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Uliganets S. I., Syrovets S. Yu., Koroma N. S., Molochko M. A.

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A geographical dimension of resource endowment of Ukrainian territories

Serhii I. Uliganets, Sergii Yu. Syrovets, Nataliia S. Koroma, Mykola A. Molochko

Taras Shevchenko National University of Kyiv, Kyiv, Ukraine, e-mail: lginfo@ukr.net

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Abstract. Given the multidisciplinary nature of this research, it is important to develop a common understanding of the security and complexity of the rational consumption of available minerals. Considerations for the availability and depletion of minerals are part of a diverse range of research focused on sustainable development, in areas such as resource critical

shortage, life cycle assessment and material flow analysis. Mineral resources are non-renewable resources that provide humanity with a wide range of goods and services. Although their value has been recognized for millennia, their large-scale industrial production did not grow until after World War II due to efficient industrial production processes and rapidly growing demand due to demographic growth, urbanization and economic wealth growth in developed countries. The proposed research confirms the high level of supply of the territory of Ukraine with mineral resources. The objective idea of mineral and self-sufficiency of Ukraine, its inclusion in the top groups of the states most provided with the most valuable types of minerals is strengthened and the high level of availability of mineral resources in Ukraine in terms of its economic and geographical areas and regions is confirmed. At the same time, a number of mineral deposits in modern social and economic conditions are preserved and not used. For the first time, a cartographic interpretation of the periodic table of chemical elements (D. I. Mendeleev's table) is given, which is reinforced by data on the distribution of mineral resources and minerals in terms of selected groups of regions within the administrative regions of Ukraine. There are 33 chemical elements extracted from more than 100 mineral deposits. The provisions and conclusions of the article testify the mineral self-sufficiency of Ukraine and can act as a lever for developing strategies for socio-economic development of the United Territorial Communities (UTC) of Ukraine, which today are the new centers of management of territories and its resources. D. I. Mendeleev's table and its mineral content are positioned as an objective factor in the specialization of Ukraine and the international geographical division of labour. It is noted that the main advantages of the Periodic Table of Chemical Elements, including its structure, logic, objectivity, a system in relation to the economic and geographical regions of Ukraine are considered as an element of monitoring the mineral component of natural resources of the country, the lever of further development of exploratory geology and geomorphology. The information obtained from this research ultimately influences the future policies of the territories and its plans for the balanced use of available mineral reserves and can be used to promote the sustainable use of mineral resources in the regions.

Keywords: mineral resources of Ukraine, minerals, deposits, system of chemical elements, table DI Mendeleev, cartographic interpretation, region, district, United Territorial Communities (UTC).

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С. І. Уліганець, С. Ю. Сировець, Н. С. Корома, М. А. Молочко

Київський національний університет імені Тараса Шевченка, Київ, Україна, e-mail: lginfo@ukr.net

Анотація. З огляду на мультидисциплінарний характер даного дослідження, важливо сформулювати загальне розуміння стану забезпеченості та складності раціонального споживання наявних корисних копалин. Міркування щодо доступності та виснаження корисних копалин є частиною різноманітного спектру досліджень, орієнтованих на сталий розвиток, у таких сферах, як критичність ресурсів, оцінка життєвого циклу та аналіз матеріального потоку. Мінеральні ресурси є невідновлюваними ресурсами, що забезпечують людству широкий спектр товарів і послуг. Хоча їх цінність визнавалась тисячоліттями, масштаби видобування мінеральних ресурсів справді зросли лише після Другої світової війни завдяки появі ефективних виробничих процесів та швидкому збільшенню попиту, зумовленому демографічним зростанням, урбанізацією та збагаченню розвинених країн. Пропоноване дослідження демонструє високий рівень забезпечення території України мінерально-сировинними ресурсами. Вперше дана картографічна інтерпретація періодичної таблиці хімічних елементів (таблиця Д. І. Менделєєва), яка посилена даними щодо розподілу мінерально-сировинних ресурсів та корисних копалин в розрізі виділених груп регіонів в межах адміністративних областей України. Наведено 33 хімічні елементи, які видобуваються на понад 100 родовищах корисних копалин. Положення та висновки статті засвідчують мінерально-сировинну самодостатність України та можуть виступати важелем розробки стратегій суспільно-економічного розвитку об'єднаних територіальних громад (ОТГ), які сьогодні є новими центрами управління територіями та її ресурсами. Таблиця Д. І. Менделєєва та її мінерально-сировинне наповнення позиціонуються як об'єктивний чинник спеціалізації України та міжнародного географічного розподілу праці. Інформація, отримана в результаті

цього дослідження, зрештою впливає на подальшу політику територій та її плани щодо збалансованого використання наявних запасів корисних копалин і може бути використана для сприяння сталому використанню мінеральних ресурсів у регіонах.

Ключові слова: мінерально-сировинні ресурси України, корисні копалини, родовища, система хімічних елементів, таблиця Д. І. Менделєєва, картографічна інтерпретація, регіон, район, об'єднані територіальні громади (ОТГ).

Relevance of the research topic.

The need for local government reform and territorial organization of power in Ukraine was due to the fact that the administrative-territorial system in the country did not meet the modern requirements of real transformation, hindered the necessary transformations in the state, and due to effective regional policy, which resulted in restraining the development of individual territories and the state as a whole. The "Strategy of sustainable development of Ukraine until 2030" approved by the Decree of the President of Ukraine provides for a comprehensive approach to reforms in Ukraine. Clause 9 of the Strategy outlines an energy saving program, which states "ensuring the widest possible diversification of ways and sources of primary energy resources, including oil, natural gas, coal, nuclear fuel, increasing domestic energy production" (Strategy of sustainable development of Ukraine until 2030, 2017). The strategy of sustainable development, together with the new administrative-territorial structure proclaimed at the state level, should become the basis for creating a new model of territorial governance. To implement effective management of territories, and resources in particular, at the local level, there is a need for a detailed assessment of the resource security of the territories of Ukraine and further formation of the methodological framework for improving the territorial organization of government in their management.

Sustainable development of mineral resources is important for the national strategy of resource endowment and environmental civilization. Rational use of mineral resources, based on the model of ecological safety of the landscape, forms a scientific basis for overcoming conflicts between the conservation of resources and their use by man, contributing to the accompanying economic development and ecological integrity. Rational use of mineral resources, based on the model of ecological safety of the landscape, forms a scientific basis for overcoming conflicts between the conservation of resources and their use by man, contributing to the accompanying economic development and ecological integrity.

Diagnostics of mineral base and self-sufficiency of Ukraine, monitoring of the natural resource environment, and the state of its subsoil is an important factor in the economic stability of the state. A component of this scientific and practical issue is the expansion and deepening of systemic ideas about the location of geochemical raw materials in Ukraine by grouping united territorial communities (UTC) by region, using

tables of chemical elements as a basis for a fundamental methodological approach.

This issue study state and main works.

A review of analytical publications and publications on the critical description of the availability and extraction of minerals, identified a significant expansion of the scope of research in the context of balanced use of their available reserves. This can be used to promote sustainable consumption of mineral resources in the regions: from mining, landscape change, and pollution to ecosystem health, sustainable development, and the rights of future generations (Christmann, 2018; Contested terrain: Mining and the Environment, 2004; Northey, Mudd, Werner, 2018; Peng, Zhou, 2019; Zhang, Wang, 2020). A significant array of publications of domestic and foreign specialists – geologists, geographers, naturalists – is devoted to the mineral resources of Ukraine, deposits of its minerals (Gursky, Esipchuk, Kalinin, 2006; Beydik, 2018, 2019; Rudko, Ivanov, Kovalchuk, 2019). On the other hand, the ingenious invention of D. I. Mendeleev, his periodic table of chemical elements for over a hundred years is at the center of both world scientific thought and practical development of the strategies laid down in it, because instead of scattered, unrelated compounds, appeared before science the only coherent system that combines all the chemical elements. Strengthening the table with examples of specific mineral deposits of Ukraine was reflected in the works of Beydik O. (Beydik, 2018, 2019), and the characteristics of mineral deposits of Ukraine are given in a number of fundamental sources (Geology of the USSR, 1958; Gursky, Esipchuk, Kalinin, 2006; Restructuring of the mineral resources base of Ukraine and its information support, 2007; Rudko, Ivanov, Kovalchuk, 2019). Suggested material is an attempt of mineral-raw material and economic-geographical strengthening of D. I. Mendeleev's table, demonstration of interdisciplinary connections at studying the geography of Ukraine and the natural-resource self-sufficiency of the country.

Formulation of the problem.

Resource management is perhaps the most important condition for the functioning of any complex territorial systems of different levels. In the analysis and assessment of the quality of management use the concept of "production and resource potential", the study of its size and structure. This concept defines the maximum potential of accumulated and prepared for processing

natural, logistical, labor, financial and information resources to meet the needs of the individual citizen and society as a whole. The results of the assessment of all resources, especially natural (raw materials), will form the main direction of the strategy of management of the territory and available resources. In the context of modern market demand resource conservation (which is to reduce resource consumption, use active resource-saving measures, support competitive positions based on reducing resource use and reducing resource consumption), new centers of management of territories and its UTC resources, according to current legislation have the opportunity not only to influence and optimize this process but also to have from this revenue to the budget (Chykalo, 2018). Resources of UTC territories can be grouped as follows:

a) natural-geographical: land, forest, water, mineral, biological, energy;

b) social and economic: tangible (movable and immovable property, communications), financial (budget revenues and expenditures, grants, subventions, grants), human, and intangible (information, technology, communications).

Thus, **mineral resources** (fuel and energy, ore, chemical raw materials, natural building materials, and non-metallic minerals), in our opinion, can provide the greatest opportunity to ensure financial capacity and self-sufficiency as separate UTC, and regions (oblasts) of Ukraine, which remain the largest administrative-territorial units in Ukraine.

There are a significant amount of natural or artificially created various substances (chemical elements and compounds, alloys, solutions, polymers) on the Earth. The distribution of chemical elements and mineral deposits on Earth is heterogeneous. This heterogeneity is reflected in the chain of security levels of mineral resources of countries and territories: very low, low, medium, high, very high. The extreme links in this chain can be represented, for example, by Paraguay (very low level of mineral supply) and South Africa (very high level of mineral supply). According to various estimates, Ukraine occupies the third (middle) – fourth (high) step in this line. We will remind that in the bowels of Ukraine about 20 thousand deposits and displays of 117 types of minerals are found out, from which 8291 deposits of 97 types of minerals are of industrial value and considered by The State Reserves. Mineral resources of Ukraine largely determine the national division of labor, Ukraine's place in world production of mineral resources. According to the potential value of confirmed mining reserves in the subsoil, it ranks 12th in the world (2.2 % of the potential value of world reserves) (Restructuring of the mineral resources base of Ukraine and its information support, 2007). As for energy, according to some experts, historically Ukraine

has huge resources – both oil and gas. This publication is an objective basis for such fundamental assessments and aims to demonstrate the country's self-sufficiency in providing the most important minerals.

The purpose of the study is to adapt the periodic table of chemical elements of D. I. Mendeleev for the systematization of ideas and cartographic modeling of the distribution of mineral deposits in the context of the regions of Ukraine. Positioning and realization of the goal serve as an evidence base of the mineral and self-sufficiency of Ukraine. To propose the grouping of UTC regions within the administrative regions of Ukraine according to the level of security of mineral deposits for optimizing the structure of the socio-economic complex of Ukraine and all its components, taking into account the provision of geochemical raw materials of a particular area, which is crucial in the formation and development of specialization, complexity, balance, and proportionality.

Research methods.

The system approach and methods of deductive, comparative geographical (analysis of maps of minerals, mineral resources of Ukraine in terms of administrative regions) analysis, mapping and cartographic modeling (cartographic interpretation of D. I. Mendeleev's table), monographic (analysis of fundamental works of leading domestic and foreign geologists and resource scientists, geological and mineral directories and dictionaries, multi-volume publications on geology and mineral resources of Ukraine) were used when the article was been writing, and modern computer technologies (Arc GIS Online, Adobe Illustrator CC) were used in data processing and systematization. Both GIS technologies and classical methods of cartographic imaging (localized icons, cartograms and map diagrams) were used in the creation of cartographic models.

Presenting main material.

In terms of theory and practice, the geographical map plays an important role both at the beginning of any study, when its fundamental paradigm is laid, and at the end, when the certain elements of integration of zoning components, its configuration and contours are deepening, clarifying or refuting. The analysis of theoretical bases, principles, criteria of grouping of territory (regions) as a whole and regional schemes of Ukraine showed some variability in scientific and practical approaches and results of this procedure (Alampiev, 1963; Christmann, 2018; Contested terrain: Mining and the Environment, 2004; Palamarchuk, 1993; Popovkin, 1993; Dolishnyi, Palamarchuk, Palamarchuk, Shevchuk, 1997; Shabliy, 2000).

Grouping is one of the main methods of studying spatial phenomena, a lever and a factor in solving a

number of scientific and practical problems. In the active period of implementation of the decentralization reform, severance of industrial relations, and the actual liquidation of economic and geographical areas, the scientific and practical significance of the last one remains less noticeable. The main idea of grouping UTC within the administrative regions of Ukraine was to optimize the structure of the social and economic complex and all its components, taking into account the supply of geochemical raw materials of a particular area, which is crucial in the formation and development of specialization, complexity, balance, and proportionality. When mastering the material, the basic data on new administrative-territorial units is territorial communities and districts in various formats on the portal "Decentralization" were analyzed.

Thus, we have identified three groups of UTC regions within the administrative regions in terms of the level of mineral deposits:

1) *Highly resource level regions* (Donetsk, Luhansk, Zaporizhia, Dnipropetrovsk, Lviv, Ivano-Frankivsk, Zakarpattia, Chernivtsi, Odessa, Mykolaiv, Kherson, Crimea);

2) *Middle resource level regions* (Kyiv, Chernihiv, Volyn, Rivne, Zhytomyr, Vinnytsia, Khmelnytsky, Ternopil);

3) *Low resource level regions* (Kirovohrad, Cherkasy, Kharkiv, Poltava, Sumy).

A systematic idea of providing Ukraine with mineral resources both as a whole and by groups of regions is given by the figure "Scheme of distribution of available and latent chemical elements of the periodic table groups of UTC regions within the administrative regions of Ukraine" (Fig. 1) and an explanation in the table "Mineral deposits by regional groups of Ukraine" (Table 1).

Chemical elements free state appear very rarely, more often they are part of various compounds, so we consider them as components of the most common minerals in Ukraine, for example, copper (Cu) is part of chalcocite (Cu₂S), tetrahedrite (Cu₁₂Sb₄S₁₃), chalcopyrite (CuFeS₂); lead (Pb) is a part of galena (PbS), boulangerite (5PbS * 2Sb₂S₃), cerusin (PbCO₃); silicon (Si) is part of quartz (SiO₂), opal (SiO₂*n H₂O), chalcedony (SiO₂), staurolite (Fe [OH] 2 * 2Al₂SiO₅) and twenty others. It concerns every element. Various combustible hydrocarbons of the type (CH₃ and CH₄) in the mixture are the part of the oil. Inert elements are an integral part of combustible gas.

As can be seen from the Table 1, more than 30 chemical elements are extracted at more than 100 mineral deposits.

Table 1. Mineral deposits by regional groups of Ukraine

Elements of rock-forming minerals	Rock-forming minerals	The main deposits
Aluminum	bauxite, alunite, staurolite, pyrophyllite, augite, epidote, spesartine, almandine, pyralpsit	Prydniprovya (Vysokopilske, Smilyanske, Kremenchuk, Kryvyi Rih), Donbass (Chasivyske), Crimea (Karadag), Volyn (Ovruch), Pobuzhya
Barium	barytes	Zakarpattia (Behanske), Donbass (Nagolny Kryazh), Zhytomyr region (Golovynske, Turchynske)
Carbon	diamonds, graphite, calcite, magnesite, dolomite, siderite, smithsonite, aragonite, cerusin, malachite	Prydniprovya (Zavalske, Petrivske, Pravdyske, Kryvyi Rih), Donbass (Mykytivske, Nagolny Kryazh, Slovyanske), Crimea (Baidaratske, Kerch peninsula), Zakarpattia (Trebusanske, Buzhanske, Berehivske)
Iron	pyrrhotite, chalcopyrite, pyrite, marcasite, arsenopyrite, hematite, magnetite, chromite, ilmenite, goethite, limonite, siderite, vivonite, staurolite, olivine, augite, egerin, muscovite, biotite, vermiculite, epidote, chlorite	Crimea (Kerch Peninsula), Donbass (Nagolny Kryazh, Mykytivske), Prydniprovya (Kryvyi Rih, Kapitonovske, Lipovenkivske, Samotkanske, Volynske, Serednyodniprovsk, Kremenchutske)
Gold	-	Dnipropetrovsk region (Nikopol district, Chortomlyn geological structure), Zakarpattia (Muzhievo)
Potassium	alunite, muscovite, biotite, lepidolite, sylvite, nepheline, feldspars	Donbass (Chasivyske) Prydniprovya (Vysokopilske, Smilyanske), Western Priazovye, Zakarpattia (Berehivske), Prykarpattia (Kaluske, Stebnytske)
Calcium	calcite, dolomite, aragonite, anhydrite, epidote, diopside, augite, fluorite, chabazite, titanite	Crimea (Baidaratske), Donbass (Slovyanske), Zakarpattia (Dilovetske, Buzhenske), Volyn, Prykarpattia, Pobuzhye, Chernihiv, Ivano-Frankivsk, Khmelnytskyi oblasts, Transnistria
Silicon	quartz, opal, chalcedony, staurolite, olivine, pyralpsit, almandine, spesartine, epidote, diopside, augite, aegirine, talc, pyrophyllite, chlorite, muscovite, biotite, lepidolite, vermiculite, topaz, titanite, zircon	Donbass (Nagolny Kryazh), Volyn (Ovruch), Crimea (Karadag), Pobuzhye, Priazovya, Zakarpattia, Prydniprovya (Kremenchuk, Kryvyi Rih, Samotkanske)
Lithium	lepidolite	Transnistria

Elements of rock-forming minerals	Rock-forming minerals	The main deposits
Magnesium	magnesite, dolomite, olivine, pyralisite, diopside, augite, talc, chlorite, biotite, bischofite, vermiculite	Middle Prydniprovya (Kryvyi Rih, Pravdyn), Priazovye, Carpathians, Volyn, Pobuzhye, Crimea
Manganese	pyrolusite, manganite	Prydniprovya (Nikopol, Ingulets), Carpathians
Arsenic	realgar, auripigment	Donbass (Mykytivske), Crimea (Kerch Peninsula), Zakarpattia (Kvasy)
Copper	malachite, azurite	There are no estimated deposits, there are only ore occurrences: Donbass (Nagolny Kryazh, Mykytivske), Priazovya (Maloyanisonske), Zakarpattia, Volyn, Podillya, Prydniprovya
Molybdenum	in the composition of molybdenite	Donbas, Prydniprovya
Sodium	nitrate, mirabilite, aegirine, nepheline, halite, feldspars	Volyn, Priazovya, Kryvyi Rih, Middle Prydniprovya, Prykarpattia (Kalush-Stebnytske deposit)
Nickel	nickel, millerite, pentlandite	Middle Prydniprovya, Pobuzhzhya (Derenyukhske, Lipovenkivske)
Tin	cassiteritis	Prydniprovya
Platinum	platinum group metals (palladium, iridium, rhodium, osmium, ruthenium)	Dnipropetrovsk oblast (Nikopol district, Chortomlyn geological structure)
Mercury	cinnabar	Donbass (Mykytivske), Zakarpattia and Crimea
Lead	galena, bulanerite, cerusite	Donbass (Nagolny Kryazh), Prykarpattia, Zakarpattia (Berezivske, Vyshkivske, Berehivske)
Sulfur	free state, chalcocite, galena, sphalerite, pyrrhotite, chalcopyrite, cinnabar, antimonite, realgar, auripigment, molybdenum, pyrite, marcossite, arsenopyrite, boulangerite, tetrahedral, barite, celestine, anhydrite, gypsum, mirabilite	Prydniprovya (Vysokopilske, Smilyanske), Donbass (Mykytivske, Nagolny Kryazh), Crimea (Kerch Peninsula), Transnistria (Rudalske, Yazivske, Lyubinske, Humenetske), Prykarpattia (Kaluske, Stebnytske)
Silver	-	Donetsk oblast (Naked ridge), Zakarpattia (Kvasivske)
Strontium	celestine, strontium	Prykarpattia, Podillya
Trumpet	antimonite, tetrahedral, bulanerite	Donbass (Mykytivske, Nagolny Kryazh), Zakarpattia
Titanium	ilmenite, rutile, augite, titanite	Zhytomyr oblast (Irshanske), Zakarpattia, Carpathians, Pobuzhye, Crimea, Priazovye, Central Prydniprovya (Samotkansky, Volyn, Middle Dnieper)
Zinc	zinc deception	Donbass (Nagolny Kryazh), Prykarpattia (Truskavets district), Zakarpattia (Berehivske, Vyshkivske, Berezivske)
Chrome	chromite, celestine	Middle Prydniprovya (Kapitonovske, Lipovenkivske), Volyn, Priazovye, Kryvyi Rih
Fluorine	fluorite, muscovite biotite, lepidolite, topaz	Vinnitsia region (Mogilev-Podolsky district), Western Priazovye, Volyn, Dnipro, Ivano-Frankivsk and Chernihiv regions, Donbass
Phosphorus	apatite, vivonitis	Donbass (Osykivske), Prydniprovya (Novopoltavske), Chernihiv and Khmelnytsky regions, Crimea (Kerch peninsula)
Chlorine	halite, sylvin	Donbass (Slovyanske, Artemivske), Prykarpattia (Kaluske, Stebnytske), Zakarpattia
Zirconium	zircon	Prydniprovya (Samotkanske, Rozsypne), Priazovya
Volatile hydrogen compounds	—	Poltava oblast (Hlynsko-Rozbyshivske), Sumy oblast (Kachanivske, Rybalske), Chernihiv oblast (Gnidynitsivske, Lelyakivske), Ivano-Frankivsk oblast (Dolynske), Lviv oblast (Truskavets, Boryslav)
Inert gases	—	Crimea (Glebivske, Dzhankoyske), Kharkiv oblast (Shebelinka), Poltava oblast (Gogolivske, Solokhivske), Dnipropetrovsk oblast (Bereshenine), Lviv oblast (Rudkivske, Khodnovytske)

The above was "converted" into a cartographic model, which is an interpretation of the periodic table of chemical elements (Fig. 1).

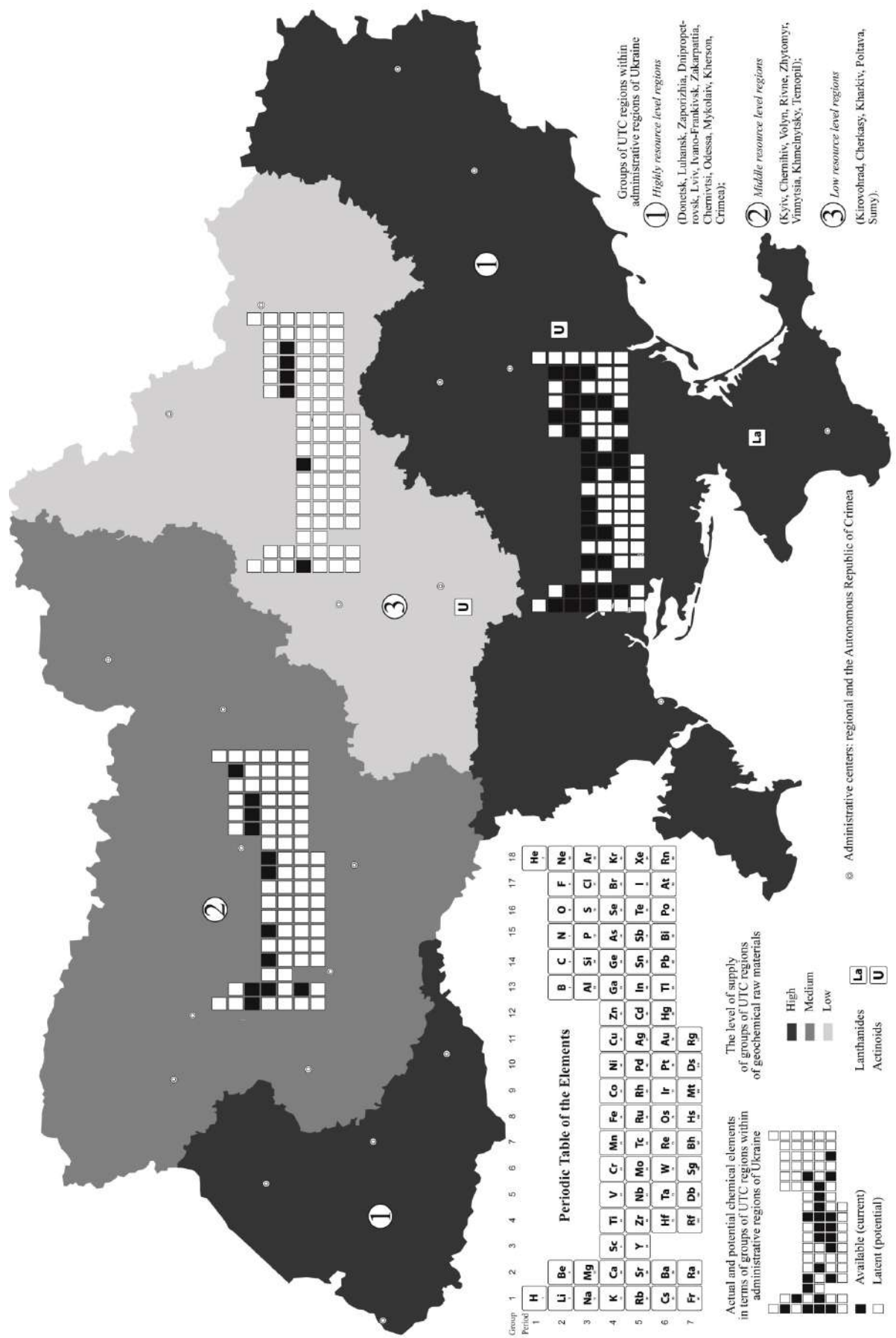


Fig. 1. Scheme of distribution of available and latent chemical elements of the periodic table by UTC groups within the administrative regions of Ukraine

The constructed map with relatively smaller / larger differentiation of available chemical elements of the periodic table demonstrates the potential of selected groups of UTC within administrative regions with relatively high concentrations of minerals, which indicates not only valuable actual deposits, but also high mineral potential of these areas (latent deposits). At the same time, a significant share of the largest European country still remains a mineral resource terra incognita, the subsoil of which is still awaiting for their use. Isn't this a fundamental factor that will give Ukraine optimism about its future? The main advantages of the periodic table of chemical elements, including its structure, logic, objectivity, regularity in relation to groups of regions within administrative regions are considered as an element of monitoring the mineral component of the country's natural resources, a lever for further development of exploratory geology and geomorphology.

Thus, D. I. Mendeleev's table enhanced by distribution data of mineral resources and minerals in terms of selected groups of UTC within the administrative regions of Ukraine is presented clearly. It should be noted that the cartographic and textual information contained in the article is open for interpretation and further steps to deepen and expand the idea of qualitative and quantitative analysis of the most important national and regional mineral deposits.

Conclusions and results.

A cartographic interpretation of the periodic table of chemical elements (D. I. Mendeleev's table) is presented for the first time, which is reinforced by data on the distribution of mineral resources and minerals in the

regions of Ukraine and were formed into three groups within administrative regions: high, medium and low-income regions. The objective idea of Ukraine's mineral base and self-sufficiency is strengthened. The uneven distribution of the available chemical elements of the periodic table on the territory of Ukraine was confirmed, the potential of the selected UTC groups within the administrative regions of Ukraine for relatively smaller / larger differentiation by chemical elements of the periodic table was demonstrated through the map. At the same time, it should be noted that a number of mineral deposits in modern social and economic conditions are preserved and not used. Information on geochemical raw materials available in Ukraine is systematized according to three items (elements of rock-forming minerals – rock-forming minerals – main deposits), which update the cartograms and map diagrams placed on the diagram. D. I. Mendeleev table and its mineral content are positioned as an objective factor in the specialization of Ukraine and the international geographical division of labor. The presented material substantiates the mineral base and self-sufficiency of Ukraine and can act as a lever for the development of new strategies for social and economic development of particular UTCs of Ukraine. The study can be continued in the following areas: the study of public policy on the design of balanced use of mineral resources and the distribution of costs for the development of resources; research in the field of external control, resource rights, and environmental justice; cultural studies that illustrate how mining affects public concern about the social and environmental consequences of national (and global) industrialization and globalization.

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