Zavod, Zolotyi Potik, Ivanivka, Mykulyntsi, Skala Podilska, Skalat, Terebovlya and Shumsk communities) participate in the US Agency project.

Within the Community Sustainable Development Strategy framework, Ivanivka ATC with the support of the United States Local Democracy Development Foundation (USAID) the strategic objective of a clean and safe environment for the human being in the environmental sphere is identified. This strategic objective involves performing more than ten tasks, which are grouped into three key operational objectives:

1. Purification and reclamation of territories under the ecological threat, together with raising the level of ecological consciousness of the inhabitants (this includes: cleaning and improvement of ponds, renovation of green spaces, parks, environmental and educational activities, etc.).

2. Commercialization of natural and landscape resources (this includes: creating recreation areas, restoring fish population in ponds, forming a community of fishermen).

3. Organize waste management (including: eliminating natural garbage dumps and developing a waste sorting concept).

Such a spectrum of diverse nature protection problems encountered by residents and the administration of ATCs not only in Ternopil region, but also in Ukraine as a whole, makes us think about the prospect of their solution. In different regions of Ukraine environmental problems have their different vectors of direction. ATCs in the eastern regions of Ukraine face environmental problems primarily related to the mining industry, air and water pollution. Issues such as unregulated recreational activities, illegal felling of forest resources, and solid waste mistreatment are typical for the western regions. The central areas are characterized by high plowed area, pollution of rivers and ponds. North of Ukraine suffers from radiation pollution, landscape destruction due to illegal amber mining and deforestation. Southern areas are characterized by problems of soil degradation, unregulated recreational activities, pollution of coastal strips, etc. Yet three key ecological problems are typical for the whole of Ukraine: solid waste mismanagement, low water quality (including drinking water and sewage) and biodiversity conservation (expanding the network of protected sites and conservation areas, reducing the intensity of deforestation and plowing).

We conducted research on the most important ecological problems of the ATCs of Ternopil region by interviewing respondents. The results of the survey of representatives of 42 ATCs in the region were

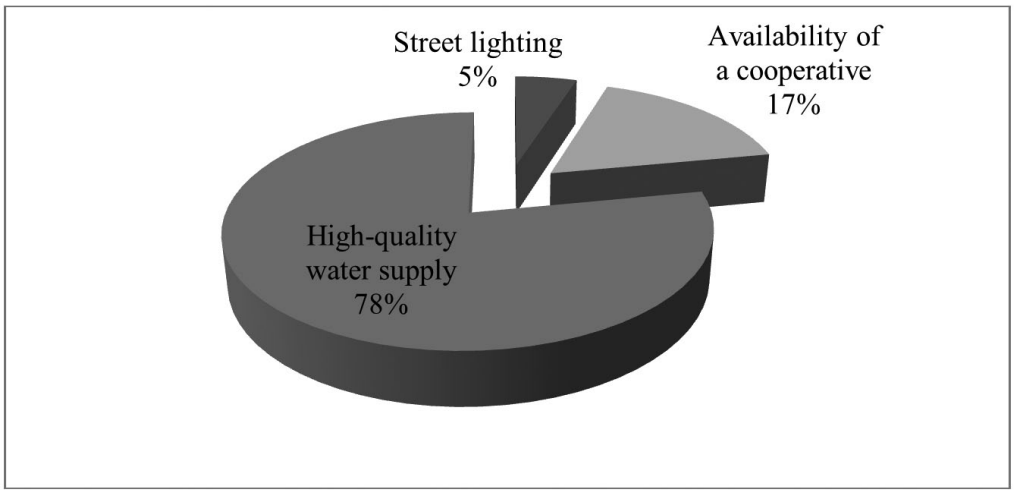

Fig. 2. Response of survey participants (representatives of Ternopil region ATCs) to the question: What issue is the most pressing for your ATC?

predictable. When asked to choose the most pressing issue for their ATC from the three options provided, 78% of respondents ticked high-quality water supply. Availability of a cooperative and street lighting options were chosen by 17% and 5% respectively (Fig. 2).

When asked about areas of nature management which they consider to be the most problematic, representatives of Ternopil oblast responded that problems with use of water, subsoil and land use remain among the pressing ones, yet the most important issue is solid waste management (Fig. 3).

Utilization, recycling, solid waste collection and disposal issues are today urgent practically all over Ukraine. Some ATCs partially solved these problems by signing contracts with waste collection and disposal services, installing waste sorting tanks, etc. The European Union is providing significant assistance in dealing with household wastes. Many grant projects on this topic have already been implemented in Ukraine, but many of them are still not open yet.

We have analyzed the geoecological situation in the context of solid waste treatment in the communities of Ternopil region. According to the register of waste disposal sites (Department of Ecology and Natural Resources of Ternopil Region, 2018), only 15 of the 42 ATCs in Ternopil region have authorized and certified landfills. More than 90 solid waste landfills in the oblast are out of work, 25 of which are within the existing ATCs. At the same time, there are no authorized dumps in such large communities as Lanivtsi, Melnytsia-Podilska, Khorostkiv and Shumsk, where the population is 12-20 thousand people. Where should members of these communities dispose of household waste, who should take care of it and who is responsible for the treatment of solid waste? These as well as some other issues remain open.

ATCs with functioning dumps face equally difficult problem. After all, as their own observations show, the basic sanitary-ecological standards are of-

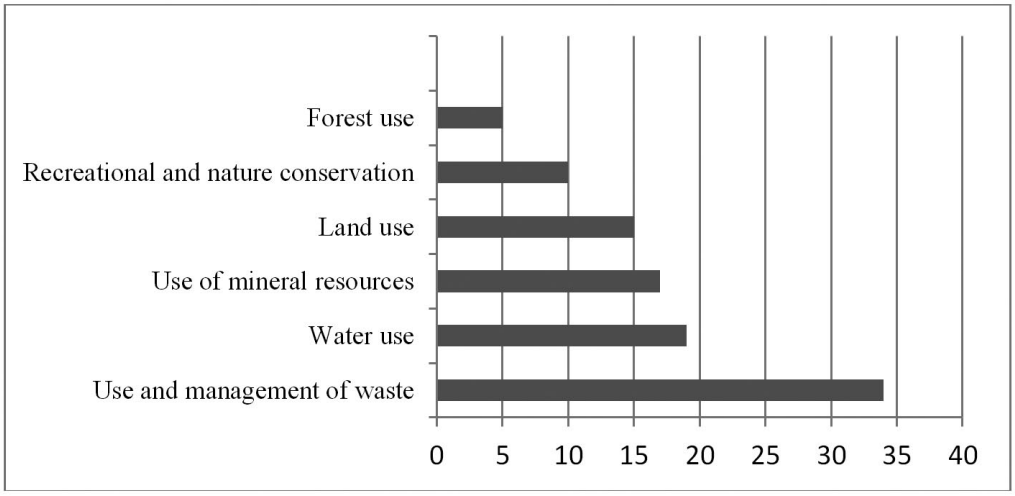

Fig. 3. Response of survey participants (representatives of Ternopil region ATCs) to the question: What area of nature management is the most problematic for your ATC? (%)

ten not observed at such objects: the distance from the nearest settlements is less than 500 m, there is no road with hard covering, open water reservoirs (rivers, reclamation ditches) are located nearby, and the necessary protective forest belt is missing, and so on. In Ternopil oblast, the design volume of all authorized landfills located within the ATCs amounts to 945 thousand m^3 of wastes. Over 328 thousand people live in these communities. On average, over a year a resident of a private house with a homestead land produces 1.2 m^3 (or 550 kg) of household waste (Stol`berg, 2000). Thus, all citizens who live in the ATCs of Ternopil region produce about 395 thousand m^3 of waste per year. That means that all existing landfills in the associated communities of Ternopil oblast will be filled in 2.5 years. Waste sorting and processing appears to be the only way out of this situation. Residents of territorial communities are obliged, first of all, to implement the changes to the Law of Ukraine «On Wastes» and strictly comply with the Article 32 of this Law: «In order to restrict and prevent the negative impact of waste on the environment and human health, unprocessed (untreated) household waste dumping is prohibited starting on January 1, 2018». Business entities that provide waste removal services should create conditions for its separate collection (Article 17 of the Law of Ukraine «On Wastes»). According to the current legislation, the sorting of domestic waste, the conclusion of contracts for its removal, the organization of authorized landfills in communities should be monitored by an official in charge who is not currently present at most of the ATCs. Therefore, the issue of waste management remains urgent and unresolved for most of the newly created administrative units of Ukraine.

Analyzing the problems of water use, which among others include water supply, drainage, pond management, state of natural watercourses, etc., we should note that one of the most urgent problems is the problem of private household waste water utilization. In the vast majority of rural and urban communities, so-called «septic tanks» (cesspools) have been built to collect sewage. Only a small part of them meets the requirements, whereas the majority leaks waste water in the soil. Drinking water wells are often found within 10-20 meters of «septic tanks», which eventually will lead to their pollution with the infiltrate. The quality of drinking water deteriorates significantly. In addition, the removal and utilization of waste water remains unregulated. Locals in most cases just get rid of drains in forest plantations, gullies, beams, on fields. None of the services monitor this process. Thus, large-scale uncontrolled pollution of soils and groundwater horizons occurs within the boundaries of settlements and their environs, which will undoubtedly adversely affect the health of people.

In urban territorial communities, the problems with the utilization of municipal wastewater are also very pressing, since most settlements in Ukraine, and in Ternopil region, in particular, lack water treatment facilities, and their drainage systems are outdated and in an emergency. Often, wastewater from buildings gets into open water without cleaning, which in turn can lead to pollution of natural watercourses and even some horizons of groundwater.

The organization of the private households› waste water removal, monitoring of discharges of communal enterprises, fish breeding and restoration of pond management, centralized water supply, drinking water quality and a number of other issues in the field of water use, which are relevant to newly established ATCs, should be decided by an appropriate official or a special ecological unit, as for most associated communities, especially rural ones, water resources are the most valuable and essential for household management.

Problems of land use faced by the associated territorial communities are, first of all, due to the imbalance of the land structure, excessive chemicalization of agriculture, the use of land outside settlements, etc. Being a typical example, Ternopil region ATCs are characterized by high agricultural development of their territory amounting to 78% (65% of which is arable land) and low forestry, 11% (standard wood coverage being within 23-40%), about 5% of the land is developed (Tabl.), which in turn forms an unsatisfactory structure of land use with just 26% share of natural lands (Kuzyk, 2018). It is considered that the optimal share of natural lands should cover 50-60% of any territory, since at least 50% of the natural lands are necessary for the geosystem to maintain a dynamic equilibrium and perform its main stabilization and regenerative functions (Tsaryk, 2009).

The most urgent problem for 21 ATCs of Ternopil region is that of solid waste sorting and recycling; 7 ATCs suffer from the lack of treatment facilities; 6 communities have to cope with inadequate state of centralized water supply and drainage; illegal felling remains the biggest problem for 5 ATCs, while only 3 communities are not happy with the operation of local quarries.

The majority of people interviewed (representatives of Ternopil region ATCs) identified their priorities in solving the environmental problems. In the context of sustainable development, environmental protection issues call for immediate solution, whereas economic problems rank second, the administrative-

Table. The general structure of Ternopil region ATCs lands

Arable land	Hayfields, pastures and perennial plantations	Woods	Developed land	Land covered by water and marshes	*Share of natural land*	*Share of anthropogenic land*
65%	13%	11%	5%	2%	***26%***	*74%*

planning issues rank third, and the social ones are fourth in this list, which again confirms the urgency and necessity of developing a systematic approach to solving environmental problems in the newly created administrative units.

And who is there to solve environmental and ecological issues in ATC? Unfortunately, the appropriate officials practically do not exist in all administrative apparatuses of territorial communities. Until recently, the district environmental safety departments have been eliminated and the modern process of reforming the system of state supervision (control) in the field of the environment is just beginning. It is planned that the newly established the State Environmental Protection Agency will have 10 interregional territorial bodies, and local communities will be given specific functions for overseeing greenery, contaminated territories, hunting, observance of the regime of the natural reserve fund objects of local importance and the fight against poaching(Resource and Analysis Center, 2018). Although, it should be noted that at the moment, the environmental inspection reform does not give a clear answer to the question of what authorities will be given to local self-governments in the field of nature management. Local environmental issues are better solved and should be solved locally.

Similar studies were carried out by the participants of the «Society and Environment» Resource and Analytical Center project (Resource and Analysis Center «Society and Environment», 2018) – «Promoting Reforms in the Regions», monitored by the Institute for Economic Research and Policy Consulting in cooperation with the «European Truth». In September 2017, representatives of the center conducted a survey among the management of the mahority of Ukrainian communities. According to the survey results, 77.6% of respondents indicated that there was no structural unit or employee responsible for environmental problems in the management unit of their community (Fig. 5), and 71.4% agreed that they needed an institution or additional authorities in the field of environmental protection (Fig. 6). According to the research of «Society and Environment» Resource and Analytical Center only in some cases the ATC apparatus has an official responsible for environmental protection. As an exception, in some communities, a structural unit is created that combines its functions of improvement, land management and ecology. At the same time, the majority of respondents interviewed (representatives of ATC) believe that for the effective operation of the management apparatus it is necessary to extend the powers to control the felling of forests,

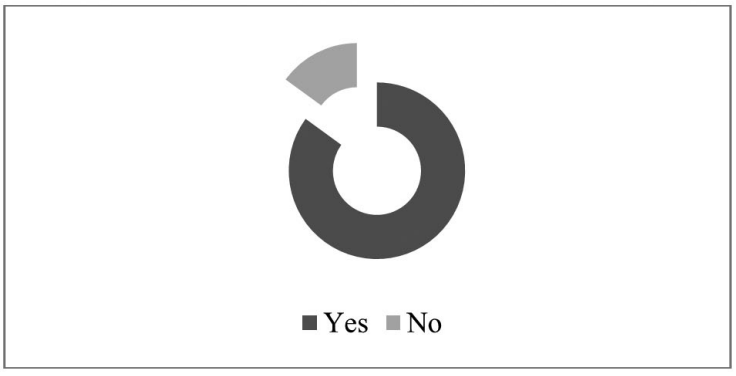

Fig. 4. Response of the survey participants (representatives of Ternopil region ATCs) to the question: Is there a need for an official responsible for the improvement and environmental situation in your community? (%)

We conducted a survey of representatives of Ternopil Oblast associated communities on whether an officer in charge for the improvement and environmental situation is needed in their community. The undisputed majority (85%) answered «yes», and only 15% (6 communities) said «no» (Fig. 4).

sewage and natural garbage dumps (Resource and Analysis Center «Society and Environment», 2018).

A position of ecologist is practically absent in most of the newly created administrative units, although the issue of environmental conservation and management of natural resources is quite pressing in

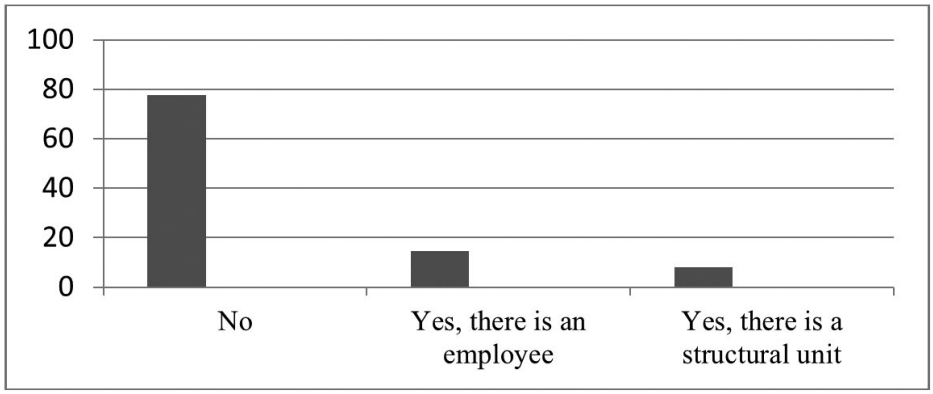

Fig. 5. Survey participants' responses to the question: «Is there a structural unit (official) responsible for ecology in the administration of your community?» (Resource and Analysis Center «SocietyandEnvironment», 2018)

the communities. A large number of surveyed ATC managers demand the extension of environmental authority and the introduction of an appropriate post. Such changes are possible only through appropriate legislative adjustments. Within the framework of this research, we propose to amend the Law of Ukraine «On Environmental Protection», in particular the Section IV «Powers of the Environmental Protection Authorities». The Article 19 The competence of the executive bodies of village, township and city councils in the field of environmental protection, after the words «city councils ...» to be supplemented with the words «associated territorial communities». The article also needs content filling with additional powers in the field of water supply and wastewater, sorting waste, control of contamination of territories and preservation of green spaces, forests, etc. In our opinion, Article 19 of the Law of Ukraine «On Environmental Protection» has the declarative nature of the theoretical component of environmental protection: environmental education, public awareness, environmental taxes, etc., while the practical component of the use and protection of natural resources, especially local ones, is omitted. Decentralization should become the mechanism of transfer the powers in the field of forest use, water use, and subsoil use. In accordance with the decentralization reform, other laws and regulations, in particular the Laws of Ukraine «On Flora», «On Fauna», «On Land Conservation», «On Wastes», «On Pesticides and Agrochemicals», «On Air Protection», «On Drinking Water and Drinking Water Supply», «On Hunting Economy and Shooting», as well as Water, Land and Forestry Codes.

In order to address local and regional environmental problems, the rational use of national and local natural resources, we propose to introduce in the associated territorial communities a position of an Ecologist who is responsible for improvement, ecology and sustainable development of the community. The duties of the environmental officer, responsible for the improvement and sustainable development of the territorial community will include:

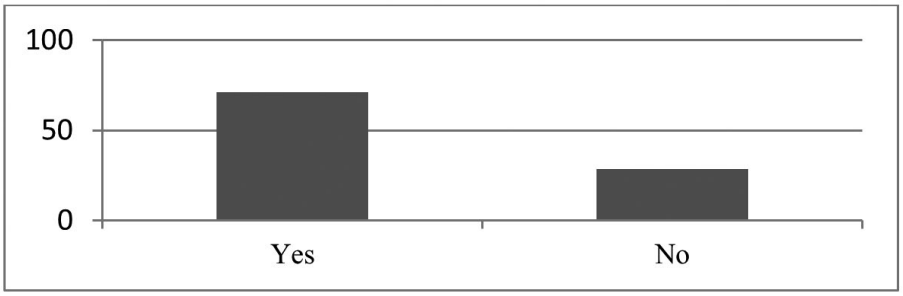

Fig. 6. Survey participants' responses to the question: «Do you need the authority of your community to exercise additional powers in the field of the environment?», (Resource and Analysis Center «Society and Environment», 2018)

- issues related to the monitoring of the environment quality (problems with natural garbage dumps, the creation of sanitary landfill sites; creation and control of the local waste water treatment plants operation; issues of illegal emissions and discharges);
- regulation of the processes of economical use of natural resources (problems of water supply and drainage, issues of optimization of land use – planting of forests and control of their operation, organization of water protection coastal strips, reduction of plow-

ing, regulation of development processes and transfer of land plots);

- assistance in increasing conservation areas within the communities, preparation of the justification for the organization of the Natural Reserve Fundobjects, preservation of unique and valuable natural complexes within the boundaries of the associated communities.

Local use of environmental taxes, the urgency of local environmental problems, and the priority in addressing environmental issues is a guarantee of the effectiveness of nature and environmental management at the local level. Through appropriate instructions of the Cabinet of Ministers of Ukraine and decrees of the Ministry of Ecology and Natural Resources of Ukraine, territorial communities will be able to make a step towards providing an environmentally safe living environment for their residents. After all, without solving key issues related to the preservation of the environment, coordinated ecological, social and economic development is impossible. At the same time it is important to prevent the complication of environmental problems through their solution, rather than to deal with the consequences of environmental ignorance. Effective management of natural resources on the basis of modern managerial approaches will help to ensure sustainable development of communities and successfully complete the process of reforming the administrative and territorial structure of Ukraine.

Conclusions. The study found is that, despite the significant benefits of new administrative units, managerial approaches to the use and conservation of natural resources (often the ones that form the local budget) remained unchanged. Management of timber, water, mineral and land resources is still carried out from the center. Practically no one cares about the main environmental problems. For example, in Ternopil oblast, only 15 from 42 ATCs have authorized landfills. In this case, it is estimated that the existing 25 landfills that operate within communities will be filled in the next 2-3 years. There is virtually no waste sorting, although there are legal grounds for this. In the communities there are no sewage treatment facilities; sewage from private households is removed to the outskirts of settlements in gullies and beams, which pollute soils and groundwater. The structure of land use is unbalanced in the majority of the territorial communities of Ukraine including Ternopil region, where the share of natural lands ranges from 25 to 45%.

The results of the survey of ATC representatives in Ukraine have shown that the cleanliness and availability of green areas is far more important than road infrastructure or street lighting. In 71% of the territorial communities, people spoke for the necessary additional powers in the field of environmental protection, since only 14% of the ATCs have an official or structural unit responsible for ecology and improvement. In most cases, these powers are exercised by the land surveyor, one of the deputy chairperson of the community or a separate utility company. Ensuring clean and safe environment for people is a top priority for the associated communiries of Ukraine in their activity. In Ternopil region, which is one of the leaders in decentralization reform, 78% of community leaders consider quality water supply far more important than existence of a cooperative or street lighting.

In this regard, the work proposes the introduction of the position of ecologist responsible for the improvement, ecology and sustainable development of the community. It is substantiated that the restructuring of ecological management in territorial communities should be legally enshrined through the relevant changes to the legislation, as well as the decrees and decisions of the appropriate departments. Consequently, the conceptual transformations of environmental and natural resources management in new administrative units will contribute to solving the local, regional and, subsequently, global environmental crisis.

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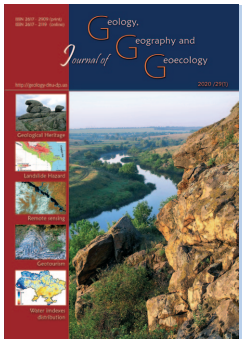

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Use of remote sensing data to study ice cover in the Dnipro Reservoirs

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Abstract. The information on the use of remote sensing data when studying the ice cover of the Dnipro Reservoirs is given. The main source of data was the images obtained by the satellites Sentinel-2, Landsat, Aqua and Terra. In addition, the observation data from the hydrological and meteorological stations were used. The combination of these data enabled to study the patterns of ice regime in the Dnipro Reservoirs, to specify some features that cannot be determined by regular monitoring. A typical feature of the ice cover of all reservoirs of the Dnipro Cascade, besides the Kyivske one, is the impact of hydropower plants (HPP) located upstream. The runoff of the rivers flowing into the Kyivske Reservoir significantly influences its ice cover. This is especially relates to the period of spring flood. Besides the Dnipro and the Pripyat Rivers, relatively small the Teteriv and the Irpin Rivers flowing from the south-west to the north-east have a rather significant effect on the ice cover of this reservoir. The distribution of ice cover in the Kanivske Reservoir, compared to the Kanivske one, is significantly less. In addition to more southern location and warmer climate, the city of Kyiv also influences the ice cover on it, namely due to the discharge of wastewater from several industrial enterprises, Kyivska TPP-5 and Bortnitska Station of Aeration are ones of them. The impact of Trypilska TPP, which located downstream, is also significant. The longest duration of ice cover in the Kanivske Reservoir is observed in its south-eastern part. A point of interest about the Kremenchuts'ke Reservoir is the fact that the ice cover in it remains for the longest period compared to the other reservoirs. The largest duration of ice cover in this reservoir is observed in the Sulska Bay. The typical feature of the Kamianske Reservoir is the accumulation of ice in its narrow parts. Within the Dniprovske Reservoir, the longest freezing period is observed in the Samara Bay. Besides the operation of hydropower station, the industrial enterprises of Kamianske town and Dnipro city have a great effect on the upper part of this reservoir. There are significant differences in the ice regime of the different parts of the Kakhovske Reservoir, which extends from the north-east to the south-west. The distribution of ice in its shallow north-eastern part is usually much larger than in narrower south-western part.

Key words: remote sensing, ice cover, air temperature, the Dnipro Reservoirs

Використання даних дистанційного зондування Землі у дослідженнях крижаного покриву дніпровських водосховищ

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Анотація. Наведено відомості щодо можливості використання дистанційного зондування Землі у дослідженнях крижаного покриву дніпровських водосховищ. Основним джерелом даних були зображення, отримані супутниками Sentinel-2, Landsat, а також Aqua і Terra. Крім того, використано матеріали спостережень на гідрологічних постах, а також метеостанціях, що прилеглі до водосховищ. Поєднання цих даних дало змогу дослідити закономірності льодового режиму у дніпровських водосховищах, знайти деякі особливості, які звичайний моніторинг зафіксувати не може. Характерною особливістю крижаного покриву всіх водосховищ каскаду, за винятком Київського, є вплив розташованих вище за течією ГЕС. Утворення криги у Київському водосховищі починається в його північно-східній частині. На крижаний покрив цього водосховища істотно впливає стік річок, що у нього впадають. Особливо це стосується періоду весняного водопілля. У цей час на крижаний покрив, окрім Дніпра та Прип'яті, впливають навіть порівняно невеликі річки Тетерів та Ірпінь, які течуть з південного заходу на північний схід. Поширення льодоставу у Канівському водосховищі, порівняно з Київським, істотно менше. Це зумовлено південнішим розташуванням водосховища, м'якішим кліматом, а також роботою Київської ГЕС і скидами підприємств м. Києва. До них, зокрема, належать Київська ТЕЦ-5 і Бортницька станція аерації. Нижче за течією додається вплив Трипільської ТЕС. Найдовше в Канівському водосховищі крига зберігається в його південно-східній частині. Цікавою особливістю Кременчуцького водосховища є те, що крижаний покрив у ньому звичайно зникає найпізніше. Найбільша тривалість льодоставу тут характерна для Сульської затоки.

У Кам'янському водосховищі часто утворюються скупчення криги в його звужених місцях. У Дніпровському водосховищі найбільша тривалість льодоставу властива для Самарської затоки. На крижаний покрив у верхній частині цього водосховища, окрім роботи ГЕС, впливають скиди промислових підприємств міст Кам'янське та Дніпро. Значні відмінності в льодовому режимі має Каховське водосховище, що витягнуте з північного сходу на південний захід. Поширення криги в його мілководній північно-східній частині звичайно значно більше, ніж у звуженій південно-західній.

Ключові слова: дистанційне зондування Землі, крижаний покрив, температура повітря, дніпровські водосховища

Introduction. It is well known that ice cover on water bodies has an effect on water quality as well as on the living conditions of fish and other hydrobionts. This also refers navigation and the stability of hydraulic engineering facilities.

The regular monitoring of ice regime in the Dnipro Reservoirs and other water bodies has some disadvantages. The obtained data enable to characterize only local conditions near the banks. The conditions in the remote parts of the water area remain unexplored. In this regard, the use of remote sensing data gives additional information on the ice cover. At the same time, these data also have some lacks, in particular, due to essential cloudiness in winter period. In turn it makes harder to get a sufficient number of high-quality images.

Analysis of previous research. There are quite a lot studies devoted to the ice cover on water bodies. Over the last decades, the most popular issue is the changes of ice cover caused by global warming. Based on the long-term observations many authors (Klavins et al, 2009, Korhonen 2006, Rakhmatullina, Grebin' 2011, Stonevicius, Stankunavicius, Kilkus, 2008, Strutynska, Grebin' 2010, Yaitskaya, Magaeva, 2018) state that the freezing of water bodies starts later while the ice break-up starts earlier compared to the previous decades. The study of Magnuson J.J. et al (2000) devoted to many water bodies in Northern hemisphere showed that the freezing of water bodies over the last 100 years in average started 5.7 days later while the ice break-up for the same period in average started 6.3 days earlier. The similar results were obtained for some lakes in Northern Poland (Marszelewski, Skowron, 2006) and for the Nemunas River in Lithuania (Stonevicius et al, 2008).

The next important point of the relevant studies is establishing the dependencies between the hydrometeorological conditions, the dates of freezing, dates of ice break-up and ice thickness as well (Brown, Duguay, 2010, Efremova et al, 2010, Kalinin, 2012). Baklagin V.N. (2018), which carried out the research of Onega Lake using remote sensing, found the essential impact of wind and wind waves on ice formation.

The analysis of long term data on the ice cover for the Dnipro Reservoirs was made by Vyshnevskyi V.I. (2011). Based on the data of regular monitoring it was determined that during the last decades the period of ice cover shortened and the ice layer became less thick. The longest period of ice cover, which was observed on reservoirs, lasted 140 days. It was recorded at Adamivka hydrological station on the Kremenchuts'ke Reservoir in a cold winter of 1995-1996. The thickest ice cover was also recorded on this reservoir at Svitlovodsk hydrological station in February 1976, when it reached 77 cm. Some results of this issue, based on remote sensing data, were presented in the research work of Vyshnevskyi V.I. and Shevchuk S.A. (2018).

Despite the large number of studies, the patterns of ice regime, primarily in the water areas, which are far from the banks, remain insufficiently studied.

The study area. The study area covered all six reservoirs of the Dnipro Cascade. The average length of the reservoirs is 100–150 km, while the longest Kakhovske one exceeds 200 km. The average width of the reservoirs is 10–15 km, while the largest (Kremenchuts'ke one) is 28 km. The maximum depth the majority of reservoirs is approximately 20 m; the Dniprovske one, which is the deepest, is 62 m (Fig. 1).

Under natural conditions before the construction of reservoirs the average water runoff of the Dnipro River in its mouth exceeded 50 km^3 per year. Nowadays it makes 42–43 km^3 per year. The decrease in runoff is caused by withdrawing water for economic needs and evaporation from the water surface.

Materials and methods. The main source of data for studying the ice cover was the images obtained by Sentinel-2 and Landsat satellites. In fact, there are two Sentinel-2 satellites which were launched in 2015 and 2017. The advantages of this data are quite high spatial resolution (10 m) and relatively small revisit time (2–3 days). The spatial resolution for the majority bands of Landsat satellites, starting from Landsat 4 (it was launched in 1982) is 30 m, revisit time is 16 days. The greatest attention was paid to the data of Landsat 8 satellite, which has been providing the images starting from March 2013. These data are available on the site of the US Geological Survey (www.glovis.usgs.gov). Another important source of data was the images, obtained by Aqua and Terra satellites. These images are taken daily, but the spatial resolution of Modis onboard spectroradiometer is comparatively not high – 250 m.

The algorithm of ice cover study was the following. First of all, a preview of satellite images was

carried out, the number of which for today are thousands. Then high quality images were selected, analyzed and downloaded. In addition, the monitoring data on ice regime, provided by the Hydrometeorological Service of Ukraine, were analyzed. These observations are carried out at 36 hydrological stations. The largest number of the stations (8) is located on the banks of winters, because even in such conditions there are periods, when the air temperature drops below 0 °C. The average monthly temperatures of January (it is considered to be the coldest month) during the standard observation period of 1961–1990 are the following: Kyiv – minus 5.6 °C, Dnipro city – minus 5.5 °C, Nova Kakhovka town – minus 4.2 °C. During the last

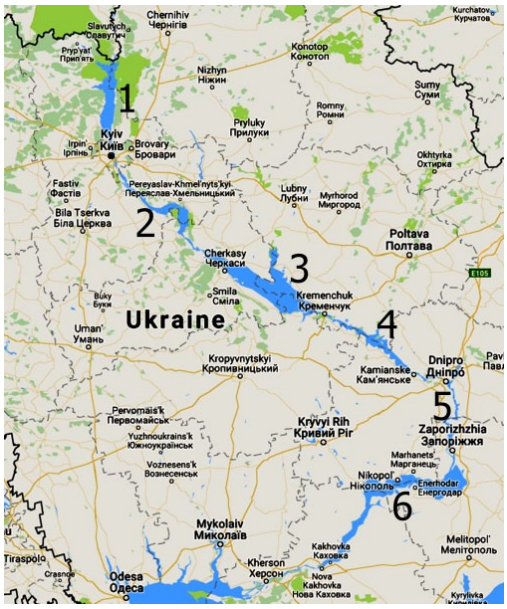


Fig. 1. Location of the Dnipro Reservoirs:
1–6 – Kyivske, Kanivske, Kremenchuts'ke, Kamianske, Dniprovske, Kakhovske respectively

the Kakhovske Reservoir, the smallest number (4) is on the Kamianske one. These data are the dates of the beginning of ice phenomena, ice cover and ice breakup, as well as the dates of the end of the ice cover period and the dates of water area cleaning from the ice. In addition, every 5 days the thickness of ice is measured.

The data from meteorological stations, located near the reservoirs, such as air temperature and wind direction were analyzed as well. Based on these data, the main patterns of the ice regime on the studied reservoirs were determined.

Results and Discussion. The ice cover on the Dnipro Reservoirs is observed every year including warm decades the average air temperature was higher than usual. Thus, during 1991–2019 the average air temperature of January in Kyiv was minus 3.4 °C. During this period the coldest winter was observed in 1995-1996 while the warmest one was in 2006-2007. The coldest month of 1996 was January, when the average air temperature in Kyiv was minus 9.8 °C (Fig. 2).

In the city of Dnipro, located on the Dniprovske Reservoir's banks, the average temperature of January during the years of 1991–2019 was also higher than normal – minus 3.7 °C. The coldest winters were observed in 1995-1996 and in 2002-2003, the warmest ones in 2006-2007. The coldest month during this period was December of 2001, the average

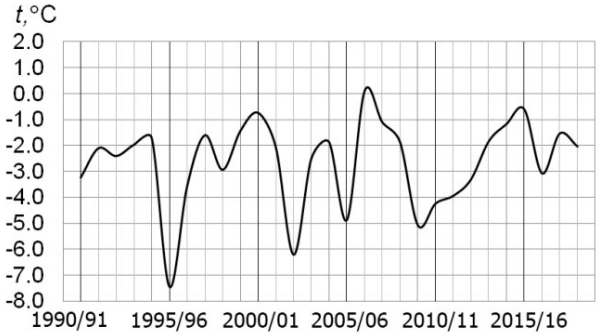
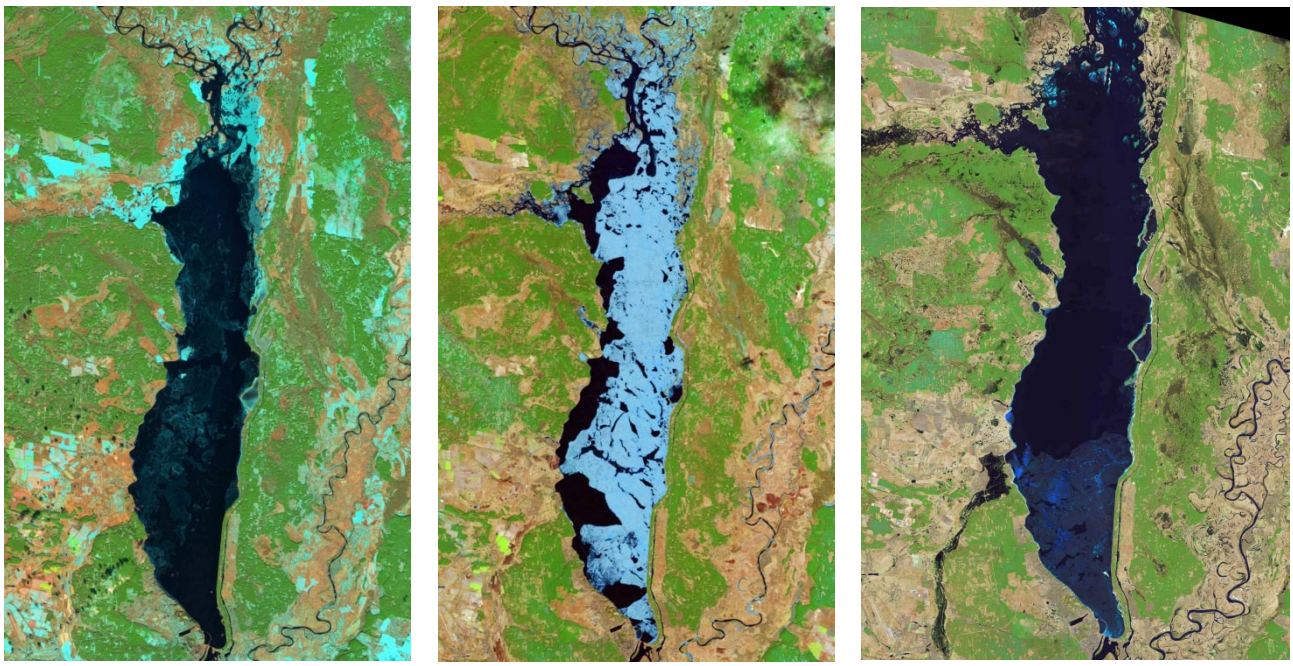


Fig. 2. Fluctuations in winter temperature (December–February) in Kyiv during 1991–2019



a b c

Fig. 3. Ice cover on the Kyivske Reservoir: a – 29.11.2018, b – 02.03.2019, c – 16.04.2013

temperature of which was minus 9.7 °C. On the other hand, January of 2007 was much warmer than usual, its average temperature was +1.5 °C.

The Kyivske Reservoir. According to the available satellite images the freezing of reservoir usually starts in the shallow bays, located in its northern and north-eastern parts. A bit later the freezing is observed near the mouth of the Pripyat River. It can be clearly seen on the image, obtained by Sentinel-2 satellite on 29.11.2018. During the winter period the numerous cracks can be formed in the ice cover – usually transversally the reservoir. As a rule, there is an ice-hole near Kyivska HPSP and Kyivska HPP due to the increased water exchange as a result of these stations operation.

The ice break-up usually starts in the western part of the reservoir. It happens due to the inflow of melting water from the right bank tributaries of the Dnipro River – the Pripyat, Teteriv and Irpin Rivers, the spring flood of which begins earlier than on the Dnipro River itself. In particular, it can be clearly seen in the image, obtained by Sentinel-2 satellite on 02.03.2019.

The cleaning of the water area from the ice in this part of the reservoir has a positive effect on its ecological state – the concentration of dissolved oxygen in the spring period near the western bank of the reservoir is usually higher than it is near the eastern bank (Vyshnevskyi, 2011). The longest period of ice cover in spring period is observed in the southern and south-eastern parts of the Kyivske Reservoir, when having low temperatures the ice can remain here until mid-April (Fig. 3).

The ice regime during the last years is of a great interest. December of 2017 was much warmer than usual, so the formation of ice cover in the Kyivske Reservoir began in January 2018. In particular, in the image obtained by Sentinel-2 satellite on 08.01.2018, there is no ice in the reservoir. The ice started to be visible in the upper part of the reservoir only on the image obtained on 13.01.2018. Almost simultaneously it was also observed at the hydrological stations of the reservoir. In particular, at the Strakholissja station the ice formation started on 12.01.2018, Tolokun station – on 14.01.2018, Lebedivka station – on 15.01.2018.

Significantly different conditions were observed in the cold period of 2018-2019. Decrease in temperature at the end of November caused the covering of some reservoir's part with ice on 29.11.2018, which can be seen in Fig. 3a. The dates of the ice cover formation at hydrological stations were the following: Tolokun – 28.11.2018, Lebedivka – 30.11.2018. At Strakholissja station, located in the northern part of the reservoir, ice cover was formed earlier – on 18.11.2018. On 02.12.2018 almost all area of the reservoir was frozen.

The last image, which clearly shows the existence of ice in the Kyivske Reservoir in 2018, dated 03.04.2018. Some ice remains were traced on 06.04.2018 as well. The same situation was observed at the hydrological stations. Thus, at Tolokun station ice cover disappeared on 03.04.2018, at Strakholissja – it happened on 04.04.2018. Complete cleaning of water from ice was respectively on 07.04.2018 and 08.04.2018.

In the spring period of 2019 the last existence of ice was seen on the image dated 09.03.2019. According to the monitoring carried by the Hydrometeorological Service the cleaning of water from ice was a few days later. In particular, at Vyshhorod and Strakholissja stations it was recorded on 11.03.2019.

The early cleaning of the Kyivske and other reservoirs from ice in 2019 occurred due to the abnormally warm weather conditions. At Vyshhorod meteorological station the air temperature rose up to +7.0 °C on 06.03.2019, up to +9.2 °C on 07.03.2019 and even up to +17.3 °C on 08.03.2019.

The Kanivske Reservoir. This reservoir is located farther south than the Kyivske one. At the same time, it is the first in the cascade which significantly affected by the HPP located upstream. Kyivska HPP located upstream usually causes the formation of the ice-hole of a few kilometers length; sometimes its length can exceed 20 km. Only in cold conditions the size of this hole reduces up to 200–300 m.

Another important factor influencing the ice regime of the Kanivske Reservoir is the city of Kyiv, in particular the discharges of the thermal power plants. One of them Kyivska TPP-5 operates on the right bank of the Dnipro River. Satellite images also show the impact of Bortnichska Station of Aeration, which purifies the wastewater of Kyiv. The water discharge of this water treatment station is 700–750 thousand cubic meters per day and the temperature of the treated wastewater, discharging into the reservoir on the southern outskirts of the city, is much higher than 0 °C.

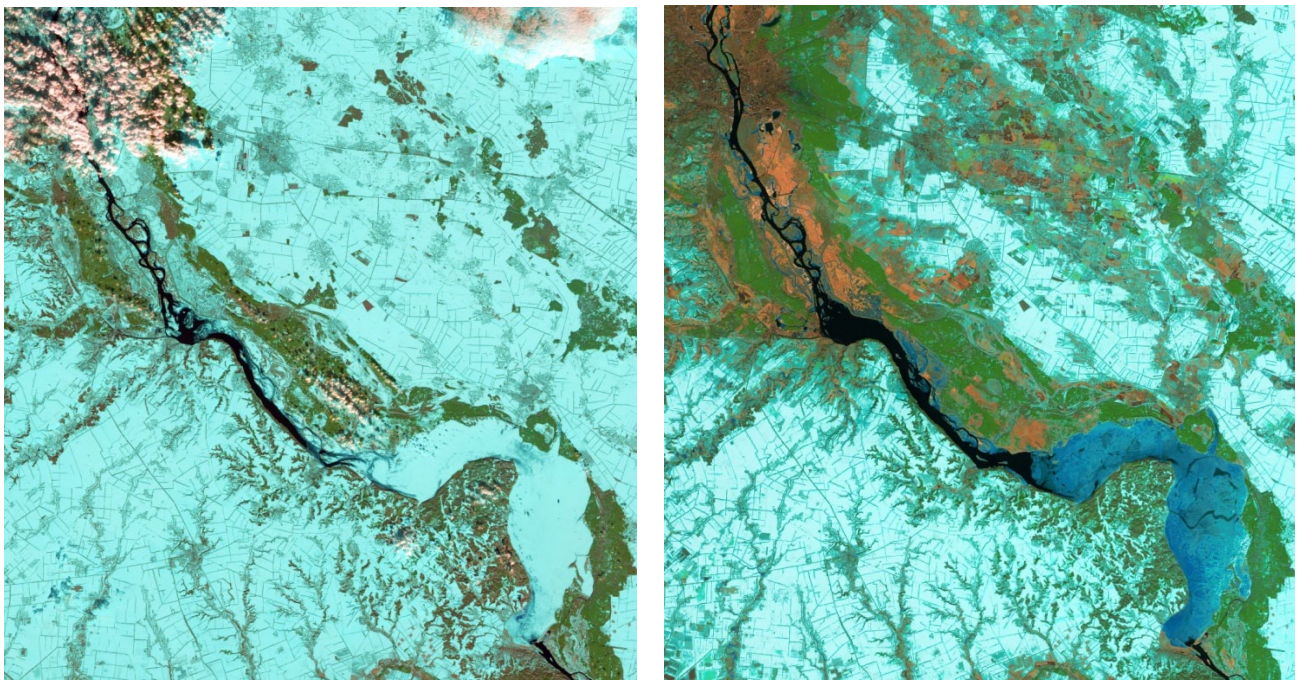
Another important object influencing the ice regime of the Kanivske Reservoir is Trypilska TPP. It is located in Ukrainka town on the right bank of the Dnipro River, 40 km downstream from Kyiv. All these factors determine that the distribution of ice in the Kanivske Reservoir is much less than in the Kyivske one. In general, ice cover is the most stable in the south-eastern part of the reservoir, which is the widest. According to satellite data, it is clearly seen that here (Fig. 4) the thickness of the ice is the largest.

The main stream of the Dnipro River alongside the right bank influences the ice cover of the reservoir as well. The period of ice cover and its thickness near the right bank are less compared to the left one. That is proved not only by satellite images, but also by the traditional monitoring data obtained at Ukrainka, Rzhyshchiv, Pereyaslav and Kaniv hydrological stations.

Mainly the formation of ice cover in this reservoir starts on its shallow bays near the left bank, namely in an elongated bay near Pereyaslav town. From there ice extends gradually upstream and downstream.

The first formation of ice in winter 2017-2018 was observed in the image of Sentinel-2 satellite obtained on 15.01.2018. In the cold period of 2018-2019, the first formation of ice in the bays of the reservoir can be seen in the image dated on 27.11.2018.

The longest period of ice cover in spring period is observed in the south-eastern part of the Kanivske Reservoir. In particular, this fact proves the information shown in the image obtained on 17.02.2019 p. The latest image demonstrating the ice in the spring of



a b

Fig. 4. Ice cover on the Kanivske Reservoir: a – 07.02.2019, b – 17.02.2019

2019 dated 09.03.2019. It was stored near the banks in the south-eastern part of the reservoir.

There are some features about the ice regime within the territory of Kyiv. They are closely connected to the vicinity of Kyivska HPP, the distance from which to Obolon urban district of Kyiv is about 8–9 km. The research findings showed that daily fluctuations of water level near Kyivska HPP are equal to 0.5–0.8 m, close to the central part of city they are 1.5 to 2 times less (Vyshnevskyi, 2011).

a b c

Fig. 5. Ice cover in the upper part of the Kanivske Reservoir near Kyiv on 07.12.2016 (a), on 16.01.2017 (b), on 25.02.2017 (c):

1 – Verbljud Bay, 2 – Sobache Hyrlo Bay, 3 – Obolon Bay, 4 – Harbor, 5 – Vydubytska Bay, 6 – the Desna River, 7 – Desenka branch, 8 – Domania Bay, 9 – Matviyivska Bay, 10 – Rusanivska Strait, 11 – Venice Strait

In this area the formation of ice cover starts in the bays of Matviyivska, Vydubytska and Berkivshchyna. Then ice appears in the large bays in the northern part of Kyiv: Verbljud, Sobache Hyrlo and Obolon. The next stage is the formation of ice on the secondary branches of the Dnipro River: the Dovbychka and the northern part of the Rusanivska Strait. The Venetian Strait begins to freeze later. The freezing of the main branch of the Dnipro River starts last of all. At first the formation of ice is observed in front of the main bridge of Podilsko-Voskresenskyi bridgework crossing, which is now under construction. This is partly due to the accumulation of ice carried by the Desna River. The next place with an early formation of ice locates downstream in the secondary branch of the Dnipro between Small and Great islands and the right bank of the river. The third place of ice formation is located downstream the Southern Bridge and coincides with the zone of significant increase of the water area (Fig. 5).

In case of thaw period, the water area is partially released from the ice. First of all, it refers the Dnipro main branch. At the same time, bays usually remain frozen.

In spring period, the first melting of ice is observed on the main branch of the Dnipro River. Gradually this process extends to the secondary branches. This is followed by cleaning the straits connecting the bays with the river branches. The longest duration of ice cover on the Dnipro River is observed in the Matviyivska Bay as well as in the bays in the southern part of the city. In all these cases, the impact of the Kyivska HPP, namely its uneven discharges during the day, is significant.

The analysis of the satellite images points to the special conditions in the Domania Bay close to the Desenka branch, marked with the number 8 in Fig. 5. This bay has the largest depth within Kyiv - more than 25 m. It is likely the ground water unloading, which takes place here, effects the ice regime. Sometimes ice cover is absent not only in this bay, but also along several kilometers downstream, on the Desenka branch.

The Kremenchuts'ke Reservoir. Similar to other reservoirs, there is an impact of HPP, located upstream, on the ice cover of this reservoir. Generally, downstream Kanivska HPP the ice cover is absent on the length more than 20 km. The ice cover in this reservoir is often in a form of a cluster of ice floes, which, depending on wind strength and direction, shift to one or another side. Throughout the cold period, the west winds dominate in this area, which cause large waves and shift the ice towards Kremenchuts'ka HPP.

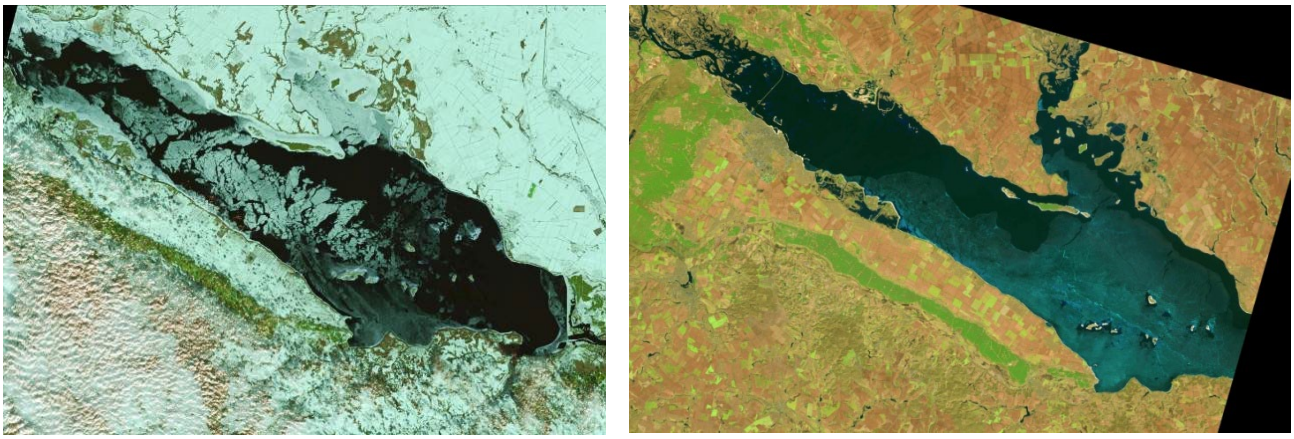
The formation of ice cover in this reservoir usually starts from its shallow bay where the Sula River (left tributary) inflows. The longest period of ice cover duration is observed on the south-eastern part of the reservoir, which is the deepest one. It can be seen in the images obtained by Landsat 8 satellite dated 11.03.2014 (Fig. 6).

The images obtained by Terra and Aqua satellites prove that the ice cover in the Kremenchuts'ke Reservoir often disappears later than in other reservoirs. It can be clearly seen in the images dated 10.04.2003, 17–18.04.2003, 08.04.2005, 10.03.2015 etc. Only occasionally, as in 2013 and 2018, the ice in the Kyivske reservoir remained longer than in Kremenchuts'ke one (Fig. 7).

The Kamianske Reservoir. This reservoir like the two other ones located upstream is significantly influenced by the HPP, namely Kremenchuts'ke. At the same time this reservoir has its specific feature – alternating wide and narrow parts. Here ice often accumulates in the places of relatively small width.

The freezing of the reservoir usually begins in its shallow bays close to its north-eastern bank. Then ice extends to the central and widest part of the reservoir. Gradually the ice extends to the south-east and partly towards the north-west. In general, the largest distribution of ice is observed in the south-eastern part of the reservoir. In the spring period, the longest presence of ice cover is registered in bays and in south-eastern part of the reservoir (Fig. 8).

It was impossible to obtain the correct date on the ice formation by the satellites in the winter period of 2017-2018 owing to the significant cloudiness in that



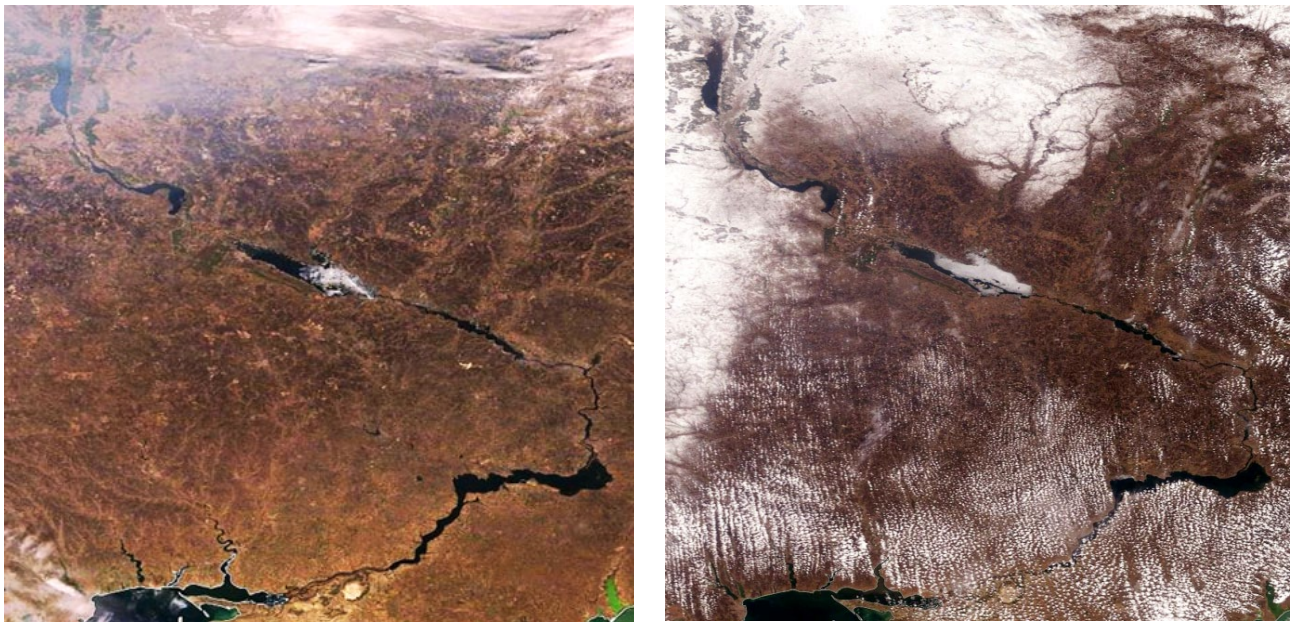
a b

Fig. 6. Ice cover in the Kremenchuts'ke Reservoir: a – 14.12.2013, b – 11.03.2014

In the winter period of 2017-2018, the ice formation in the Kremenchuts'ke Reservoir began in mid-January. For the first time it is seen in the image of Sentinel-2 satellite dated 15.01.2018. In the cold period of 2018-2019 that happened much earlier – on 29.11.2018. The image, demonstrating the ice cover for the last time in 2018, is dated 03.04.2018. Similarly, in the spring period of 2019 the image demonstrating the ice cover for the last time was obtained on 16.03.2019. As it can be seen, in the Kremenchuts'ke Reservoir the ice disappeared later than in the Kyivske and the Kanivske ones.

period. The ice is clearly visible only in the image of Sentinel-2 obtained on 23.01.2018. The weather conditions made it difficult to determine the correct dates of freezing in the cold period of 2018-2019 as well. The first image in which the ice can be seen near banks dated 08.12.2018. The image, where the ice can be seen for the last time in 2018, dated 02.04.2018, in the spring period of 2019 – 08.03.2019.

The Dniprovske Reservoir. The features of this reservoir, influencing its ice cover, are relatively small width and the largest depth among the others ones.



a b

Fig. 7. Ice cover on the Dnipro Reservoirs: *a* – 10.04.2003, *b* – 10.03.2015

Another important factor is its southern location, compared to the Kamianske Reservoir. As a result, the freezing of the deepest southern part of the reservoir is observed rather late, at least later than it is in its central part. There are some local factors which influence the ice regime as well. The distinguishing feature is the presence of a shallow bay at the mouth of the Samara River in the north-eastern part of the reservoir. The ice cover duration in this bay is the largest. But there are no reliable data proved this fact due to the absence of hydrological observations.

The anthropogenic activities, namely HPP located upstream, as well as the wastes of industrial enterprises (in particular, metallurgical ones) of Kamianske town and Dnipro city, significantly influence the ice regime of the Dniprovske Reservoir, especially in its upper part. As a result, there is usually no ice cover in the upper part of the reservoir along the distance of about 25 km. Generally it is formed on the upper outskirts of Dnipro city, where the river is divided into several branches. Downstream in the distance from the Kaydatskyi to the Amurskyi bridges, the wastes of industrial enterprises, in particular Dniprovskyi Metallurgical Plant, significantly influence the ice cover. There are some places downstream, where storm water drainage comes from the right bank of Dnipro city. One more large enterprise, significantly influencing the ice regime of the reservoir, is Pridneprovskaya TPP. It is located in the south-eastern part of the city downstream the mouth of the Samara River. As a result of that even in cold winters an ice-hole is formed here (Fig. 9).

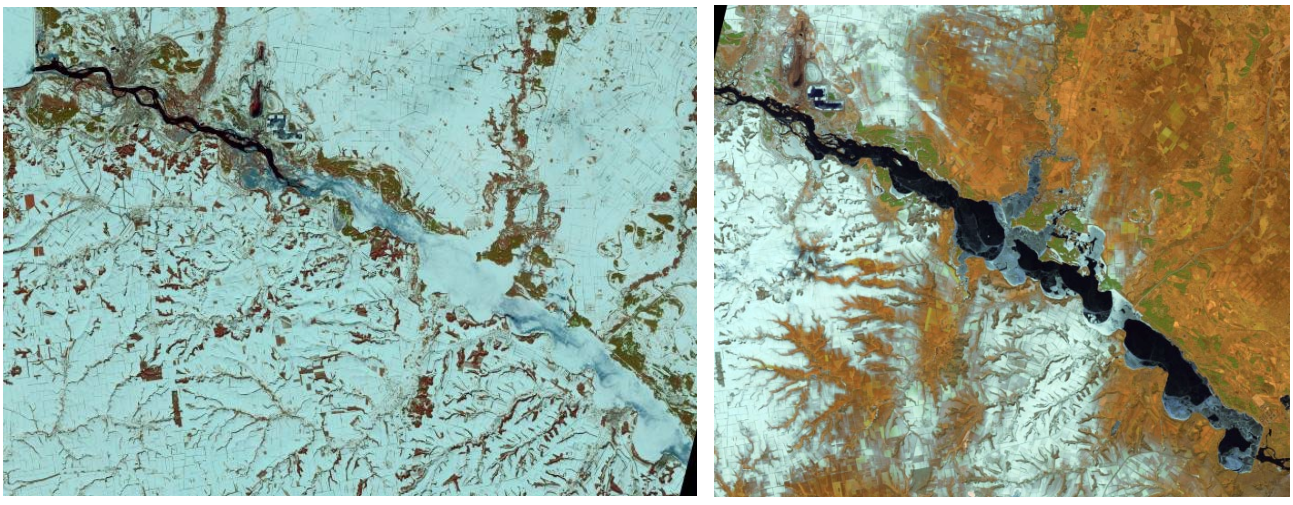


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Fig. 8. Ice cover in the Kamianske Reservoir: a – 23.01.2017, b – 12.02.2015

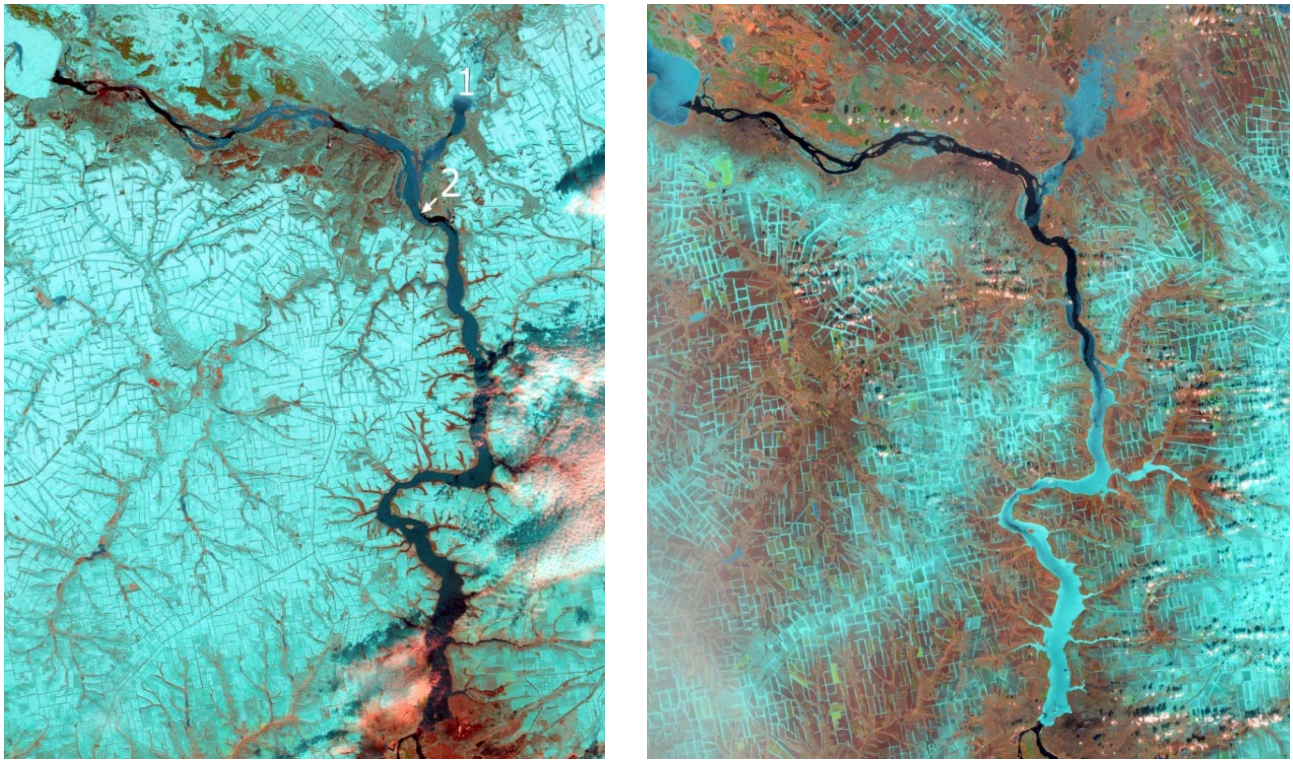

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Fig. 9. Ice cover in the Dniprovske Reservoir on 17.01.2019 (a) and 26.02.2017 (b):
1 – Samara Bay, 2 – location of Pridneprovskaya TPP

The ice regime of the upper part of the Dniprovske Reservoir is significantly influenced by weather conditions, in particular thaws. In this regard, upstream the Lotsmano-Kamianka hydrological station the ice cover is unstable, during the winter period it can be formed and disappear several times.

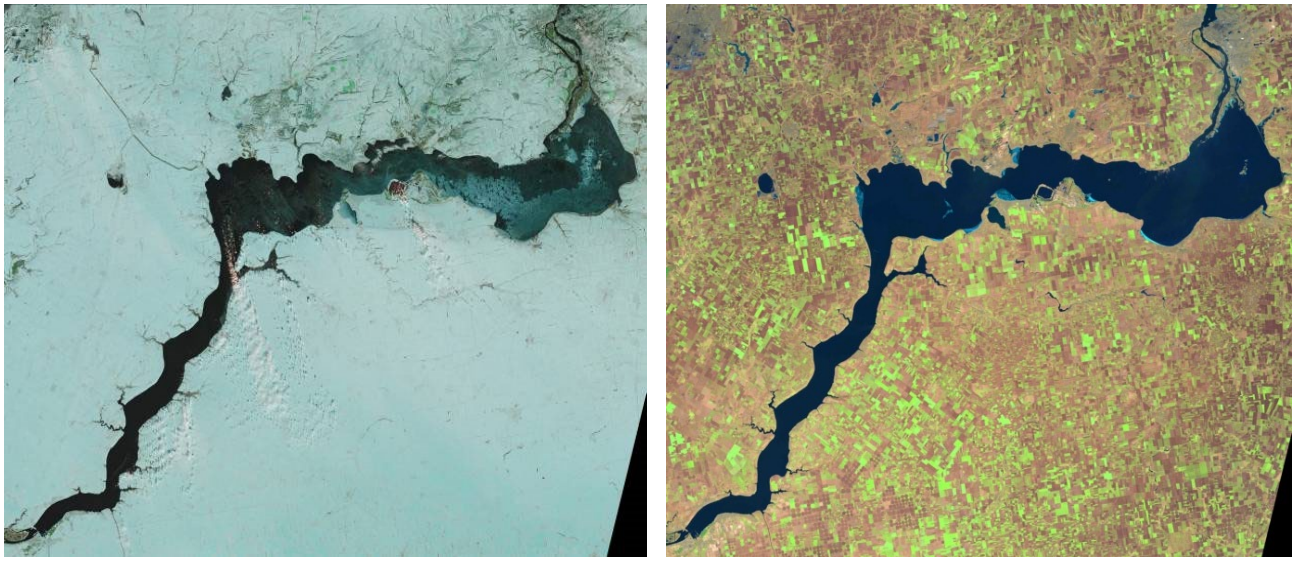
The freezing of the reservoir usually begins from the Samara Bay, as well as from the other shallow bays. Then the freezing is observed in the middle part of the reservoir. The ice cover extends from here downstream and partly upstream. These phenomena are similar to those ones, which can be observed in Kamianske and partly Kanivske and Kremenchuts'ke reservoirs.

In the winter period of 2017-2018, the formation of ice cover in the Dniprovske Reservoir began in January, but it was impossible to obtain the correct satellite date due to the significant cloudiness in that time. In the cold period of 2018-2019, the ice cover began to form earlier than usual – it can be seen for the first time in the Samara Bay in a clouded image obtained by Sentinel-2 satellite on 21.11.2018.

The ice melting in spring period starts from the upper north-western part of the reservoir. At the same time the ice cover in bays can still remain. The long presence of ice cover is observed in the Samara Bay and in the southern part of the reservoir as well. The ice melts last of all in the Samara Bay. It can be seen in the image, obtained by Sentinel-2 satellite on 28.03.2018. The large duration of ice is observed in Mandrykisvka bay close to the right bank in the southern part of Dnipro city. The last image on which the ice is visible on the reservoir in spring of 2019 has the date 06.03.2019.

The Kakhovske Reservoir. The important feature of this reservoir, influencing the ice cover, is the most southern location of it. Another distinguishing feature is the large size and considerable length of the reservoir – more than 200 km. The north-eastern part of the reservoir is much shallower and wider than the opposite part near HPP. The climatic conditions in winter period are also different – in the north-eastern part they are colder. These factors cause the spreading of ice cover in the shallow north-eastern part of the reservoir is significantly larger than it is near Kakhovska HPP. According to the monitoring data, the duration of the ice cover at Plavni hydrological station, located in the north-eastern part of the reservoir, is 20–25 days longer than near Nova Kakhovka town.

In warm winters, ice cover in the area near Kakhovska HPP does not form. It is proved by the images obtained by Landsat 8 satellite on 24.01.2014, 12.02.2015, 30.01.2016, 20.02.2018, 23.02.2019 etc. Moreover, in warm winters ice cover in the north-eastern part of the reservoir cannot be the continuous as well. That is proved by the images dated 20.01.2014, 12.02.2015 and 20.02.2018 (Fig. 10).



a b

Fig. 10. Ice cover in the Kakhovske Reservoir: a – 20.01.2014, b – 20.02.2018

The largest duration of ice cover in this reservoir is usually observed in the bays in the north-eastern shallow and wide part of the reservoir. It is proved by the image obtained on 20.02.2018.

The ice regime of the Kakhovske Reservoir, like most others, is influenced by industrial wastes. Namely, they are Zaporizka TPP and Zaporizka NPP, to the west of which an elongated ice-hole is usually formed. There is also a rather narrow water area in the upper part of the reservoir with the length of about 30 km that is also greatly influenced by Dniprovska HPP and enterprises of Zaporizhzhya city. That prevents ice formation in this area.

During the winter of 2017-2018, the ice in the Kakhovske Reservoir can be seen for the first time in the image of Sentinel-2 obtained on 24.01.2018. Before that date the reservoir was covered by clouds for more than a week. Next winter, the ice began to form much earlier. In particular, some small plots of ice can be seen in the image dated 03.12.2018. The image where the ice cover in the Kakhovske Reservoir can be seen for the last time in the spring period of 2018 dated 26.03.2018, in 2019 – 24.02.2019. In last case it were very small areas close to the banks in wide part of the reservoir. As it can be seen, the duration of ice phenomena in the Kakhovske Reservoir is much shorter than in the ones located upstream.

Conclusions. Using remote sensing data enables to characterize the ice cover in the reservoirs, constructed on the Dnipro River. The important factor influencing the ice regime is the location of the reservoirs and correspondingly climatic conditions. Thus, the duration of ice phenomena and ice cover in the Kyivske Reservoir is significantly larger than they are in the Kakhovske one located in the lower reach of the Dnipro River. In most reservoirs, besides the Kyivske and Kakhovske ones, their central parts freeze first. Freezing of water area, located upstream, is restricted by the operation of HPP. In turn, freezing of deep-water area adjacent to the dam is restricted by the significant heat storage of water mass as well as wind waves.The combination of several factors (more southern location, the operation of Kyivska HPP, discharges from some enterprises of Kyiv cause the extension of ice cover in the Kanivske Reservoir is much less than it is in the Kyivske one. The largest duration of ice cover, as a rule, is observed on the Kremenchuts'ke Reservoir, located in the middle of the cascade. In the Kamianske reservoir ice often accumulates in its narrow places. In general, the extension of ice in its southeastern part is the greatest. The Dniprovske Reservoir has the smallest duration of ice phenomena and ice storage in its upper part. In addition to the impact of the upstream hydroelectric power station, this is due to the influence of discharges from industrial enterprises of Kamianske town and Dnipro city. The longest ice phenomena in this reservoir is observed in the Samara Bay. In general, the shortest duration of ice cover is observed in the Kakhovske Reservoir, which has the most southern location. This especially relates to the southwestern part of this reservoir adjacent to the dam.

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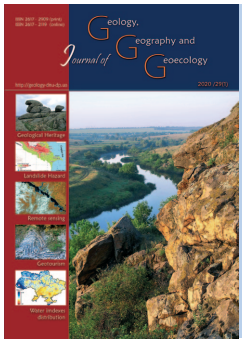

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International legislation as an important instrument in the creation of geoparks in Ukraine

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Abstract. The article considers international legislation as an instrument in the process of establishment of Geoparks in Ukraine. Because the notion "geopark" is relatively new to Europe, and even newer to Ukraine, it is necessary to study the legal aspects of this issue. It was determined that the establishment of geoparks in Ukraine is hindered by numerous problems, particularly: absence of target-legislation, unproductive dialogue with authorities, from local to national and difficult economic conditions. We found that solving the problems should start from the assessment of state and international normative-regulatory acts and characterization of the impact of the latter in the legal field of Ukraine. We found that domestic scientific works do not have many references to the international legislation. Therefore, the necessity arises of developing an international "legal map" in the issue of protection of geoheritage. For this purpose, we analyzed 14,335 international documents relevant for the territory of Ukraine with their respect to their relationship to the protection of nature, natural and cultural heritage, out of which 79 were analyzed in detail. We determined the peculiarities, according to which the international legal acts can be identified and can characterize them by 3 groups: Treaties between states on collaboration; Treaties between states on particular natural objects; important international documents. We determined that 48 of them have different levels of importance in the issue of establishment of Geoparks. We determined that many international documents recommend, encourage, obligate the authorities to support protection of nature, the natural heritage, including geoheritage. With active use of such documents, it is possible to significantly advance in solving the abovementioned problems of establishing Geoparks. Most characterized normative-regulatory acts which are directly or indirectly related to natural objects and territories that could be included in future Geoparks, making them an important tool in preservation of geoheritage. The presented results correspond to all the recent changes in the legislation as at the beginning of 2019. The results can be used by scientists in the process of establishment of real Geoparks in Ukraine, as well for preservation of geological heritage in general.

Keywords: geopark, geoheritage, international legislation, international document, legal map

Міжнародне законодавство, як важливий інструмент створення геопарків в Україні

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Анотація. У статті розглядається міжнародне законодавство, як інструмент у процесі створення геопарків в Україні. Оскільки поняття «геопарк» відносно нове для Європи, а тим більш для України, є необхідність вивчення юридичних аспектів цього питання. Встановлено, що створення геопарків в Україні має безліч проблем, зокрема: відсутність цільового законодавства, недієвий діалог із владою від місцевих до національних рівнів та складні економічні умови. З'ясовано, що починати вирішення цих проблем потрібно з оцінки державних й міжнародних нормативно-правових актів та характеристики впливу останніх в правовому полі України. Виявлено, що у вітчизняних наукових роботах дуже мало посилань на міжнародне законодавство. Тому виникає необхідність створення міжнародної «юридичної мапи» у питанні охорони геоспадщини. Із цією метою було проаналізовано 14335 міжнародних документів, які діють на території України, щодо їх відношення до охорони природи, природної та культурної спадщини, з яких детально опрацьовано 79. Визначено особливості, згідно яким міжнародні правові акти можна віднести та охарактеризувати за 3 групами: Угоди між державами про співробітництво; Угоди між державами про конкретні природні об'єкти; Важливі міжнародні документи. Встановлено, що 48 з них має різного рівня цінність у питанні створення геопарку. З'ясовано, що багато міжнародних документів рекомендує, спонукає, зобов'язує владу позитивно діяти у напрямку охорони природи, природної спадщини, у тому числі й геоспадщини. При активному використанні таких документів можливо суттєво просунутись у вирішені зазначених проблем створення геопарку. Більшість охарактеризованих нормативно-правових актів напряму або опосередковано стосуються природних об'єктів та територій, які можуть входити до майбутніх геопарків, що робить їх важливим інструментом у питанні збереження геоспадщини. Викладені результати відповідають усім останнім змінам у законодавстві на початок 2019 року. Результати можуть бути використані науковцями для створення реального геопарку в Україні, так і в цілому у питанні збереження геологічної спадщини.

Ключові слова: геопарк, геоспадщина, міжнародне законодавство, міжнародний документ, юридична мапа

Introduction. At a time when the world community, and especially Europe, is moving towards conservation of the geoheritage by establishing Geoparks in the global network, geosites and objects protected by international institutions – there are no such objects in Ukraine. Scientists of many countries are already studying how to improve the work and the infrastructure of the existing Geoparks, as for example in Brazil and Germany (Corrado Venturini, 2019; Eduardo Guimaraes, Paulo Felipe, Ribeiro Bandeira, Joao Marcos Ferreira de Lima Silva, Rafael Celestino Soares, 2018), in Holland the geopark is considered a brand and the attitude of the inhabitants to it is being studied (Arie Stoffelen, Peter Groote, Erik Meijles, Gerd Weitkamp, 2019), therefore: the relevance of solving the problem of establishing such Geoparks in Ukraine is of great importance. In the previous studies, one of the determined problems was the absence of "a legal map" (Yaholnyk, Manyuk, 2015) in the issue of establishing a geopark, and the corresponding Ukrainian laws were analyzed. However, a no less important aspect of creating a "legal map" is the international legislation.

In most Ukrainian studies on establishing Geoparks, a certain pattern emerges. Practically in all the works, there is either only a small number of references to the international legislation, or a complete absence of such references (Tofig Rashidov, Talat Kangarli, Ilkin Kangarli, 2018; Kravchuk, Bohutskyi, Zinko, Brusak, Krychevska, Blahodyr, Shevchuk, 2013; Manyuk, 2007; Maria Helena Henriques, José Brilha, 2017; Shevchuk, 2011). Some researchers explain such pattern by the fact that legal aspects are complex and do not stimulate those who are trying to legitimize geological monuments (Heichenko, Flore, 2014). Among the publications of foreign authors, the norms of international law are mentioned and explored, but not entirely, as for example in Azerbaijan, where the aspect of creating Geoparks also remains unsolved, the importance of the international law is almost ignored; (Tofig Rashidov, Talat Kangarli, Ilkin Kangarli, 2018) in the articles focused on the study of the legislation, 5 to 10 different international acts are mentioned, for example in the article "Geoconservation legal status and geopark establishment in Greece" (Haidarlis, Sifakis, Brachou, 2017). Therefore, the relevance of the results of the studies provided in the article have an exceptional character for Ukraine – because the mentioned documents were signed or ratified particularly by Ukraine, and furthermore the methodology of the studies, conclusions, list of international acts and their significance for preservation of geoheritage can be useful for foreign researchers as well.

The objective of the study was to develop an international "legal map" regarding creation of a geopark within the legal field of Ukraine, based on the existing normative acts which our country has ratified and signed.

It was found that in the international legislation which is in force in the Ukrainian legal field, no term "geopark" exists. Therefore, since target documents are absent, normative acts approximated to the problem should be used.

Firstly, we should determine what the international law is composed of and how it functions. The international legal act as the main legal source of the current international law can have different names and forms: agreement, declaration, contract, communiqué, pact, convention, charter, tract, protocol, statute, exchange of diplomatic correspondence, etc. Differences in the names do not have a legal significance, because a treaty regardless of its name is an agreement which creates rights and obligations for the parties, therefore all of them have legal force (Skakun, 2001).

Concluding of international treaties is regulated by The Vienna Convention on the Law of Treaties between countries and international organizations, adopted in 1986 at the Conference under the aegis of the UN in Vienna. Among the stages of concluding an international treaty, a special place belongs to its ratification (The Law of Ukraine, 1986). Ratification (approval) is an act of international right using which a state, through the responsible bodies with the rights to conclude agreements, expresses its agreement to take responsibility within the international framework according to a corresponding treaty (Skakun, 2001).

We analyzed the international documents, the legal force of which extends to Ukraine, and attention was paid to their relation to the aspect of protection of nature, natural and cultural heritage, particularly everything that can directly or indirectly be related to the problem of establishing a geopark. Among all legal acts, 79 documents were found and analyzed in detail. Among them, 48 were found to be significant for solving the problem of creating a geopark. They can be conditionally divided into 3 categories:

-Treaties between countries on collaboration (22);

-Treaties between countries on particular natural objects (6);

- Important international documents (20).

Treaties between countries on collaboration. The first category includes international bilateral international treaties about collaboration in the sphere of preserving the environment, between the Ministry of Ecology and Natural Resources of Ukraine, Minis-

try of the Protection of the Natural Environment of Ukraine, or government of the country with a similar body of power in another country. According to the Vienna Convention on Succession of States in respect of Treaties, Ukraine is successor of all the international normative acts concluded and ratified by the Ukrainian RSR, therefore the agreements signed before the independence have legal force (The Law of Ukraine, 1978). A number of countries the agreements are signed with already have Geoparks, and some, like Uzbekistan, are at the final stage of receiving the status, and therefore they can be asked for help and exchanging experience at the legal level (Table 1).

Table 1. Treaties between states on cooperation

Geographic position in relation to Ukraine	Other Party of the Treaty	Year of signing	Number of Geoparks
Borders with the territory of Ukraine	Russian Federation	1994	-
	Belarus	1994	-
	Slovakia	1994	1
	Poland	1993,1992	1
	Romania	1991	1
	Hungary	1990	2
located on one continent	Latvia	2017	-
	Lithuania	2016	-
	France	2015	7
	Macedonia	2010	-
	Sweden	2008	-
	Turkey	2007	1
	Bulgaria	2003	1
	Uzbekistan	1998	1/-
	Denmark	1994	1
	Israel	1994	-
	Germany	1993	6
	Georgia	1993	-
	Italy	1989	10
located on another Continent	USA	1992	-
	Canada	1989	3

All treaties are small in size – containing 4 to 14 articles, in which the parties first approve their intentions about cooperation. Further, the main spheres and directions of cooperation are enlisted, usually containing such issues as: ecology, protection of the environment, monitoring, development, coordinated survey and mutual help, pollution and wastes, and many others. Variability of the issues increases if the countries are located close to one another, for example in the treaty with Belarus, 26 such directions can be seen. Then the forms of collaboration in different directions are formulated. In such documents, issues of monitoring and assessment of actions of collaboration are set out separately. Also, these treaties can initiate creation of various commissions and committees. Then the concluding provisions are written.

An important aspect in the context of establishing a geopark is that most of these treaties in the spheres and directions of collaboration envisage preservation and protection of natural objects, including objects of future Geoparks. For example, the text of the Treaty between the Republic of Latvia and Ukraine mentions: "protection of nature, bio-, -geo- and landscape diversity of the protected territories"; (The Law of Ukraine, 2010), with Republic of Bulgaria: "Protection and rational use of the territories and objects of nature protection fund" (The Law of Ukraine, 2003) - there are many such examples. All of them can contribute to cooperation and help of other countries in establishing Geoparks. Also exchange of experience and data would be useful.

Treaties between countries on particular natural objects. Treaties between countries on collaboration sometimes contain directions related to particular natural objects, but more significant are target documents

on such objects. In Ukraine, there are 3 such objects. According to the surveys conducted earlier, the most promising territories for Geoparks in Ukraine are national parks (Yaholnyk, Manyuk, 2015). Many of the objects protected by international treaties are located in the territory of operating national parks in Ukraine and many of them are promising regarding establishment of a geopark. Therefore, the abovementioned objects and normative acts related to them are of great significance.

Mountain system of the Carpathians. The main protected object in our country is the mountain system of the Carpathians. At least 4 documents are related to it. At the same time, in the Carpathians, a lot of national parks and separate zones with geological objects are located – therefore these territories are considered very promising. They include territories of the national parks Zacharovany Krai, Uzhansky, Skolivsky Beskydy, Verhovynsky, Halytsky, Hutsulshchuna, Karpatsky, Syniohora (Kravchuk, Bohutskyi, Brusak, Zinko, Shevchuk, 2012; Kravchuk, Bohutskyi A, Zinko, Brusak, Krychevska, Blahodyr, Shevchuk, 2013; Zinko, 2011). One of the first international documents on the Carpathians was the Krakow Declaration "Implementation of the Pan-European Ecological Network (PEEN) establishment of the "Green Backbone of Central and Eastern Europe" (The Law of Ukraine, 1998). Mostly, the document concerns the protection of the ecosystem of the Carpathians and the river basin of the Danube, the main theses are: sustainable development of the highland area and the pre-mountain area, nature-protection education, support and development of tourism, solving the problems of the local population – all of them completely correspond to the purpose of establishment of a geopark according to the criteria of UNESCO (The Law of Ukraine, 1998; UNESCO, 2015).

In 2003 the main document on protection of the Carpathians was signed – the "Framework Convention on the Protection and Sustainable Development of the Carpathians", signed by 8 countries: Ukraine, Poland, Romania, Serbia, Montenegro, Hungary, Slovakia, Czech Republic. The main theses worth noting are: Article 4 Part 1 – policy orientated towards preservation, sustainable use and restoration of the landscape diversity; providing a high level of protection and sustainable use of natural resources and semi-natural environments (The Law of Ukraine, 2004) Article 9 Part 1 – foster sustainable tourism, based on the unique nature and landscapes, benefiting the local population; (The Law of Ukraine, 2004) Article 13 Part 1 – increase in ecological knowledge and support of the corresponding education institutions and programmers; (The Law of Ukraine, 2004) - that is protection, tourism, increase of the awareness and communication with the public, which are some of the main criteria of UNESCO regarding establishment of geopark (UNESCO, 2015).

To the Framework Convention, according to Articles 18 and 19, changes, protocols and appendices could be added. Among such protocols important are "2009 Protocol on Preservation and Sustainable Use of Biological and Landscape Diversity in the Framework Convention on the Protection and Sustainable Development of the Carpathians" – the most important addition, because in more detail it reveals the problem of protection of nature objects, 32nd Article of this document focuses on the protection of landscape and its diversity; (The Law of Ukraine, 2004) "2009 Protocol on the Sustainable Tourism within the Framework Convention on the Protection and Sustainable Development of the Carpathians" is also an important addition, because it fully corresponds to the purpose of establishment of a geopark (The Law of Ukraine, 2004).

The basin of the Dniester river. In 2017, the Treaty between the Government of the Republic of Moldova and the Cabinet of Ministers of Ukraine on Cooperation in the Field of Protection and Sustainable Development of the Dniester River Basin was signed. The ecosystems of the basin of the river belong to the national parks such as the Dniester Canyon and Lower Dniester National Nature Park, which in turn are candidates for future Geoparks (Zinko 2012, Kravchuk, Bohutskyi, Zinko, Brusak, Krychevska, Blahodyr, Shevchuk, 2013) According to the Article 1 Part 1 – one of the goals of the treaty was collaboration in ecological use and protection of the natural resources and ecosystems of the Dniester river – among which, there are many geological objects which could be the basis for establishing a future geopark, including for example, canyon-like sections of the Dniester river (The Law of Ukraine, 2017). The treaty could be a valuable tool, if a geopark would be established in the territories being protected by this normative act (The Law of Ukraine, 2017).

The coast of the Black and the Azov seas. The Convention on the Protection of the Black Sea against Pollution was signed in 1992 and ratified in 1994. Later, in 2007 the Black Sea Biodiversity and Landscape Conservation Protocol were ratified. The Protocol and the Convention protecting the Black Sea are substantial documents which contain many measures, aims, recommendations, duties regarding the ecology of the Black Sea in general (The Law of Ukraine, 2007). However, in the context of establishing a geopark, in-

teresting are the sections on the protection of the landscape, landscape diversity and coastal zones. These documents, apart the sea itself, protect the coastal territories, including geological objects on the territories which are promising for establishment of a geopark, in the Crimean area: the *Bulganak* field of mud volcanoes, Opuksky Nature Reserve, Kara Dag, Grand Canyon of Crimea (Kravchuk , Bohutskyi, Zinko, Brusak, Krychevska, Blahodyr, Shevchuk, 2013).

Important international documents. "Important" means significant in the context of the problem of establishing Geoparks. Knowledge of international law is a big step towards the idea of establishing protected geological territories. Every international document always refers to the earlier signed documents in force. In the European Community any document: application, request, agreement, etc has greater value if it refers to other legal acts, because then it functions in the legal field of such documents. Contact with the Ukrainian local authorities of regional and state levels mostly concerns request for help for drawing up documents – from business documents, applications, addresses to the projects of laws and amendments in them. And the more references there are to the Ukrainian or international legislations, the more substantial they will be in the legal context.

Because the terms "geopark" and "geological monument" are mentioned in none of the documents, the attention should be paid to the terms close to such, or which partly characterize them, for example: environment, natural environment, natural resources, landscapes, ecosystem and others.

Therefore, we propose considering all the international documents in which the protection of natural objects is mentioned, which would directly or indirectly help in the process of establishment of geopark – their name, content and usefulness. A total of 28 such documents were selected; they will be considered in the order of appearance.

The first document is the Statute of the International Union for Conservation of Nature and Natural Resources signed in 1948 (The Law of Ukraine, 1948).The International Union for Conservation of Nature (IUCN) and Nature Resources becomes a good ally in the questions of the protection of the environment. Its goals fully correspond to the purpose of establishing Geoparks. Particular theses of the Statute deserve special attention. According to Article I Part 1, the Union supports the collaboration between separate persons who work on preservation of natural resources and nature protection – that is help in establishing Geoparks could be asked for by both group of scientists or even one scientist (The Law of Ukraine, 1948). Part 2 refers to encouragement of any international and national measures for preservation of organic life and natural environment – areas, natural objects which are subjects of scientific, historical and aesthetic interest. Such areas and objects also include geological relics (The Law of Ukraine, 1948). The IUCN has developed a system of categories of protected nature territories, in which the highest level, «Ia» is a nature reserve of strict regime which may be located in particular on notable or highly-representative examples of geological systems. An important direction of the work is also implementation of the educational programmers and propaganda aimed at persuading the public of the necessity of preserving natural resources and protection of nature (The Law of Ukraine, 1948).

In 1954 the Statute of the United Nations Educational, Scientific and Cultural Organization was adopted. This document is the establishment of UNESCO. One of the main goals of the organization, according to the first article, is the preservation and protection of the global heritage of the mankind, including geological heritage. This principle became the basis for the future preservation of the geoheritage and establishment of network of Geoparks (The Law of Ukraine, 1954).

In 1957 the Treaty establishing the European Community was signed – one of the most important documents of the previous century within Europe. Apart from the main provisions of functioning and integral principles of the European Community, notable is section XIX titled "Environment" composed of three articles - 174,175,176 (The Law of Ukraine, 2005). The articles describe preservation, protection, solving problems related to the environment, use of natural resources. The geologic objects of a territory which are promising for establishing a geopark are understood as coming under these terms, therefore they also become objects for which this normative act functions. Also, the section describes collaboration of the member states with third countries, which Ukraine is now (The Law of Ukraine, 2005). Thus, this document is a practical tool in questions of help from the EU countries, exchanging experience on establishing Geoparks, etc.

In 1971 *the Convention on Wetlands of International Importance especially as Waterfowl Habitat* was adopted – also known as the Ramsar Convention, finally ratified by Ukraine in 1996.Wetlands are present in most of the territories promising for establishment of Geoparks, most (over 10) of which are included in the Ramsar International list. Protection of these objects in the context of establishing Geoparks

is of great significance. According to Article 1 wetlands are the territories of swamps, marshes, bogs, mires, water bodies of constant or temporary, lentic or circulating, fresh-water or saline ones (The Law of Ukraine, 1996). Important is the statement in Article 4 Part 1 on supporting the preservation of such territories by creating nature reserves, regardless of whether they are included to the international list or not, and provision of care for them (The Law of Ukraine, 1996). That is if in the territory, such areas would be present, this convention would also protect the territory of the geopark.

In 1972 the Recommendation concerning the Protection, at National Level, of the Cultural and Natural Heritage was adopted. This is a very important international document, containing direct recommendations on protection of natural heritage at the national level, i.e. inside the country. It describes in detail what the natural heritage is: "*natural* features consisting of *physical* and *biological formations* or *groups* of such formations, which are of special value from the aesthetic or scientific clause of view; *geological* and *physiographical formations* and *precisely* delineated *areas*…", "…natural sites or precisely delineated natural areas of special value for science, conservation or in terms of natural beauty, or in their relation to the combined works of man and of nature" (The Law of Ukraine, 1972).

The ultimate goal of this document is protection, preservation and popularization of cultural and natural heritage – this should be supported by the state, becoming a determining factor of national development (The Law of Ukraine, 1972). State organs should increasingly find ways to finance the preservation and popularization of the heritage, with possible involvement of private interests. Also an entire section focuses on financial measures for the support at all the levels: local, regional and national, benefits for private interests, etc (The Law of Ukraine, 1972).

One of the most important sections is "Educational and cultural action" because its content completely coincides with the recommendations of UNESCO on establishment of Geoparks in the aspect of education (UNESCO, 2015). In general, the document is important in terms of contact with the authorities at the national level and is one of the additional tools which can be referred to (The Law of Ukraine, 1972).

In 1972 *the Declaration of the UN Conference on the Human Environment* was signed. It is worth noting some important theses: Part 1 of the Declaration, clause 6 – improvement and protection of the human environment for the present and future generations is the most important goal of the mankind; (The Law of Ukraine, 1972) clause 7 – appeal to all governments and nations to put maximum efforts for the protection and improvement of the environment; (The Law of Ukraine, 1972) Part 2, Principle 2 – natural resources of the Earth and the most representative examples of the natural ecosystems should be preserved; (The Law of Ukraine, 1972) – these clauses are important, they can be referred to practically in any nature-protection document.

Principle 24 states that the international problems related to the protection and improvement of the environment should be solved by cooperation of countries, based on multi-party and bilateral treaties. According to Principle 25, the State should support the activity of international organizations for their coherent, efficient and dynamic role in the work on the protection and improvement of the human environment – the latter principle emphasizes the problem in Ukraine, for the state does not contribute to cooperation with the UNESCO in the issue of establishing Geoparks, therefore this principle should be used in the dialogue with the authorities (The Law of Ukraine, 1972).

In 1972 the most important of all international documents regarding the establishment of Geoparks was adopted – the Convention on the Protection of the Global Cultural and Natural Heritage (The Law of Ukraine, 1988). According to Article 2 of the Convention, the "natural heritage' in particular is understood as "geological and physiographical formations and precisely delineated areas … of outstanding universal value from the point of view of science or conservation; natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty" – this is the main notion which should be used in determining the natural heritage (The Law of Ukraine, 1988).

According to Article 3, our country should determine and distinguish different values on its territory, according to the definitions of cultural and natural heritage (The Law of Ukraine, 1988). According to Article 4 the countries are obliged to provide determination, protection, preservation and popularization of the natural heritage. (The Law of Ukraine 1988). Article 5 mentions how particularly it should be done, i.e.: pursue general policy orientated towards provision of the cultural and natural heritage with certain functions in the public life; take corresponding legal, administrative and financial measures; encourage scientific studies in this sphere – these articles can be referred to in the process of establishing Geoparks (The Law of Ukraine, 1988). Article 6, part 1 contains an important thesis that the cultural and natural relics are the global heritage, for the protection of which the

international community should cooperate (The Law of Ukraine, 1988). To implement all of that, the Intergovernmental Committee for the Protection of the Cultural and Natural Heritage of Outstanding Universal Value, called the World Heritage Committee was established. Its work is regulated by the III section of the Convention. The Committee composes, enlarges and publishes the "World Heritage List", enlisting outstanding cultural and natural relics from the lists provided by the countries which are the parties in the Convention. One can be familiarized with this process in Article 11 (The Law of Ukraine, 1988). The subjects of the application can be: protection, preservation, promotion or restoration of these relics, partly funded by international organizations. For these purposes the Fund for the Protection of the World Cultural and Natural Heritage was established, as indicated in Section IV of the document. Besides financial, the Committee can provide other forms of help, as described in Article 22 (The Law of Ukraine, 1988).

An important section is also VI section "Educational Programmers", which indicates what the party countries should aim for, using the corresponding means, and particularly educational and informational programmers, increasing the respect and commitment of their nations to cultural and natural heritage; obligation to broadly inform the public about the measures taken for the execution of the Convention. It is hard to overestimate the importance of this document on the protection of nature and the geological heritage in particular (The Law of Ukraine, 1988).

In 1978 *the Statute of the International International Council on Monuments and Sites* was adopted. In our country, there is a Ukrainian unit of this organization, ICOMOS. It deals with the issues of protection of cultural monuments and historical places (The Law of Ukraine, 1978).

At first glance, it seems that the organization has an indirect relation to Geoparks, but if we consider the statute and the main law of this International Board, this assumption is refuted. Very useful is Article 3, Part 1, Clause b on objects which together with the landscape, historic, scientific and ethnological value, and the main thing, its natural environment, form "ensembles" which are protected by this organization (The Law of Ukraine, 1978). There are such "ensembles" in our possible Geoparks, for example there is monastery in the National Park Sviati Hory, which is built into Cretaceous rocks. Because this is an international organization and one of the structural units of UNESCO, determination of one of the objects of geopark as an object protected by the ICOMOS would foster the process of establishment of Geoparks.

There is a number of normative acts which specialize particularly on wildlife, but contain aspects useful for establishment of geopark and protection of geological objects (Table 2).

In 1991 *the Protocol on Cooperation between the Ukrainian Soviet Socialist Republic and UNESCO* was adopted. It has legal force according to the Vienna Convention on Succession of States in respect of Treaties, therefore all the theses regarding Ukrai-

Table 2. Normative acts specializing in wildlife

Title	Ratification year	Nomenclature	Important theses
Convention on the Conservation of European Wildlife and Natural Habitats	1979	Section II "Protection of the environments" (The Law of Ukraine 1996)	Protection of territories with representatives of flora and fauna
World Charter for Nature	1982	"General principles", "Functions" (The Law of Ukraine 1982)	Document, among others goals, is orientated at protection of unique areas, all types of ecosystems and habitats of rare species
Declaration on Conservation of Flora, Fauna and Their Habitats	1988	Clause 8 (The Law of Ukraine, 1988)	Practically all the goals mention protection of environments of flora and fauna. Significant aim is strengthening the existing national parks and other protected natural territories – which directly corresponds to the transition of the nature territories protected at the national level to internationally-protected geopark
Convention on Biological Diversity	1992	Article 2 (The Law of Ukraine 1992)	This document defines the term which is mentioned in other normative acts, its definition particularly relates to geological objects. Specifically: "means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."

nian SSR are in force for modern Ukraine. Because the country has joined the Convention on Protection of the Cultural and Natural Heritage of 1972, among others, UNESCO would welcome applications from Ukraine for inscription of new natural locations for the World Heritage List (The Law of Ukraine, 1991). UNESCO and Ukraine have agreed that in their collaboration they shall take into consideration this Protocol and implement measures on the following development and enlargement of statements in practice (The Law of Ukraine, 1991). Referring to this document will positively contribute to the dialogue with UNESCO on the subject of establishing Geoparks.

In 1992 the *Convention on the Protection and Use of the Transboundary Watercourses and International Lakes* was approved. Because the basins of rivers are geological objects, and in some cases, (for example, the River Dniester) prominent objects for establishment of Geoparks (Kravchuk , Bohutskyi, Zinko, Brusak, Krychevska, Blahodyr, Shevchuk, 2013), this document has great value for the protection of such geological territories. The whole document contains articles on the protection of such objects (The Law of Ukraine, 2003).

In 1992 *the Rio de Janeiro Declaration on Environment and Development* was adopted. The document contains fundamental principles on which most normative acts on the nature protection are based . A separate mention should be made for Principle 10 about development and support of the awareness and participation of the population by broad provision of information by the state (The Law of Ukraine, 1992). This corresponds to one of the criteria of the UNESCO on establishment of Geoparks (UNESCO, 2015)

In 1995 *the Ecological Programme for Europe* was adopted. This is systematization of most nature-protection documents which are relevant for the territory of Europe, compiled into one programme. The programme emphasizes growth of the potential of the existing nature-protection organizations, most of which are mentioned in this article. Moreover, there is a whole section aimed at improvement of protection of biological and landscape diversity, which can be referred to in the process of establishment of Geoparks (The Law of Ukraine, 1995).

In 1998 *the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters* was adopted. It is an important document which encourages authorities to enter into dialogue and distribute information among the population of Ukraine. This law contains some statements which could be used during communication with the authorities, particularly Article 3 ,Clause 3 on supporting ecological education and improvement of the level of public awareness of problems of the environment, corresponding to the criteria of UNESCO for the establishment of Geoparks – ecological education of the public (The Law of Ukraine, 2005; UNESCO, 2015). Also no less important is Clause 4 of Article 3, describing the provision of required recognition of organizations which are working for protection of the environment and provision of needed support, which is very important for organizations involved in preservation of geological relics in dialogue with authorities (The Law of Ukraine, 2005).

In 1999 *the Treaty between Ukraine and the United States of America on Regional Ecological Center in Ukraine* was signed. (The Law of Ukraine 1999) In 2000 it was adopted at the state level. The Regional Ecological Center (REC) is one of the international organizations which work on protection of the environment. In 2000, Ukraine, at the international level and state levels, approved the creation of a center of REC in the country. Up to 2018, according to different data, it implemented 40-60 projects, and in 2018 the legal status and opening of its office in Kyiv were ceremonially signed by Deputy Minister of Ecology and Natural Resources Mykola Kuzio and executive director of the REC Myhailo Dymovski (UNIAN, 2018). Apart the support and consultative help, the REC has a programme of grants which could be used during the establishment of Geoparks (REC Kyiv, 2000).

In the Statute of REC in Kyiv, each clause indicates help to all those interested in the protection of the environment, from consultations to financial support, etc. Clause 8 of the Statute indicates the main task which corresponds to the main goals and criteria of the UNESCO in the aspect of Geoparks (The Law of Ukraine 1999; UNESCO, 2015).

In 2000 *the European Landscape Convention* was adopted. It is an important normative act indicating and characterizing landscape as natural object, according to Article 1, clause a: as territory the character of which is the result of impact or interaction of natural and human factors – which according to legal practice can be used as definitions in other documents which lack definition (The Law of Ukraine, 2005). Because most geological objects in the territory of possible Geoparks have more aesthetic value, they can be considered landscape relics, as for example, the Cretaceous rocks in the Dvorichansky National Park. Landscape objects are protected according to this Convention, allowing them to be used and referring to it in the process of establishment of Geoparks (The Law of Ukraine, 2005).

In 2000 *the UN Millennium Declaration* was adopted. This is an important document for the whole of

mankind, consisting of the main theses on development of the global community. According to clause 6, the UN considers that a number of fundamental values shall be exceptionally important for international relations in XXI century shall be a number of fundamental values, including particularly: "Respect to nature" and also section IV focused on protection of the environment – this again confirms the importance and relevance of the idea of establishing Geoparks in Ukraine. This document is important and may be referred to in the dialogue with authorities and international organizations (The Law of Ukraine, 2000).

Conclusions. Processing and analysis of all the above mentioned international acts and assessments in their legal field of Ukraine, allows us to draw the following conclusions:

1. In the legal field of the country, the laws on protection of geoheritage are incomplete, though our state has ratified and signed many international normative acts which positively affect the issues of establishment of Geoparks.

2. An international "Legal map" was developed, which should be used during developing documents at the state level. This would provide these documents with legal force.

3. On the question of establishment of Geoparks, one should apply for help from other countries with which corresponding treaties are signed.

4. In the international legislation, no terms "Geoparks" and "geologic relic" are present, and therefore the protection of geological objects should be considered using more approximate terms: environment, habitat, ecosystem, natural objects, natural heritage, etc.

5. Issues of protection of the geoheritage is a subject of growing concern within the global community and corresponding steps towards its preservation are being made.

6. We determined that many documents oblige our state to support protection of geoheritage, being an important tool in dialogue with authorities, which should be used.

7. Results of this work should bring our country closer to the establishment of Geoparks in Ukraine.

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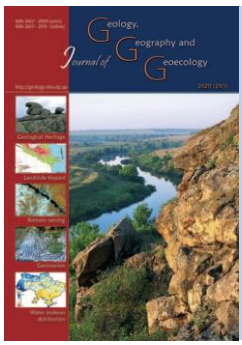

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