Koptieva T.S.

ALTITUDE DIFFERENTIATION AND DIVERSITY OF THE MINING LANDSCAPES OF KRYVORIZHZHIA

Series: "Anthropogenic landscapes of the Right bank Ukraine"

Ministry of Education and Science of Ukraine

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Koptieva T.S.
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The monograph examines the current state of altitudinal differentiation and the diversity of mining landscapes study. Using as example the Kryvyi Rih landscape-technical system, the altitudinal differentiation and diversity of mining landscapes, which were formed in the process of developing iron ore, crystalline rocks of the Ukrainian Shield and other minerals, were studied. An analysis of the available domestic and foreign experience in optimizing the mining landscapes of Kryvorizhzhia was carried out, and own approaches to their cultivation were proposed, taking into account altitudinal differentiation and diversity.

For geographers, landscape scientists, ecologists, specialists in nature protection field and rational nature management, local historians and students.

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PREFACE

The research of horizontal and vertical differentiation of mining landscapes is a relatively new direction of research on anthropogenic landscapes. The phenomenon of altitudinal differentiation of mining landscapes is closely related to their diversity. Study of the diversity of mining landscapes involves the identification of landscape complexes of different hierarchical levels at any territory for scientific, educational and economic purposes, and also is necessary for recommendations on their use for various economic needs, tourism and recreation, the creation of reserve fund objects.

On the territory of Kryvorizhzhia, the mining industry has been operating for about 150 years, and during this short period of time it transformed natural landscapes into anthropogenic ones, which nowadays are leading in the landscape structure of this region. Every year their area increases, mainly due to mining landscapes. Mining landscapes spread over the entire territory of Kryvorizhzhia, which is caused, first of all, by the peculiarities of the spatial occurrence of iron ore deposits of the Kryvorizhzhia iron ore basin. They occupy almost 40,000 hectares and are of essential importance in the functioning of the modern Kryvyi Rih landscape and technical system. As a result, the territory of Kryvorizhzhia is sufficiently representative for the study of both altitudinal differentiation and the diversity of mining landscapes with the aim of their further rational use.

The author will be sincerely grateful for interesting additions and constructive comments regarding the content of the fifth monograph from the series "Modern Nature and Landscapes of Ukraine", published under the general editorship of Professor G.I. Denysyka.

THEORETICAL AND METHODOLOGICAL BASIS OF THE RESEARCH OF ALTITUDE DIFFERENTIATION AND DIVERSITY OF MINING LANDSCAPES

1.1. Terminological apparatus in the process of mining landscapes research

Geographers, geologists and landscape scientists of Ukraine have been dealing with issues of terminology related to the understanding of anthropogenic, and among them mining landscapes, since the second half of the 20th century.

Hlushchenko was the first in Ukraine to study both anthropogenic and mining landscapes, particularly the south of Ukraine [17]. He considered the typology of anthropogenic-natural geocomplexes of the Kerch Peninsula, characterizing mining developments.

In the late 70s - early 80s of the 20th century study of anthropogenic landscapes of Bukovyna and Podillia was started by a group of physical geographers of Chernivtsi University. Their program included issues of the theory of anthropogenic landscape science (L. I. Voropai), studies of technogenic (G. I. Denysyk), residential (M. M. Kunytsia) landscapes, etc. In the subsequent study of anthropogenic, in particular, industrial landscapes of Right Bank Ukraine, individual scientists continued [24]. Among the works related to the study of industrial landscapes, the researches of L. M. Bulava [3] and Yu. G. Tiutiunnyk [108] deserve attention, in which the industrial landscapes of Kryvbas were characterized for the first time on the basis of field research, their classification schemes were proposed, and partially investigated geochemical properties and the corresponding maps were compiled. In the future, the research started by L. M. Bulava and Yu. G. Tyutyunnyk was continued by other scientists.

V. L. Kazakov [49] worked on theoretical issues of anthropogenic landscape science, classified technogenic, in particular, mining landscapes, developed and substantiated their terminology, and proposed a mechanism for rational use. H. M. Zadorozhnia [39] for the first time investigated derivative processes and phenomena in the mining landscapes of Kryvorizhzhia in detail.

The concepts of "altitude differentiation" and "vertical differentiation" were developed in 1947, when the phenomenon of vertical differentiation of landscape complexes on the plains was discovered for the first time during the study of the landscapes of the East European Plain [80]. This phenomenon characterizes certain differences in the relief, associated with fluctuations in absolute and relative heights, and causes intrazonal changes (Fig. 1.1).

A little later, it was noted that along with the concept of "vertical differentiation" there is the concept of "altitude differentiation", and that these concepts should be distinguished. In geographical literature, the concepts of "vertical differentiation" and "altitude differentiation" (zonation, zonality) are used widely, but ambiguously. There are even attempts to identify them. At the same time, these are different concepts, and each of them characterizes a corresponding natural phenomenon.

The word "vertical" came into Ukrainian language from the French " vertical ", it comes from Latin " verticalis ", which means "vertical". Accordingly, under by vertical differentiation of natural components and landscape complexes, it is expedient to consider only those features and properties that are reflected in a vertical section [8].

The vertical differentiation of landscape complexes is characterized by a corresponding set (in section) of natural components (masses of the solid earth crust with surface forms, soils, waters, animals, plants, air). If at least one of these components is missing, then we are talking about partial, incomplete vertical differentiation of landscape complexes, and if all of them are present - about entire or complete. Regarding the meaning of the term "altitude differentiation", it (phenomenon) combines both the properties of vertical and horizontal differentiation of natural components and landscape complexes [25].

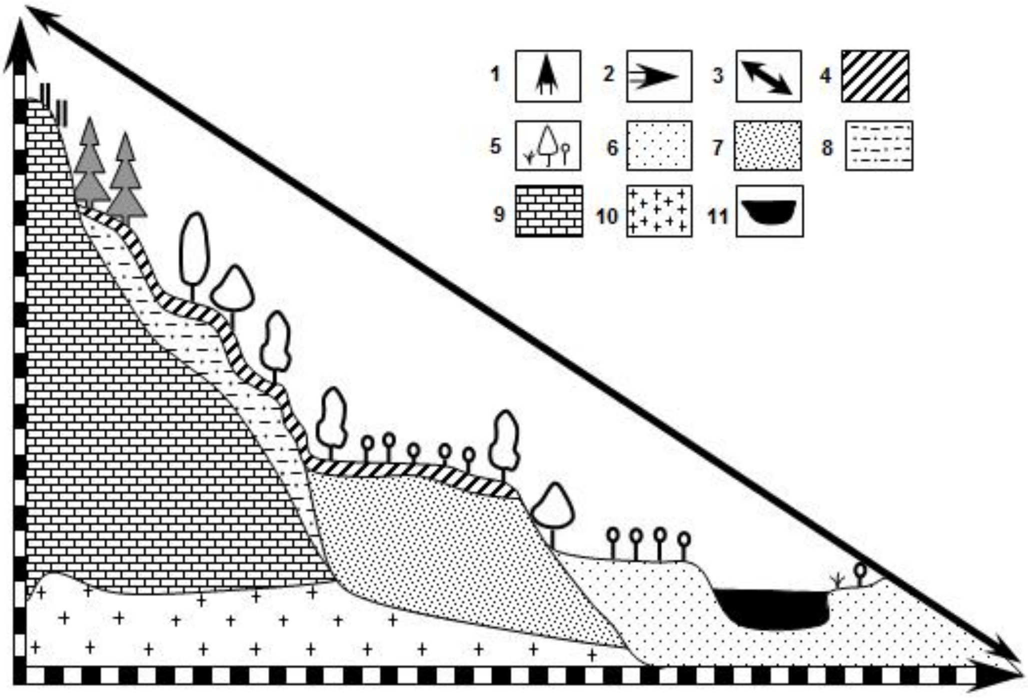

Fig. 1.1. Differentiation of natural components and landscape complexes [8]

1 – vertical; 2 – horizontal; 3 – high altitude; 4 – soil cover; 5 – plant cover; 6 – floodplain alluvium; 7 – alluvium of the supraflood terrace; 8 – loess-like loams; 9 – limestones; 10 – crystalline foundation rocks; 11 - water masses.

That is, in the process of a detailed examination of the height differentiation of natural components or landscape complexes, it is necessary to identify and investigate the features of their horizontal differentiation depending on the height of the location (vertically) and the degree of dismemberment of the territory. In addition, the climatic factor has a significant influence on the altitudinal differentiation of natural complexes and natural components. In general, when revealing the altitudinal differentiation of landscapes, it is advisable to pay attention to both the features of the components of the landscape complex and their vertical structure.

The term *"anthropogenic landscape"* is the most recognized among the scientific community, although it is not the only one. The concept of anthropogenic landscape, without a doubt, entered the most authoritative geographical and nature protection dictionaries and reference books, encyclopedias, in particular the three-volume "Geographical Encyclopedia of Ukraine" [13], but it is interpreted ambiguously. The difficulty of studying anthropogenic landscapes is evidenced by mistakes that even experienced landscape scientists sometimes make in matters of landscape theory. V. M. Pashchenko [89] and Yu. G. Tiutiunnyk [108] combined natural, natural-anthropogenic, anthropogenic, anthropogenic-technogenic and technogenic complexes. Anthropogenic and technogenic landscapes cannot be considered simultaneously in one evolutionary series, because technogenic landscapes are only one of the genetic groups of anthropogenic landscapes. To denote this concept, the terms "anthropic" [71, p. 17], "anthropogenized", "humanized", "cultural", etc. were introduced. These terms are not substantiated, they are not supported by scholars.

It is important to note that highlighting a new term is appropriate when it has a new meaning. The previously mentioned terms can be used, but not in relation to new landscape complexes created by man. Understanding and interpretation of the anthropogenic landscape in international dictionaries and the "Geographical Encyclopedia of Ukraine" is close to the broad: "Anthropogenic landscape (from the Greek άνθρος - man and ɤευυὰw - I generate, create) - a landscape changed by human activity in the process of performing socio-economic functions with appropriate technology of nature management" [13, p. 44].

The definition of anthropogenic landscapes as modifications of natural landscapes is erroneous. To modify means to make changes to something without changing its inner essence. The restoration of the landscape complex to its original state is possible only when its structure or at least one of its geocomponents was not fundamentally changed , and therefore it did not function as anthropogenic.

Technogenic landscape. In the landscape sphere of the Earth, the number, role and importance of anthropogenic landscape complexes of technogenic origin is constantly increasing. The most anthropogenic and energy-rich landscape complexes currently occupy 6–7% of the land surface. Landscape complexes of technogenic origin include cities and villages, industrial and energy complexes, transport complexes, etc.

The widespread distribution of technogenic landscapes often leads to an exaggeration of their role and importance in the structure of anthropogenic landscapes. This is followed by attempts to identify anthropogenic, and even more often industrial, landscapes with technogenic ones.

Such a broad understanding of technogenic landscapes, as well as their identification with anthropogenic ones, is wrong, and this has been proven by further research. Technogenic landscapes are only one of the genetic groups of anthropogenic ones, such as slash-and-burn, arable, pyrogenic and others. To equate technogenic landscapes on the one hand, and industrial or other anthropogenic landscapes on the other hand, means mixing groups of geocomplexes separated by different classification features. Not all anthropogenic landscape complexes, even if technology was involved in their formation, can be considered technogenic.

It is expedient to connect technogenic landscapes only with those antropogenic landscape complexes created as a result of interaction between technology or geotechnical system with natural environment the lithogenic base of which has been radically changed, and accordingly, the landscape structure has been created anew [24]. The most typical representatives are the quarry-dump landscapes formed in places of mineral extraction. Technogenic landscapes also include gardens, forest plantations, agricultural and other lands, created on the terraced slope of a stream, river valley, mountain or on alluvial, embankment surface, etc.

In addition, the recognition of the essential importance of technology in the formation of modern landscapes allows us to state that each type or group of types of technical systems corresponds to its own class of technogenic landscapes [17]. For example, hydrotechnical and hydromelioration systems – water management classes of technogenic landscapes, transport – road, industrial and factory – landscapes of industrial dispersion of ingredients, mining and technical system – mining landscapes. All these technogenic landscapes has fundamentally changed lithogenic base, and therefore they cannot be anthropogenic modifications, and cannot be considered only as a stage of the development of a natural landscape complex. It is worth realizing the fact that without the intervention of man and technology, an abandoned quarry will not turn into a black soil plain, as well as a water reservoir - into floodplains.

Technogenic landscapes are complex socio-economic and natural formation. Features of their structure and interaction with adjacent landscapes are often determined by the history of their formation. In a course of the research of technogenic landscapes, it is necessary to take into account that the influence of technology on the development of the landscape is determined not so much by natural as by socio-economic factors.

Technogenic substance – technomass. The constant growth of the importance of technology in the formation of modern landscapes and the creation of new substances leads to the fact that in anthropogenic landscapes a specific component of mostly non-natural origin is actively formed and rapidly accumulates - technogenic substance or technomass. Technomass gradually saturates all horizons of the landscape sphere and enters the processes of hypergenic metabolism. The concept of *technomass is* general, to denote a complex of the most diverse material substances created by human labor. Undoubtedly, the most technological mass enters the landscape sphere of the Earth in the process of extraction and processing of mineral resources, especially various metal ores.

Metallization of anthropogenic landscapes is one of the main features of technogenesis of the past centuries. Humanity uses a wider range of man-made rocks (concrete, brick, glass, asphalt, asbestos cement, etc.) in the construction of cities and villages, industrial facilities and roads, military and religious objects.

Industrial landscape. In the process of classifying anthropogenic landscapes according to the types (content) of economic activity of the population, eight of their classes were distinguished, including industrial landscapes [81]. By origin, they are technogenic, as well as road, belligerent, a large part of residential and others. Hence, the concept of "industrial landscape" is much narrower than "technogenic landscape".

The role and importance of technogenic and industrial landscapes in the structure of the earth landscape sphere is constantly growing. The well-known views of V. I. Vernadskyi and V. G. Bondarchuk about the scale and significance of the industrial activity of the population in the life of the planet Earth. Taking into account the peculiarities of development, landscape structure and impact on the natural environment, industrial landscapes are divided into industrial and mining landscapes [49].

Peculiarly industrial landscapes are formed around large industrial enterprises of the processing industry or within industrial districts. In Ukraine they are concentrated in Donbas, Kryvbas, Promyslovyi Prydniprovia, Lviv-Volyn basin and others. Areas dominated with industrial landscapes are characterized by: the most active formation and rapid accumulation of a specific component - technomass; the existence of a two-tiered (terrestrial and underground) structure of usually unique landscape complexes; complete anthropogenization of all geocomponents and landscape complexes; definite temporal and spatial boundaries of industrial landscapes, which makes it possible to distinguish industrial landscapes from other anthropogenic landscapes in most cases.

V. H. Bondarchuk proposed to call the landscapes formed under the influence of mining and mining technology, *mining and industrial*. To understand the term "mining landscape", he focused on the landscape-geomorphological feature, and found the difference between them only in external features: "...coloring is a characteristic feature of the iron ore landscape" [2, p. 292]. In modern studies, the term "mining landscape" is widely used, but its meaning contains a fundamentally new meaning.

In the scientific literature, there is the use and combination of two different terms - "mountainous" landscape and mining landscape. The combination of two completely different terms is failed. The mountain industrial landscape comes from the word "mountain", that is, if you refer to the explanatory dictionary, "mountain" is associated with mountains; which is located in the mountains. Usage from the dictionary: ridge, massif, slope, range, spire, terrain, gorge, crystal, rock, wind, disease, region, country, district, village, settlement, pasture, road, path, waterfall, stream, river, lake, resident, eagle, bird, oak, grass. The dictionary includes: mountain-climatic, mountain-skiing, mountain-steppe, mountain-shooting" [100]. As for the definition of the word "mining", it refers to the development of the bowels of the earth - the study, extraction and use of minerals. Usage from the dictionary: engineer, master, institute, school, business, specialty, combine harvester, development, mechanics, technique, equipment, installation, production, enterprise, plant, specialisation, industry, breed. The dictionary includes: mining drilling , mining, mining and metallurgical, mining ore, mining rescue [100]. The use of the term mining landscape is inappropriate for Kryvorizhzhia because the term mining landscape refers to mountainous terrain, and Kryvorizhzhia is located in a plain area [69].

The rapid development of the mining industry in the Kryvyi Rih iron ore basin led to the formation of a powerful zone of technogenesis, which today is characterized by a high degree of damage in relation to the landscape environment [65]. In particular, in a relatively short period of time, for more than 150 years, the significant changes in the landscape structure of the region have been occured, and nowadays not natural, but anthropogenic landscapes here occupy the leading position.

Since 1881, anthropogenic transformations of mainly steppe landscapes have been taking place constantly. The leading geotechnical systems that have been changing landscapes are mainly industrial - mining (open and underground), mining and metallurgical, mining and construction, etc.

The mining landscape is one of the two subclasses of industrial landscapes that arise as a result of overburden and extraction mining operations, storage of "empty" rock and waste from processing and beneficiation of minerals, formation of underground cavities in mines with their subsequent extinguishment and displacement of forged blocks of the earth's crust. The mining landscape is formed on the basis of such technogenic formations: dumps, quarries, mine subsident zones. Within them, all the components of former landscapes have been radically transformed, therefore the structure of the mining landscape is specific, they are significantly different from other landscapes of Kryvorizhzhia and are an element of the ecological framework of territories where people live (Fig. 1.2).

Fig. 1.2. The terraced slopes of the iron ore quarry of the Southern iron ore processing plant

1.2. Landscape diversity and modern problems of its research in mining landscapes

Study of landscape diversity involves the use of knowledge about landscape complexes of different hierarchical levels, which have scientific, educational and applied importance in anthropogenic landscape science.

Landscape diversity reflects the multiplicity of landscape complexes actually existing on the earth's surface, regionally – each time special, original elements as a real-quantitative composition and peculiarities of their spatial combinations, which creates unequal initial conditions for settlement, living, economic activity, socio-economic and cultural development people.

Study of landscape diversity in general is a new direction of landscape science, which develops and implements recommendations on the operational capability of landscapes and their further use to satisfy the various economic requirements, the implementation of tourist and recreational activities, and the functioning of nature reserve fund objects.

Diversity is generally understood as the presence and combinatorial combination of similar and different peculiarities in a set of system elements, and the specificity of such a combination forms one or another level of diversity. It is also considered as a set of types of differences of world objects at any space (territory, water area of the planet), which are revealed on the basis of the chosen measure [34, 89] or as a function resulted from the violation of the expected [89].

Natural diversity (geodiversity) is a complex of differences and similarities between the elements of one or another set, which creates integrity [34]; a certain range of geological structure, land structure, soil features and the entire set of systems and processes [18] (hydrological, climatic, geological processes, soil and relief formation are meant here). Thus, landscape diversity is subject to general laws of nature and is conditioned in its manifestation by the presence of external and internal differences in the composition, structure, and dynamics of geocomplexes [64]. Considering the meaning of the concept, landscape diversity is determined by the scientific goal of the study, which consists in inventorying, systematizing and explaining various specific features of landscape diversity.

Landscape diversity is the entire multiplicity of landscape complexes actually present on the earth surface [18]. The definition of the diversity of landscape complexes within general terms is similar to the definition of biological diversity, that is, it is based on the definition of the number of classes, families, kinds, and types of landscapes in a certain territory.

The term "landscape diversity" was officially used for the first time during the Ministerial Conference on the Environment in Sofia in 1995. Subsequently, it was discussed in more detail at conferences in Moscow in 1997, in Florence in 1998, and in Kyiv in 1999–2000 [18].

The study of the problem of landscape diversity interested scientists at the end of the 20th century. In Ukraine, the first to investigate this problem were: M. D. Hrodzynskyi [21], P. G. Shyshchenko [112], V. M. Pashchenko [89] and V. T. Hrynevetskyi [18]. The definition of "landscape diversity" was introduced by V. M. Pashchenko [89] and V. T. Hrynevetskyi [18] .

O. M. Marynych [77], G. P. Pylypenko [90], V. P. Palienko [86] and A. O. Kornus [72] investigated the dependence of landscape diversity on the geomorphological features of the territory.

H. P. Pylypenko [90] stated that landscape diversity is based on a wide range of differences in relief, climate, soils, flora and fauna. O. M. Marynych [77] admitted the fact that significant landscape diversity is characteristic of regions with vertical differentiation (mining landscapes). A.O. Kornus [72] studied the landscape diversity and vertical differentiation of the Left Bank of Ukraine.

The problems of assessment, methods of researching landscape diversity and systematics of landscapes are studied in the works of O. M. Marynych [77] , A. O. Domaranskyi [34] , S. I. Kukurudza and M.Y. Rutynskyi , V. I. Hetman, M. P. Stetsenko, A. O. Tkacheva , Z. I. Buchko , O. M. Petrenko , S. P. Romanchuk.

The problems of systematization and classification of Ukrainian landscapes were raised in particular by V. M. Pashchenko , O. M. Marynych , and L. Yu. Sorokina. O.

M. Marynych [77] suggested creating a taxonomy of landscapes not only taking into account classes, kinds, types, etc., but also identifying tracts and landscape areas.

Parameters for assessing landscape diversity were developed by A.O. Domaranskyi [34] , O. M. Marynych [77] , M. D. Hrodzynskyi [21] , I. M. Voina [6].

M. D. Hrodzynskyi [21] noted that the landscape diversity can be assessed by 30 indicators. O. M. Marynych claimed that " qualitative and quantitative indicators of different ranks should be the basis for characterizing landscape diversity" [77]. Temporal transformations of the landscape diversity were characterized by V. M. Pashchenko [89].

V. I. Hetman [16] , M. P. Stetsenko [103] , A. O. Tkachev [107] and V. I. Oleshchenko [82] study landscape diversity and find the ways to preserve and recreate it in natural areas and mostly in protected areas.

The following researchers are engaged in studies of landscape diversity in mining landscapes: G. I. Denysyk [24] , V. L. Kazakov [49] , H. M. Zadorozhnia [27] , S. M. Smetana [102] and others. S. M. Smetana developed a taxonomic classification of technogenic landscapes. S. M. Smetana used a taxonomic system of typological structures for the classification distribution of technogenic landscapes. The consideration of the main important characteristics was realized from the class level to the kind level according to the following faceted scheme.

Class - characterizes slopes, bottoms, plateaus, slopes, and thus allows to follow the main types of transfer and accumulation of substances and energy, determines the main parameters of the microclimate.

The subclass reflects four main groups of granulometric composition of rocks (stone, sand, clay, mixture), which have a significant impact on the accumulation of substances, the processes of soil cover formation, and the filtration of atmospheric precipitation.

The series takes into account the transformation of hydrological and geochemical flows due to the intensity of matter and energy transfer.

The subseries accounts for the energy characteristics of certain localities , which depend on the slope angle, exposure, surface albedo, condensation precipitation, etc.

Clan - characterizes the main ecologically important differences in the chemical composition of rocks (acidic, basic, saline, neutral and others).

Type - evaluates the conditions for the formation of plant cover in accordance with the determined characteristics of higher taxons. Its assessment is often complicated by the fact that the vegetation cover is not yet formed and undergoes the significant changes year by year. The most complex taxon is type that depends mostly on the characteristics specified in the higher taxons. Thus, at the level of the class, subclass and row, the main characteristics of moisture and nutrient supply are determined, although the microclimatic indicators at the level of the subrow may slightly level other indicators.

V. L. Kazakov [51] developed a structural-morphological classification of technical landscapes, where the criteria of taxonomic structures based on the nature and content of technical geocomponents were identified.

G. I. Denysyk and H. M. Zadorozhnia [27] developed a taxonomic system of mining landscapes. This classification distinguishes varieties of industrial landscapes caused by a certain type of human use of nature, which makes it possible to distinguish a type, subtype, kind of landscapes.

1.3. Problems of study of altitudinal differentiation of mining landscapes

The first attempts to study the altitudinal differentiation of nature were recorded in ancient Greece. The Greek philosopher Theophrastus (370–285 BC) was the first to notice the dependence of vegetation cover, soils, and moisture on the altitude in the mountains [9]. Konrad von Gessner studied the changes in vegetation in accordance to altitude and distinguished climatic altitudinal zones. The first researcher who claimed that the development of vegetation depends not only on latitude, but also on height above sea level was K. Mentsel. A. Humboldt [9] summarized knowledge about altitudinal differentiation, which covered only climate and living nature.

In prospect, researchers as a rule considered the connection of landscape complexes with the height of the area, namely: H. Skau [99], G. I. Tanfiliev [106], A. Zupan [44], H. M. Vysotskyi [11], F M. Milkov [80], I. M. Voina [9] and others.

O. M. Marynych [77] and P. G. Shyshchenko [112] were the first geographers in Ukraine to study altitudinal differentiation on the plain. Also, O. M. Marynych distinguished geomorphological levels and showed how the relief affects the height differentiation in plain areas. In general, geographers noted not only that landscape complexes depend on the absolute height above sea level, but also on different types of terrain [15].

K. I. Gerenchuk [15] described in detail the types of localities of the Ternopil region, in particular indicating the absolute and relative altitudes that affect the flora and fauna and their economic use. G. I. Denysyk [25] surveyed the types of localities in the forest-steppe zone of Ukraine, in particular, Podillia. Subsequently, three altitudinal levels were distinguished, which differ from each other in structure and surface height: lower, middle and upper within the floodplain type of areas. A. V. Berezhnyi divided the altitudinal differentiation of the slopes of river valleys into four microzones: the lower accumulative, the middle transit, and the two upper (erosive-denudational) ones - the riparian and watershed.

Geographers also highlighted the altitudinal differentiation of individual geocomponents. M. I. Shcherban investigated the altitudinal differentiation of climatic indicators in the area of the Kaniv Mountains. P. S. Pohrebniak, Y. R. Sheliah-Sosonko singled out the altitudinal differentiation of vegetation in different regions of the forest-steppe.

Today, the problem of researching the altitudinal differentiation of anthropogenic landscapes is more relevant. In connection with the dynamic development of urbanization, mankind rapidly built ramparts, dams, dug ditches, appeared cities, which became the large metropolises later, that is, anthropogenic landscapes with their inherent height structure were created. There is no difference between natural and anthropogenic landscapes except for their origin. That is, the study of altitudinal differentiation of anthropogenic landscapes, in particular mining landscapes, has a lot in common with the study of this phenomenon in natural landscapes. Among Ukrainian geographers, G. I. Denysyk [24], E. A. Ivanov [48], A. N. Kornus [72], L. M. Kyryliuk [58], and I. M. Voina are engaged in studies of altitudinal differentiation of anthropogenic landscapes. [9]. The study of altitudinal differentiation of anthropogenic landscapes takes place in urban, residential, agricultural, forest, beligerative, road, mining and water landscapes.

The altitudinal differentiation of mining landscapes can be traced both on old and new landscape complexes (tracts of quarries, trenches, canals, dumps, embankments and terricones). During the functioning of the mining industry, new types of localities are formed, which are inherent only to mining landscapes. Many scientists were engaged in the study of anthropogenic types of localities that are directly related to mining landscapes: V. G. Bondarchuk [2], E. A. Ivanov [48], G. I. Denysyk [26], A. V. Hudzevych [22], I. M. Voina [9]. The scientific works of researchers present the most diverse forms of anthropogenic relief (negative and positive), which were formed during the extraction of minerals [79]. The relief changes under the influence of the mining industry, forming a landscape complex in both vertical and horizontal directions.

1.4. Interrelation and interdependence between altitudinal differentiation and landscape diversity

Geomorphological features of different types of terrain are manifested through such characteristics as the flatness of the territory, the steepness and exposure of the slopes, the subsoil surface, moisture and temperature indicators. The combination of these components leads to increase in landscape diversity.

In particular, there is frequent repetition of slopes of significant steepness in the highlands. The mechanical composition and moisture of the soil, the microclimate of the upper and lower microstrips depend on the steepness of the slopes, and the climatic differentiation is more pronounced due to the differences in the exposure of the slopes. The significant dismemberment of the relief causes a combination of different types of terrain at small distances (slope, slope, supraflood-terrace, floodplain), where there are different types of soil and the most diverse types of vegetation grow.

In contrast to highlands, weakly dissected plains are geomorphologically a relatively homogeneous territory, where one or two types of terrain dominate, and therefore in their natural state were covered with uniform forest or steppe vegetation or swamps and meadows.

The definition of the diversity of landscape complexes is somewhat similar to the definition of biological diversity, that is, it is based on the determination of the number of classes, families, kinds, and types of landscape complexes in a certain territory.

There is no universally accepted classification of landscapes so far. Among the Ukrainian landscape scientists, a successful classification was offered by L. Yu. Sorokina [104]. In general, most scientists distinguish the following taxons: section, system, subsystem, class, subclass, group, type, subtype, clan, subclan, form, subform. This classification was developed for the study of natural landscapes. Now, the classification of anthropogenic landscapes, which occupy larger area in comparison compared with natural landscapes, is more relevant.

Classification (from Latin classis - classification and ficatio - to do) means the division of landscapes in accordance with certain characteristics into groups (classes) that are in strict subordination to each other. The term "classification" and the term "taxonomy" are equally used (from the Greek taxis - order, row, rank). A taxon is a classification structure of any hierarchical level, which is distinguished on the basis of certain criteria. That is, the terms "classification" and "taxonomy" are synonymous.

Developing a classification scheme for anthropogenic landscapes, it is necessary to take into account that they are superimposed on a natural basis, so the taxonomic ranks of these classifications coincide. Only the principles of their selection differ.

The highest classification structure *is **the section of landscapes.*** Its selection is based on such a general indicator as the type of contact and interaction of geospheres (lithosphere, atmosphere and hydrosphere) in the structure of the landscape envelope. According to it, land, water (or underwater) and other landscapes are distinguished.

The system of landscapes is distinguished by differences in the water-heat balance in different geographical zones and includes systems of arctic, subarctic, boreal and other landscapes. The systems combine both plain and mountain landscapes, which are similar in microclimatic properties, due to their location in the same geographical zone.

Landscape systems are divided into ***subsystems depending on*** the continentality of the climate. For example, in the subboreal system sub-systems of moderately continental and continental landscapes are distinguished from semi-humid landscapes .

All of the taxonomic structures listed above characterize the diversity of landscape complexes at the regional level. Therefore, the classification of higher taxonomic groups of Kryvyi Rih landscapes is following:

Section **-** terrestrial landscapes;

The system is subboreal seven-humid landscapes;

Subsystems are moderately continental landscapes;

In the future, all terrestrial landscapes are divided into two orders: natural and anthropogenic [79].

Orders consist of ***classes.*** This is where the differences between natural and anthropogenic landscapes begin. Landscapes with the same morphostructural characteristics are combined in natural ones, i.e. plain, mountain, intermountain and intermountain-basin landscape classes are distinguished. The anthropogenic order unites landscapes by the sphere of economic use and includes eight classes: agricultural, mining, residential, road, water, forest, recreational, and beligerative. At the same time, the most general features of certain classes of anthropogenic landscapes (for example, agricultural or mining) are preserved in all classes of natural landscapes on plains, mountains, and foothills. At the same time, in terms of their internal structure, the mining landscapes of the plains are closer to the same mining landscapes of the mountains than to the adjacent agricultural or water anthropogenic complexes [79].

Some classes of anthropogenic landscapes are divided into ***subclasses*** according to their use. Among them, industrial landscapes are divided into industrial and mining landscapes; agricultural - into meadows and pastures, fields and gardens; residential - rural and urban; forest - conditionally natural, secondary (derivative) and forestry; water - for reservoirs, ponds and canals.

Classes and subclasses are divided into ***types of landscapes*** according to zonal features: a certain ratio of heat and moisture, which determines the zonal distribution of types of soil and plant cover. There are tundra, taiga, forest-steppe, steppe and other types of flat landscapes. In the classification of landscapes of Ukraine, four types of plain landscapes are distinguished according to four natural zones: 1) deciduous forests; 2) mixed coniferous-deciduous forests; 3) forest-steppe; 4) steppe (Fig. 1.4). There are also azonal types of landscapes. Zonal types of landscapes are divided into ***subtypes*** that reflect the gradualness of zonal transitions. In the Ukrainian classification, the steppe type of plain landscapes is divided into northern steppe, middle steppe and southern steppe (dry steppe) subtypes [79].

The subclass of mining landscapes is divided into quarry-dumping, peat-swamp, terricone-pseudokarst; the subclass of urban residential landscapes includes low-rise, high-rise, industrial-residential, water-recreational, garden-park, and the subclass of water landscapes - reservoirs - is divided into shallow and deep-water types of landscapes.

Types and subtypes of landscapes are divided into ***clans.*** The main criterion for determining the kind is the genesis of landscape complexes. G.I. Martsynkevych and co-authors [7] refer to this taxon moraine-sandr landscapes, alluvial-terrace landscapes, etc.

In our case, the selection of the kind is determined by belonging to a certain type of locality. Thus, in the mining and industrial landscapes of Kryvorizhzhia, which are azonal, anthropogenic types of terrain are distinguished: pit-peat wastelands, single-pit , pit-hilly-lake , rocky badland ", subsidence terrace-dump, etc.

However, there are other views regarding the selection of the concept of kind. O.M. Marynych, V.M. Pashchenko, P.G. Shyshchenko [78] consider provincial differences due to different continentality of the climate to be the main criterion for distinguishing the type of landscapes. For example, poliskyi mixed-forest landscapes (corresponding to the poliskyi province of the zone of mixed forests).

The lower classification structure is ***the kind of landscapes.*** Kinds of anthropogenic landscapes are distinguished by the common complex of features: origin and lithological composition; the character of the relief; characteristics of soils, vegetation and economic use [7]. Landscapes of the same kind are characterized by the largest number of common features and maximum structural similarity. However, the main criterion for selection of kinds of landscape complexes is the nature of economic use. The terrain, soils, and vegetation depend on them. Examples of kinds of anthropogenic landscapes are rural residential landscapes on sloping loess slopes, field landscapes on plowed plains, etc.

Classification of landscapes is important as a basis for research, mapping and scientific characterization of landscape diversity. Essential is also practical (applied) value of typological classification of landscapes. The number of specific landscapes on the globe should be measured by a five- or six-digit number [7, 45]. In practice, the classification of landscapes is important when assessing natural conditions for mining development or urban planning. It is often too difficult and even impractical to investigate and evaluate each landscape complex separately. It is much more profitable to develop certain measures in relation to typical natural conditions, that is, to a certain number of landscape groups. For this purpose, it is used classification, where many landscape complexes are divided into a certain number of classes, types, kinds, etc. It can be expected that typologically close landscapes will have a similar set of natural conditions and resources and, at the same time, will respond in the same way to economic influence.

Fig. 1.4. Ravine Pivnichna Chervona is an oasis of the Ukrainian steppe on the territory of KLTS

1.5. Research methods of altitudinal differentiation and diversity of mining landscapes

Method of terminological analysis was used when choosing the terminological apparatus for study altitudinal differentiation and the diversity of mining landscapes. The method of terminological analysis involved the study of terms and the concepts denoted by them, the development or clarification of the content and scope of concepts [111].

To determine the altitudinal differentiation and diversity of mining landscapes, *a landscape territory analysis* was used. This analysis was conducted using a system approach. *The system approach* made it possible to follow the structure of types of localities, tracts and to calculate the number of similar tracts in a certain territory.

In order to carry out an analysis of the development, origin, and formation of mining landscapes on the territory of Kryvorizhzhia in chronological order, *the principle of historicism was applied*. The principle of historicism includes the method *of historical-genetic series of maps*, which is used to determine the conditions for the emergence of mining landscapes, the study of their development and gradual transformation from natural landscapes to anthropogenic ones.

Mining landscapes are formed on the basis of already existing natural or other anthropogenic landscapes. Therefore, recovery based on *the retrospective method analysis* of the front landscape base is a necessary condition for a thorough study of mining landscapes [61, p. 39].

By combining historical-archaeological methods, the method of retrospective analysis with the method of historical-geomorphological analysis, it is possible to investigate the historical features of the distribution of landscapes with altitude [10, p. 23].

Field research methods were used to study the altitudinal differentiation of mining landscapes. Random sampling was carried out at the Burshchit dump (absolute altitude), Zhovtnevyi and Karachuniv granite quarries (relative altitudes).

The observation method is a systematic purposeful study of a natural area, which must meet the following requirements[10]:

- premeditated planning (observation is carried out for a certain clearly defined task);
- regularity (executed according to a plan drawn up in accordance with the observation task);
- purposefulness (observe only certain aspects of phenomena that are of interest during research);
- activity (the observer is actively looking for the necessary objects, signs of the phenomenon);
- systematicity (observation is conducted continuously or according to a certain system).

Observation as a method of cognition made it possible to obtain primary information in the form of a collection of empirical knowledge.

The diagnostic method was used to learn the main properties and signs of the object under study. This method was applied in the areas study of mining landscapes.

The method of landscape-geomorphological analysis made it possible to investigate the modern forms of the relief of Kryvorizhzhia and to reveal the dependence of the placement of mining landscapes on the relief of the territory. That is, altitudinal landscape levels and types of localities were investigated.

Using *the comparative method of* natural analogues, similarities and differences between anthropogenic complexes and natural analogues were established, geomorphological, climatic, soil-biotic processes in mining landscapes were determined.

With the help *of the method of abstraction,* landscape diversity was considered depending on the altitudinal differentiation of landscapes, without taking into account other factors of the formation of landscape diversity. In general, the content of the abstraction method consists in the imaginary departure from non-essential properties, connections, relationships of objects and in the simultaneous selection and fixation of one or more important features that are of particular interest to the researcher [10, p. 27]. Basing on the conducted researches *the mapping of the territory* was carried out. Mapping of mining landscapes was carried out using maps, scale 1:10,000–1:25,000, which made it possible to map landscape complexes of the rank of facies, types of tracts, landscape areas, and localities. In some cases, it is possible to show fragments of types of mining landscapes (quarry and dump, mine, pseudokarst, monopit). Map scales smaller than 1:50,000 reflect only individual landscape complexes of the highest rank - landscape type, landscape class [106].

The creation of landscape maps was carried out using *the modeling method*. This method reflects the information obtained by means of a survey on a topographical basis. First, the types of localities are plotted, and then tracts and sub-tracts are distinguished within them [10, p. 27]. Composite landscape maps based on this study reflect information on the diversity of mining landscapes.

The method of profiling was important, the essence of which is to build a landscape profile within a certain type of terrain. The geological structure, relief, main soil-forming rocks, as well as the steepness of the slopes and absolute altitudes of the territory, vegetation cover, etc. were displayed on the profile .

With the help *of methods of synthesis and analysis,* different landscape complexes were identified in a certain area of the study, having analyzed the regularities of their placement and characteristic features. When applying *the method of generalization,* the conclusions of the theoretical, methodological and practical nature of the research were substantiated.

The method of anthropogenic landscape forecast made it possible to develop ways to improve the structure of mining landscapes, prevent their destruction, improve their qualitative characteristics, and predict future changes that will occur in the altitudinal differentiation of mining landscapes of Kryvorizhzhia. Sufficient attention is also paid to *the constructive and geographical directions of research,* which are highlighted in the works of E. A. Ivanov [48].

The landscape-dynamic direction was a process of analysis and assessment of the ecological situation of mining areas, which are based on the scientific and methodological basis of landscape geophysics [48]. With the help of this method, the degree of pollution and the composition of pollution, the migration ability of geosystems depending on their chemical composition, and the physical and chemical properties of mining landscapes, as well as possible areas of accumulation of pollution, etc., were studied.

Landscape-geochemical studies are conditioned by the features of migration and accumulation of radionuclides in geosystems, which are similar to the features of migration and accumulation of other chemical elements of technogenic origin. *Landscape and biogeocenotic studies* are carried out through a systematic approach to the study of landscapes and biogeocenoses, which are closely related to each other and are carried out due to the processes of exchange of matter and energy.

Calculation method. The definition of the diversity of landscape complexes, as it was mentioned, is similar to the definition of biological diversity, that is, it is based on the definition of the number of classes, clans, kinds, types of landscapes in a certain territory. The diversity of anthropogenic landscapes can be studied using a simple standard method of measuring the spatial density of landscape complexes. For this purpose, it needs to be counted the number of types of tracts on a certain natural sector and divide it into the area of each studied sector. In this way, it is possible to calculate the typological diversity of the natural sector [21].

When studying typological landscape diversity, formula 1 [21] was used:

Formula 1.

$$\mathbf{TD = m / S}$$

TD – indicators of typological diversity of landscapes; m – number of types of landscapes; S is the area of the territory under investigation;

Landscape diversity is also characterized by indicators of chorological diversity, which is calculated by the difference in the number of landscape contours on a natural sector and the area of the sector itself (formula 2 and 3) [67]:

Formula 2.

$$\mathbf{CD_1 = S / N}$$

Formula 3.

$$CD_2 = N / S$$

CD_1, CD_2 – indicators of chorological diversity; CD_1 – average area of one contour of LC (landscape complexes); CD_2 – the number of LC contours per unit area; S is the area of the territory under investigation; N is the number of landscape contours.

The use of the above-mentioned methods made it possible to follow in detail the dependence of landscape diversity on the altitude of localities. Empirical and theoretical knowledge methods helped to integrate specific observations, descriptions, and calculations. In general, the most effective are landscape-geomorphological, comparative-geographical, historical-landscape analysis, methods of modeling, profiling and anthropogenic landscape forecasting.

So, the active development of anthropogenic landscape science led to the appearance of a number of different terms and concepts, some of which did not find their application in scientific works: anthropogenic, anthropic, humanized, cultural, mining landscapes. For the first time, V. G. Bondarchuk proposed the term "mining landscape". As a result of the classification of anthropogenic landscapes, F. M.Milkov singled out a class of industrial landscapes, in the structure of which the subclass of mining landscapes is the leading one. In mining landscapes, their altitudinal differentiation is clearly observed, which is determined not only by the natural conditions of the location region, but also by the features of mineral extraction.The phenomenon of altitude differentiation combines the properties of vertical and horizontal differentiation of natural components and landscape complexes. This phenomenon can be compared with altitudinal zonality in the mountains, however, on the plains it is characterized only by intrazonal changes and manifests itself due to the presence of altitudinal landscape stages, levels and tiers. Altitude differentiation determines a number of important processes and phenomena, among which is an increase in landscape diversity. Under landscape diversity, it is expedient to understand the multiplicity of landscape complexes actually present on the earth's surface. Ukrainian scientists became interested in landscape diversity only at the end of the 20th century, and research into the diversity of mining landscapes began at the beginning of the 21st century.

Analytical review of natural-geographical and landscape studies on the studied issues makes it possible to conclude that more attention was paid to the horizontal differentiation and diversity of mining landscapes and to the altitudinal differentiation and diversity of their natural (natural and anthropogenic) components. Altitude differentiation and diversity of mining landscapes was not reflected in scientific developments, and, accordingly, in practical recommendations for their rational use.

Among the main areas of research on altitudinal differentiation and diversity of mining landscapes of a separate region of Ukraine–Kryvorizhzhia, landscape-dynamic, landscape-geochemical, landscape-biocentic and landscape-ecological, as well as the principles and methods inherent in them, are appropriate and optimal (Fig. 1.5).

Fig. 1.5. Mining landscapes of the KLTS, for example, the Gleivatskyi quarry

KRYVYI RIH LANDSCAPE TECHNICAL SYSTEM: HISTORY OF THE DEVELOPMENT AND LANDSCAPE ORGANIZATION

2.1. Stages of formation and boundaries of the Kryvyi Rih landscape-technical system

The Kryvyi Rih landscape and technical system (hereafter KLTS) was formed on the territory of the city of Kryvyi Rih, Dnipropetrovsk region. The basis of its development is the Kryvyi Rih iron ore basin, the industrial reserves of which alone amount to more than 18 billion tons of iron ores. The KLTS has been formed for almost 150 years. The extraction of minerals, mainly iron ores, was accompanied by a complete transformation of natural landscapes and the formation of peculiar, as yet poorly researched, anthropogenic landscapes on their basis. The KLTS was formed unstable in spatial and temporal dimensions. This makes it possible to distinguish three stages in the process of its development:

– *handicrafts* (IV century BC - XVII century). In the Neolithic and Eneolithic, fine-grained quartzite was mined within the territory of modern Kryvorizhzhia, which was used as a substitute for flint. During the bronze age, tools and weapons were made from stone raw materials, and they were also used to build houses.

The development of iron ores in Kryvbas was started by the Scythian tribes, who smelted iron and made weapons (until the middle of the 1st millennium AD). During the times of Kyivan Rus, Kryvorizhzhia was a "Wild Steppe". After the Tatar-Mongol invasion, the territory was occupied by nomads who mainly engaged in cattle breeding and agriculture;

– *initial industrial development* (XVIII – first half of XX centuries). The emergence of capitalist relations in Western Europe stimulated the development of industry in Ukraine. After the discovery of "iron slate" by V. F. Zuiev in Kryvorizhzhia, O. M. Pol in 1876 began the industrial development of iron ores, in particular the Saksagan ore field.

In the second half of the 19th century due to exploration of iron ores by geologists R. Kulshyn , M. P. Barbot-de-Marny , L. Strippelman , S. Hartunga , L. Siemiechkin , S. O. Kontkevych , V. A. Domger , P. P. Piatnytskyi there was a powerful industrial development of Kryvorizhzhia and, accordingly, the active formation of mining landscapes. At the end of the 19th century the open method of developing useful raw materials from under a slight layer of overburden rocks prevailed - up to 9 m. Dumps are low, wide, with a slope angle of 6–8°. The depth of the quarries did not exceed 40 m. However, after the purchase of 21,000 hectares of land for mines in 1895–1897, their number increased significantly [52]. The use of the underground method of iron ore extraction began in 1898. At the same time, the area of mining developments grew - from 800 hectares in 1934 to 2,700 hectares in the middle of the 20th century. The depth of the quarries reached 90 m, the height of the dumps - from 12 to 25 m [28, 51, 87]. In 1935, the first collapse sinkholes were formed above the underground workings;

– *active industrial development* (second half of the 20th - beginning of the 21st century). During the 50s and 70s of the 20th century mining processing plants were built in Kryvyi Rih, which gradually grew into powerful mining complexes - the basis of the modern landscape and technical system of Kryvbas. Together with the technical development of means of conducting mining operations, the morphometric indicators of quarries and dumps are also increasing.

At the beginning of the XXI century within the KLTS, the average depth of quarries is more than 400 m (quarry of the Southern Mining and Processing Plant), the height of dumps and dam-sludge storages is up to 100 m (dumps of the Hannivskyi quarry, tailings Voikivskyi , Mykolaivskyi), the depth of the mines is up to 1400 m ("Rodina" mine, "Yuvileina" mine) [51]. According to the calculations of V. P. Palienko , the total area occupied by quarries in Kryvbas is 33.34 km² , dumps – 60.0 km² , tailings – 52.74 km² , and the surface subsidence zones above mine fields make up 34.71 km² [83]. The formation of mining landscapes continues to this day.

According to the territorial location, the KLTS sublatitudinally extends from north to south for 96 km, from west to east - for 62 km, and occupies an area of 4.1 thousand km^2, which is 0.67% of the territory of Ukraine.

Administratively, the KLTS covers the entire territories of two districts - Kryvorizkyi and Shyrokivskyi , parts of the adjacent Apostolivskyi , Piatykhatskyi and Sofiivskyi districts of Dnipropetrovsk region, as well as small territories of the Vysokopilskyi district of Kherson and Kazan districts of Mykolaiv region.

It should be taken into account that the borders of the KLTS are dynamically changing, this is primarily influenced by the continuous intensive development of industry. In the mid-70s of the 20th century, the boundaries coincided with the boundaries of the Inguletsko -Saksaganskyi valley-ravine physiographic region of the steppe spurs of the Dnieper Highlands of the Dniester-Dnieper Northern Steppe Province [62]. At the end of the 80s of the XX century mining construction was carried out in the eastern part of the Middle Inguletskyi inclined physiographic district. In the period from the 90s of the 20th century to 2010, the boundaries of the quarries in Kryvorizhzhia were changed and new territories were set aside for landfilling. On the basis of these data, the boundaries of the KLTS were determined, taking into account all the specified changes (Fig. 2.1).

So, the northern border of the territory covers the mining operations of the Central Mining and Processing Plant (CMPP) of the Artemivskyi and Petrivskyi ferruginous quartzite deposits of the Apostolivskyi and Sofiivskyi districts also belongs here. The Visokopilskyi bauxite deposit and the Ingulets River, which flows to the borders of the Dnipropetrovsk, Mykolaiv, and Kherson regions, are confined to the southern border. The western border is defined by the western edge of the Verbova River basin, the Huriv recreational zone, various orographic elements, and the highway[51, 87, 92].

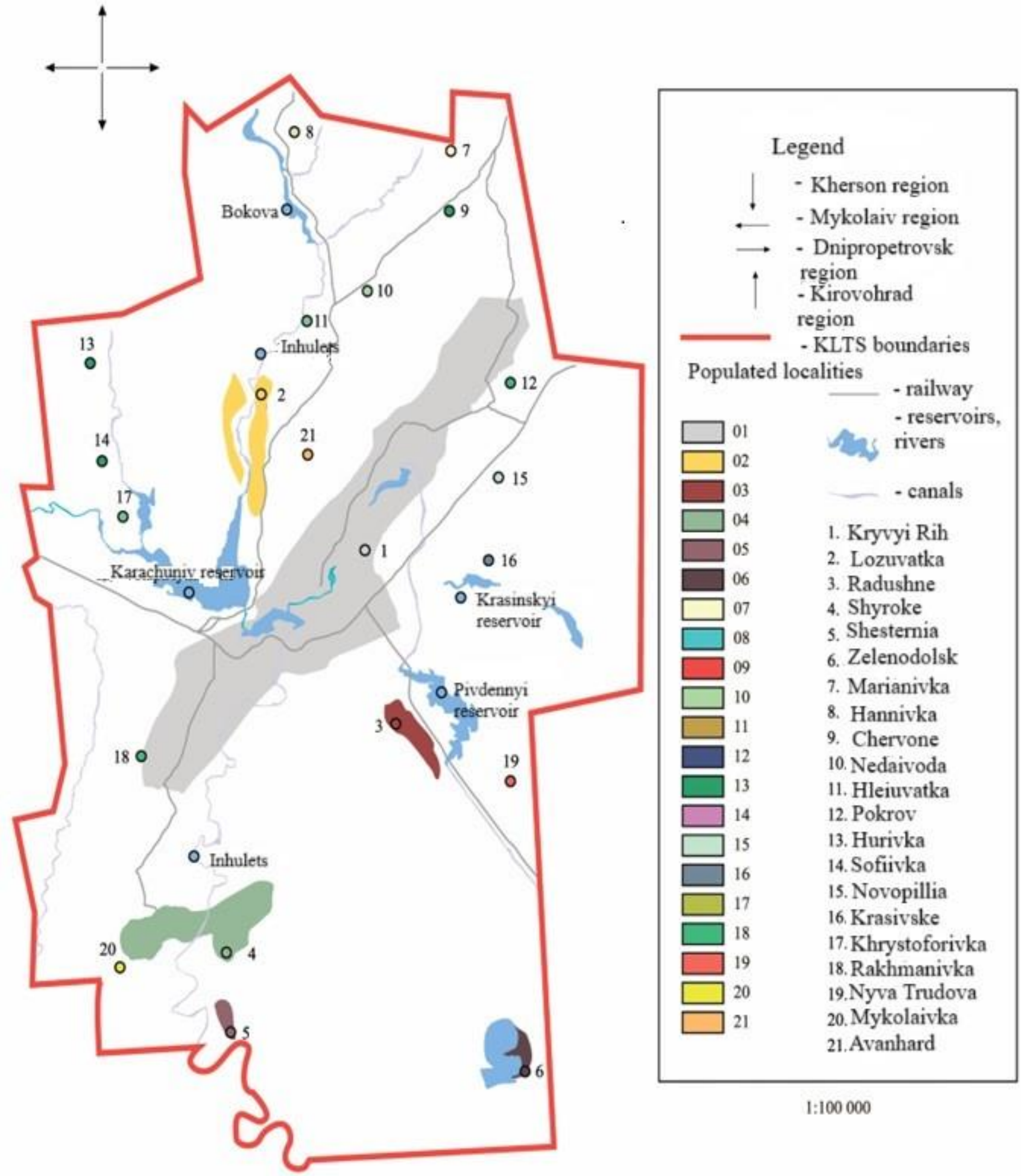

Fig. 2.1. Boundaries of the Kryvyi Rih landscape and technical system [51]

2.2. Natural conditions and mineral-raw material base of the Kryvyi Rih landscape-technical system

Due to the unique spatial location, the natural conditions of the KLTS are heterogeneous. The KLTS is located in the central part of the Ukrainian Crystalline Shield, in *the geological structure* of which two structural layers are distinguished: the crystalline basement, composed of metamorphosed volcanogenic-sedimentary and granitoid formations of the Precambrian, and the sedimentary cover, the section of which is represented by Cenozoic sediments. The KLTS on the eastern par belongs to the Kryvorizkyi-Kremenchutskyi fault, in the bowels of which there are large deposits of iron ores (Fig. 2.2). I. S. Paranko [87] noted that the KLTS is a rather complex geological construction, the structure of which includes Mesoarchean , Paleoproterozoic , and Cenozoic rocks.

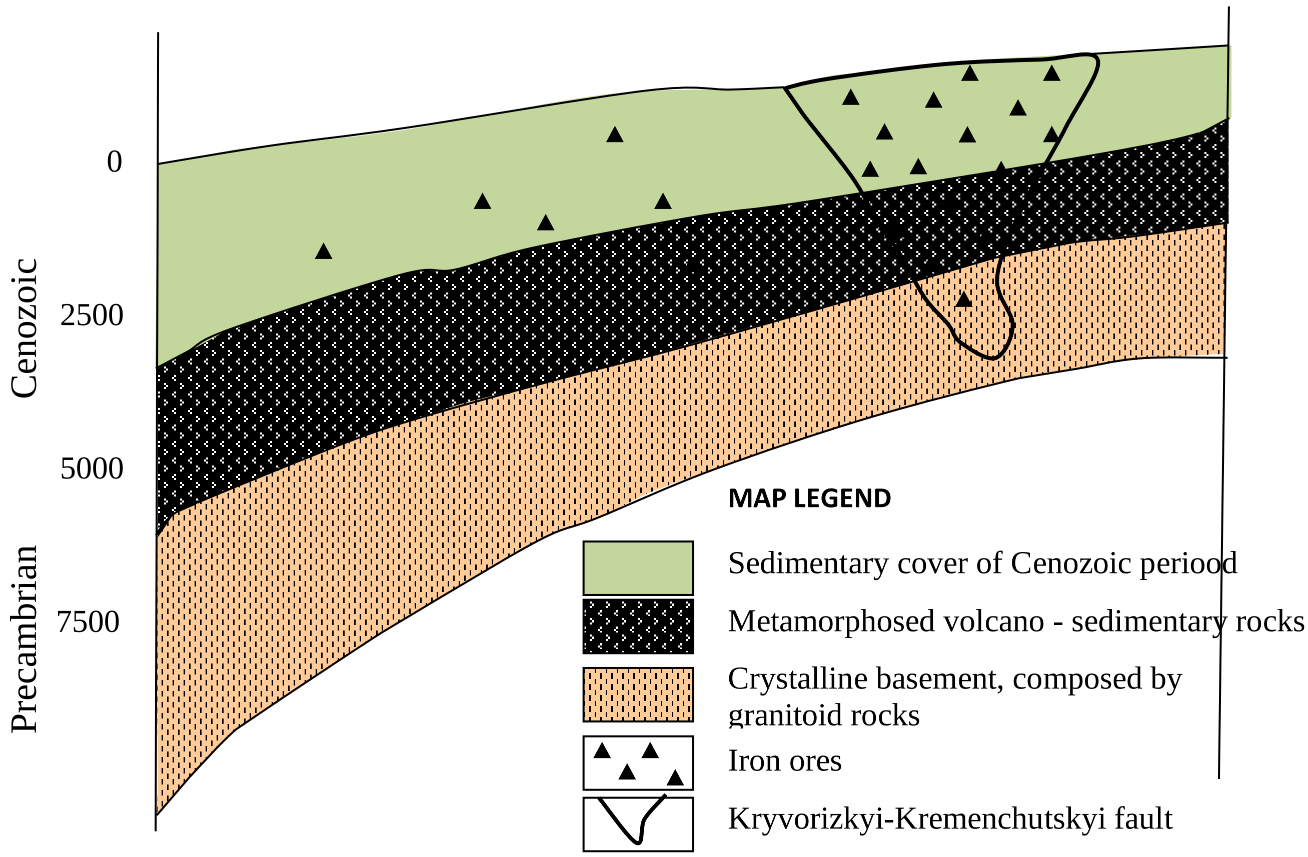

Fig. 2.2. Geological structure of the Kryvyi Rih landscape-technical system. According to [87]

Concerning morphostructure, the KLTS belongs to morphostructures of the 1st, 2nd, and 3rd orders. The 1st-order morphostructure includes the East European polygenic plain, which is associated with the tectonic structure of the East European platform. The north and south of the KLTS belong to the 2nd order morphostructures. In the north of the KLTS is the Dnieper geomorphological region of basement layer-denudation uplands. In the south of the KLTS is the Black Sea geomorphological region of strato-accumulative and strato-denudation plains. The morphostructure of the IIIrd order includes the Central Dnieper Denudation Upland Inhulo-Inhuletsk loess accumulative dismembered and the Northern - Black Sea Plain (Fig. 2.3). In general, the Ukrainian Shield and the Black Sea Basin form II-order morphostructures, and III- and IV-order morphostructures form tectonic blocks [51, 78, 85, 92]. On the basis of the Ukrainian shield and its rocks, the surface forms of the relief of the KLTS were formed. The main element *of the morphostructural relief* is the loess-loam upland and lowland watershed plateaus (absolute heights of 200–250 m), which are complicated by various *morphosculptures* – fluvial, karst, suffusion, gravity, and eolian. The relief is mainly represented by meso- and microforms. In scientific works [39, 40], the processes that stimulate the development of morphosculptural relief in the territory of Kryvorizhzhia are studied in detail.

Due to the action of temporary watercourses, erosion, transportation of material and its accumulation, a fluvial relief is formed. *When a mining complex is formed, the active action* of fluvial processes immediately begins on the lithogenic base, which transforms and stabilizes it.

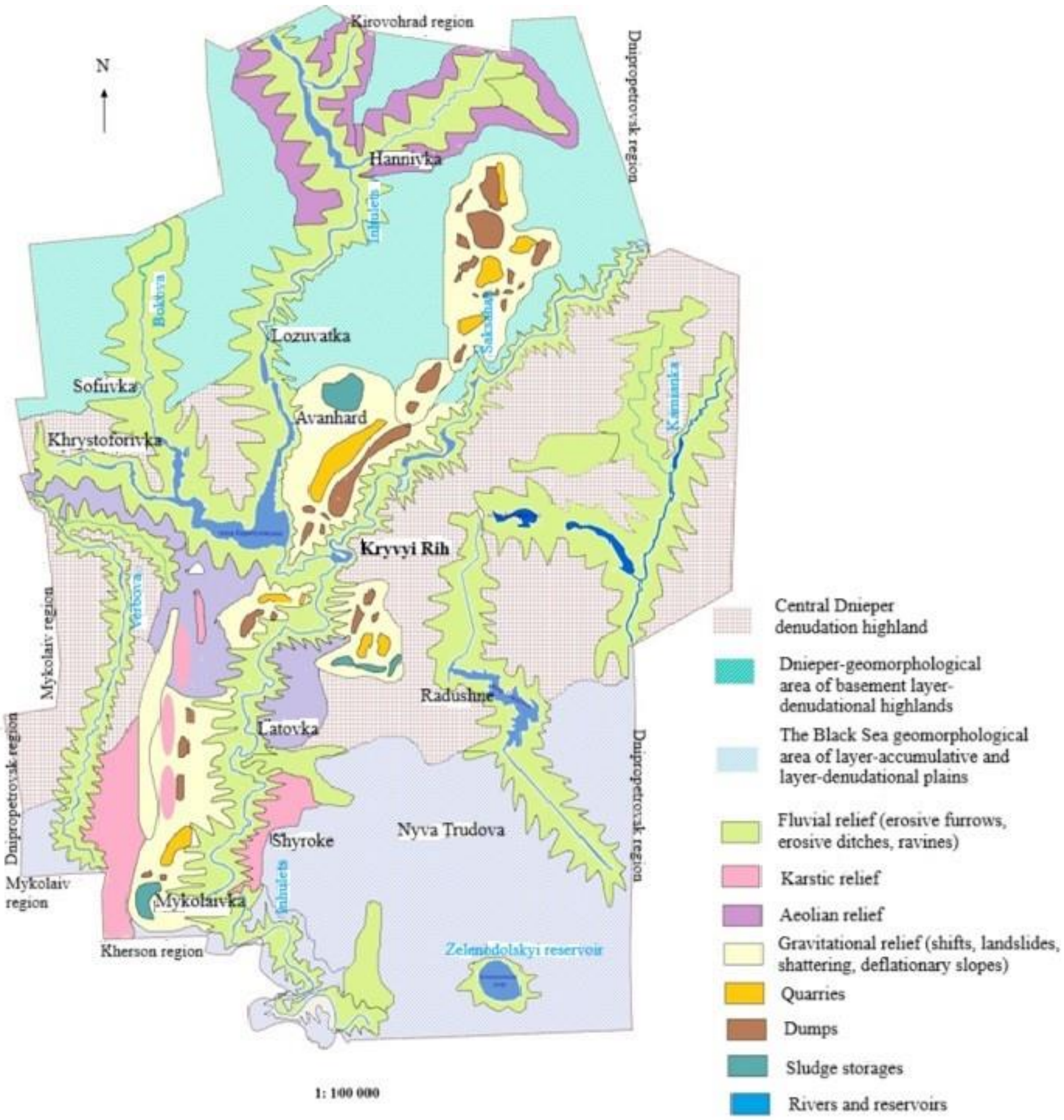

Fig. 2.3. Morphostructures and morphosculptures of the KLTS. According to [85, 92]

The development of the mining fluvial relief is influenced by the following factors: peculiarities of the formation and functioning of the mining complex; lithological and granulometric composition of rock; climatic conditions of the territory; the presence of vegetation on the surface of the mining complex.

The main forms of fluvial relief are:

– erosion furrows - formed as a result of erosion of slopes under the influence of rainwater and snow. They are found in mining complexes, in river valleys, gullies and basins;

– erosion rivulets - formed with a depth of 1 m to 1.5 m, found on the slopes of dumps and quarries;

– gullies are present on the slopes of dumps, which are composed of loose rocks, and on the slopes of exhausted quarries. They are widespread in the southern part of the KLTS [51].

Fluvial relief is the most common relief on the territory of the KLTS.

The aeolian relief was formed on the sandy deposits of the 1st floodplain terrace of the Inhulets River. It is characterized by sandy hills, partially covered with various grasses and shrubs.

Gravitational relief is not widespread on the territory of the KLTS. It is characterized by small cirque-like landslides on the sides of river valleys, streams and ravines, there are also soil spills on steep slopes, which are represented by microslides. The most common gravity relief is the gravity relief of slopes. Its main forms are:

– landslides, which are present in all mining landscapes of the KLTS and are formed under the condition of steepness of slopes of 35°;

– scree formed as a result of slow gravity on loose and cracked crystalline rocks common in mining landscapes. There are also screes and landslides on the slopes of the valleys of the Inhulets and Zhovta rivers [78, 92].

– deflection slopes are an inherent formation on the slopes of quarries and dumps, which are composed of clay tips. They are widespread in the southern part of the KLTS.

The sufosis relief is represented by shallow rounded steppe bottom and sufosis basins. It is widespread in the Inhulets-Visunskyi interfluve and the Ingulets-Kamiankivskyi watershed plateau. Sufosis processes are represented in the karst areas of Kryvorizhzhia (Kobylna ravine) [78, 92].

Karst relief is formed due to the presence of natural and technogenic factors. The natural ones include the features of the relief and the geological structure of the territory, the development of the rafter-ravine system. Technogenic factors include the spontaneous development of limestones, explosive mining methods, which leads to a decrease in the strength of rocks; violation of the hydrodynamic regime of underground waters and the formation of dumps [51]. Karst relief is widespread in the southern part of the KLTS.

According to morphogenetic features, the karst and karst relief of Kryvorizhzhia is spatially confined to two districts. The first district belongs to the Kryvorizkyi district of the Kryvorizkyi-Kremenchutskyi karst region, which is confined to the Kryvorizka crystalline folded zone. The second district is included in the Nyzhnii Prydniprovskyi District of the Black Sea-Azov Karst Region. The development of karst occurs in the Neogene limestones of the cover of the Ukrainian shield, which lie shallowly [43, 92].

The climate of the KLTS belongs to the Atlantic-continental European insufficiently humid, warm, temperate climatic region. According to the Kryvyi Rih meteorological station, the average annual air temperature in the central part of Kryvyi Rih is +8.5°C (in the north of the region +7.9°C, in the south +9.0°C). The average air temperature in July is +22.2°C, in January – -5.1°C. Annual indicators of total solar radiation are equal to 107–110 kcal/ cm^2 , radiation balance – 46–49 kcal/ cm^2 . The average albedo of the KLTS is quite high in summer (30%), and reduced in winter (35%) [51, p. 44].

The annual amount of precipitation in the northern and central regions of the KLTS is 425–450 mm, in the southern part – 400–425 mm. A "heat island" has formed over the residential and industrial landscape of the city of Kryvyi Rih - it is warmer here, especially in the cold period of the year by 1.8°C, more precipitation, fog, reduced doses of solar radiation, sometimes smog occurs.

The surface waters of the KLTS are formed by 8 small (except Inhulets) rivers belonging to the Dnipro basin: Inhulets (Fig. 2.4) with its tributaries Saksagan, Zelena, Zhovta, Bokova (with its tributary Bokovenka), Verbova (tributary of the Visun River, which, in its turn, flows into the Inhulets river); Kamianka is a tributary of the Bazavluk River. Their streams are either channelized or occupied by ponds. In addition, 9 reservoirs with a total area of 9,340 hectares have been created within the

KLTS only to provide water for communal services, and there are also 25 agricultural reservoirs.

The territory of the KLTS belongs to the southern part of the Ukrainian basin of fractured waters, covers part of Shyrokivskyi , Apostolivskyi , Kryvorizkyi , Sofiivskyi and Piatykhatskyi districts. The general direction of the flow of underground waters of the KLTS is to the south, towards the Black Sea tectonic depression, as well as to river valleys, gullies, ravines, and meadows [92].

Fig. 2.4. The Inhulets River in Kryvyi Rih Grand Canyon

The southern parts of the Shyrokiv and Apostoliv districts belong to the northern part of the Black Sea artesian basin (Fig. 2.5).

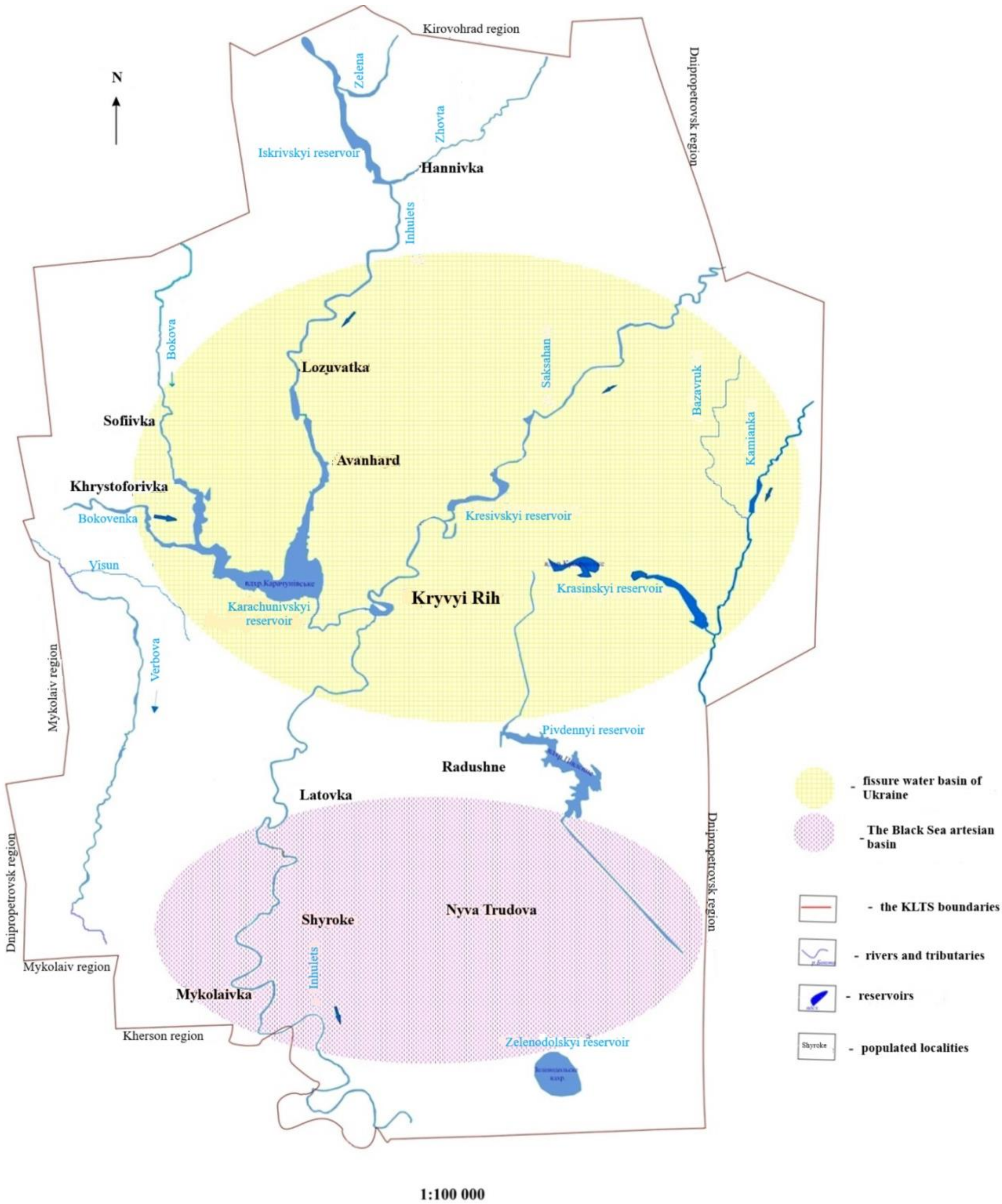

Fig. 2.5. Surface and underground waters of the Kryvyi Rih landscape-technical system

In *the soil cover* of the Kryvyi Rih landscape-technical system, ordinary low-humus black soil prevail - 67.5% of the territory. Common medium-humus black soil are also common (northwestern regions). Southern low-capacity, low-humus black soils (20.3% of the area) in the southern part of the KLTS were formed as a result of the germination of fescue-feather grass vegetation here. Meadow and black soils are widespread on the territory of the KLTS, namely in the floodplains. Saline meadow, black soil-meadow deep-slightly saline and slightly saline soils are present in the bottoms of the ravines and beds of the KLTS (Fig. 2.6).

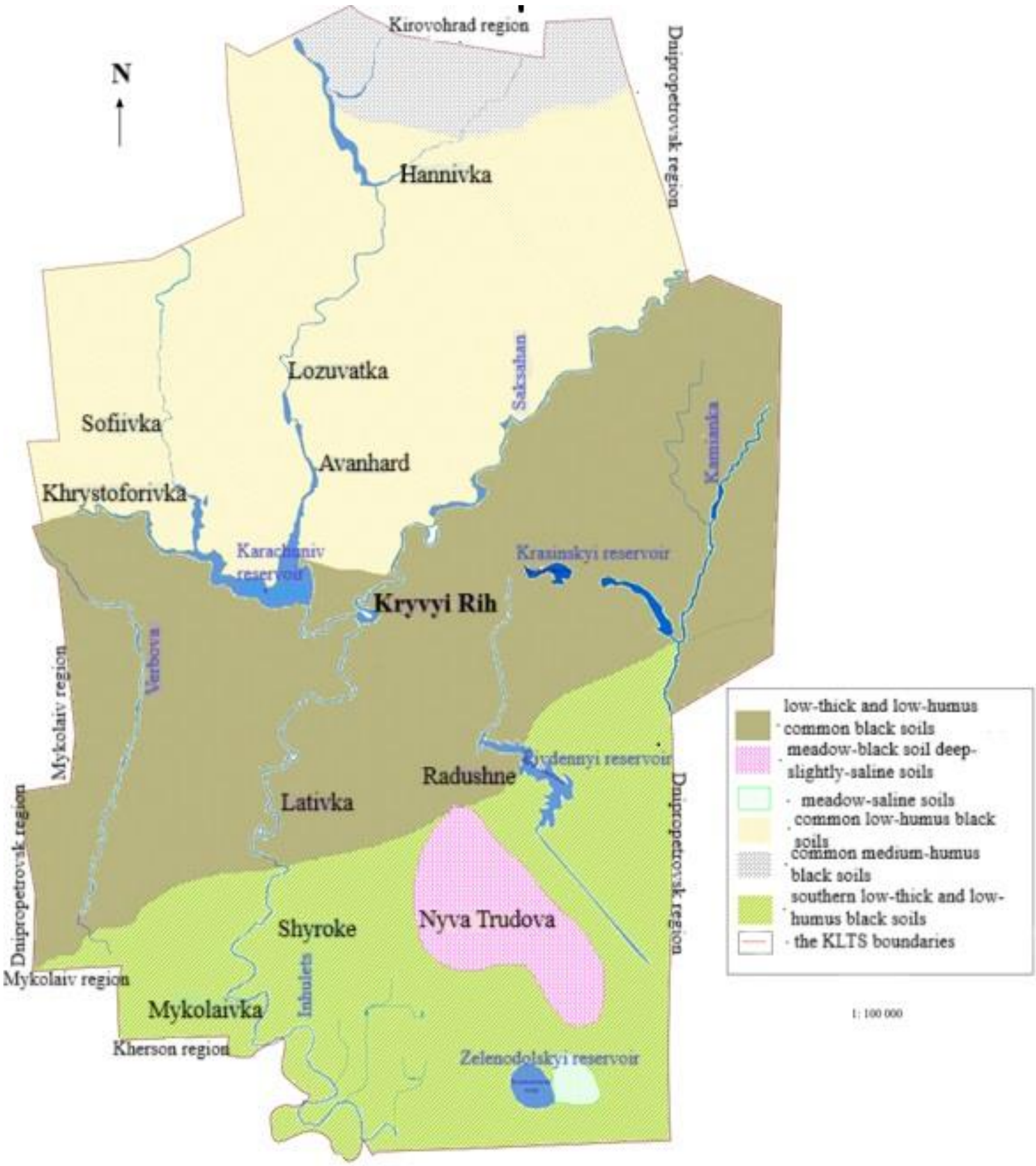

Fig. 2.6. Soil cover of the Kryvyi Rih landscape-technical system. According to [92]

The vegetation of KLTS is represented by more than 1260 species of higher plants. The indigenous type of vegetation is the steppes, the species composition of which is dominated by perennial herbaceous plants, in particular turf-forming grasses: feather grass (Stipa) , fescue grass (Festura) , koeleria (Koeleria) , wheat grass (Agropyron) , June grass (Poa) , and others.

The steppe part of Ukraine is the part of the Black Sea Steppe Province. Within its borders, two provinces are distinguished - Azov-Black Sea and Middle Don. In the Azov-Black Sea region, three subzones are distinguished : multi-grass, sage-grass steppes, which is characterized by Lessing mat-grass and meadow brome; fescue-feather grass steppes, to which the Ukrainian feather grass belongs; absinthial-herbaceous steppes, which represent such plant species as crested wheatgrass and Tauric wormwood [75, 92, 101].

Mesoxerophyte types of forbs occur in the lower forms of the relief: alfalfa Romanian, violet sage, longleaf. In the reservoirs formed in streams and individual old trees, the vegetation is represented by meadow-swamp and meadow-steppe groups, where there are common wheatgrass, smooth brome, sedges [28].

In the KLTS there are forest massifs that were formed in the floodplains of rivers and small ravines (Fig. 2.6). Tracts of ravine forests are available in the northern steppe subzone, namely in the strip of the forb-fescue-feather grass steppes in the north and in the center of Kryvbas. They include the following types of plants: common oak, Norway maple, field elm, small-leaved lime, common pear; alder buckthorn, blood-red hawthorn, dog rose and steppe rose are typical for shrubs; the grass cover includes grass-leaved stitchwort, goutweed, lily of the valley; willow is inherent in floodplain forests [28].

Dominant vegetation on the mining landscapes was planted in the process of reclamation or has sprouted independently (mostly from tree and shrub species - Tatarian maple, pyramidal poplar, snap willow, silver berry, etc.; the following plants are characteristic among the various herbs: knotweed common, yellow starthistle, yellow sweet clover, milk-witch gowan, meadow grass, couch grass, steppe spurge, wormwood Austrian, fescue, phlomis pungent, etc.).

Settlements of steppe animals were preserved only in protected areas, as well as in the exclusion zones of anthropogenic landscapes. In connection with the presence of significant areas of forest crops and forest strips, forest park zones, garden and park species of animals are also common. Rare species of animals make up only 40% of the total variety of fauna of the KLTS [51]. A peculiar synanthropic complex of animals is gradually forming, which adapts to the conditions of the residential and industrial landscape of the Kryvyi Rih landscape and technical system.

Fig. 2.6. Karachuniv forest on the territory of KLTS

2.3. The landscape structure of the Kryvyi Rih landscape-technical system

During the 150-year operation of the KLTS, the natural landscapes of its territory underwent the largest radical changes as a result of the extraction of iron ores and the storage of production waste. In particular, along the iron ore deposits of the Kryvorizka structure, the northern steppe landscapes, Saksahan and Inhulets rivers were completely destroyed. Instead, anthropogenic, mostly residential and industrial landscapes were formed and are actively developing, which are now the background within the KLTS. Modern natural landscapes of the KLTS were formed due to landscape-creating factors, primarily lithogenic (geological structure of the territory, relief and their development), climatic, hydrological (functioning of surface waters), hydrogeological (groundwater), soil, vegetation [68]. In general, the landscapes of the KLTS acquired natural features during the Pleistocene epoch of the anthropogenic period of the Cenozoic era - the last 1.5 million years. L. M. Bulava notes that the history of the landscapes of the KLTS is less complicated than in the northern regions of Ukraine, since Kryvbas was located in the post-glacial zone [3].

Kazakov investigated the modern landscape structure of the KLTS. He defined two subtypes, superorders, subclasses and orders of landscapes, as well as 6 clans and 53 kinds of landscape geosystems [51].

The main classes of KLTS landscapes are agricultural, residential, industrial (mining dumps, quarries, precipices and factories), water management, transport (road), forestry, recreational, recreational, service, wasteland (dumps, landfills, etc.), reserve and other landscapes (Fig. 2.7).

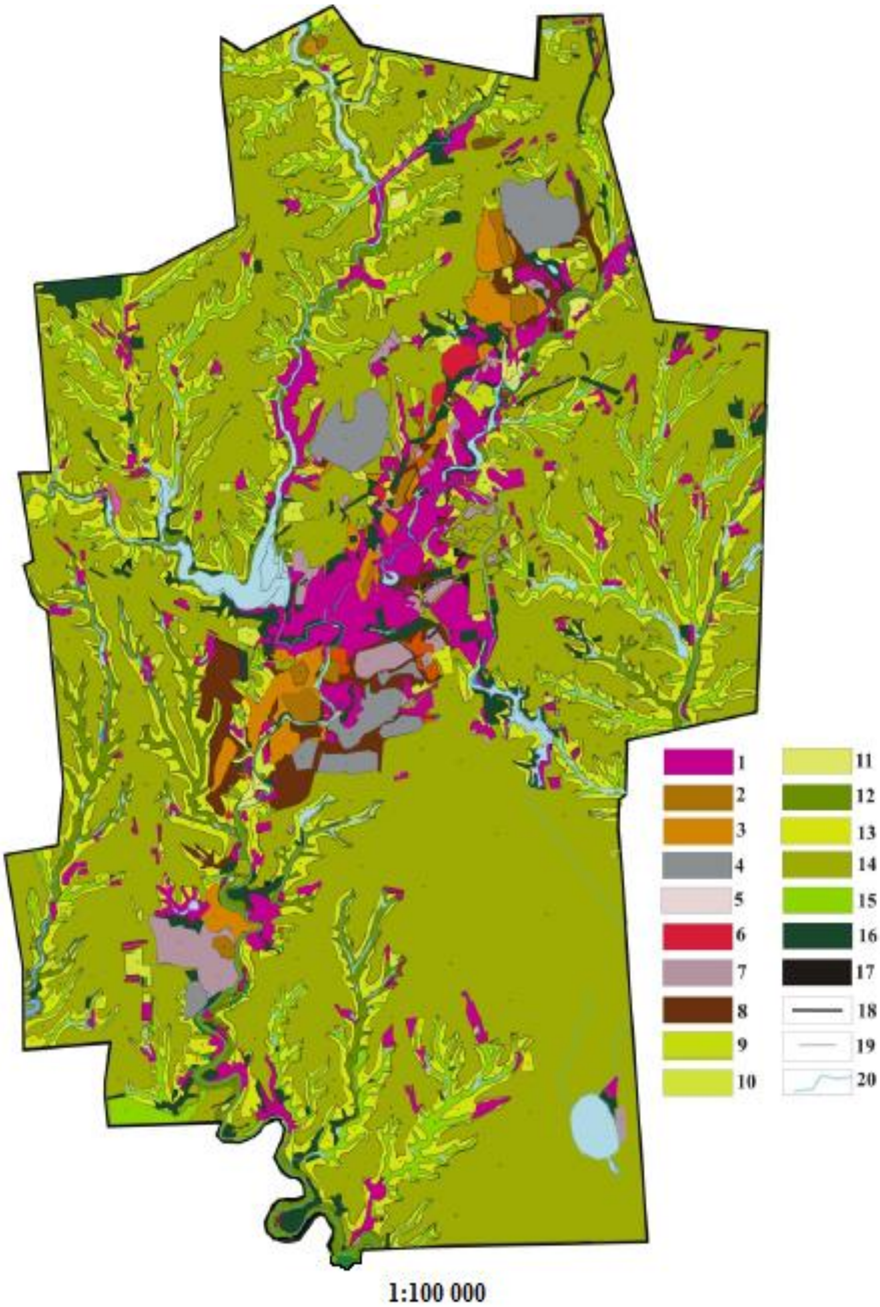

Fig. 2.7. The landscape structure of the Kryvyi Rih landscape and technical system [51]

1 – residential; 2 – quarry; 3 – waste; 4 – extractive; 5 – mine; 6 – sinkhole-sedentary; 7 – factory-and-works; 8 – post-industrial; 9 – kailyard; 10 – garden; 11 – pastures; 12 – field floodplains; 13 – field slopes; 14 – field water-dissected; 15 – field valley-ravine; 16 – forestry; 17 – tafal (burial); 18 – boundaries of the Kryvyi Rih landscape-technical system; 19 – borders of landscape types; 20 – rivers, canals.

Agricultural landscapes occupy the largest area of the KLTS - 61.2%, they are separated into field, kailyard, garden, pasture and cottage ones.

Residential landscapes occupy 13.1% of the territory of the KLTS. According to

V. L. Kazakov, they are divided into 2 subtypes: non-residential (cemetery) and residential.

Maintenance landscapes include domestic, administrative, scientific-educational and commercial subtypes.

Forestry landscapes are plantations of forest massifs. There are no natural forests on the territory of the KLTS, only forest protection and forest belt landscape complexes.

Water management landscapes include reservoirs, ponds, canals and sumps. The most of them, especially ponds, are in the floodplains of the Visun, Bokova, Zhovta, and Zelena rivers.

Belligerent landscapes are landscape complexes of military origin (military ranges, trenches, ditches, barrows, and others). The barrows are of several thousand to several hundred years old, almost all of them have been plowed up.

Road landscapes are represented by railway, automobile, pipeline and electric, pedestrian subtypes. The active formation of road landscapes began 200 years ago, and now there is a dense transport network.

Recreational landscapes began to take shape at the end of the 19th century. They include parks, estates, sanatoriums, health centers, camping sites and other recreation areas. Now the areas of recreational landscapes continue to grow.

Barren landscapes are the so-called "abandoned lands", they include post-industrial, post-settlement, garbage, agricultural and wasteland subtypes.

As for industrial landscapes, they are dominate on the territory of the KLTS. They are divided into peculiarly industrial and mining. Peculiarly industrial landscapes refer to large industrial enterprises or districts. Mining landscapes are formed because of mining and mining processing equipment. Mining landscapes fundamentally change all components of the natural environment, influence the substance composition, development and structure of natural and anthropogenic landscapes.

In general, the powerful Kryvyi Rih landscape-technical system was formed and has been actively functioning on small and compactly organized territory as a result of the close interaction of nature, technology and man for almost 150 years. Three stages are clearly distinguished in the process of its development: handicraft development (IV century BC – XVII century); initial industrial development (XVII - the first half of XX century) and active industrial development (the second half of XX - beginning of XXI century). They differ in temporal intervals, but they really reflect the peculiarities of the formation of the most powerful landscape and technical system in Ukraine and Europe.

The boundaries of the Kryvyi Rih landscape-technical system are not stable, but rather nominal, because due to the active impact of the mining industry on the landscape structure, they are constantly changing. The presence of large reserves of iron ore (more than 18 billion tons), favorable natural conditions and the demands of practice led to the formation of a powerful zone of technogenesis on the territory of Kryvorizhzhia. Territorially, the KLTS sublatitudinally stretches from north to south for 96 km, from west to east for 62 km and occupies an area of 4.1 thousand km ^{2}, which is 0.67% of the territory of Ukraine.

The modern landscape structure of Kryvorizhzhia is represented by various anthropogenic landscapes, among which the most common are agricultural, residential and industrial. In the structure of the Kryvyi Rih landscape and technical system, industrial landscapes prevail everywhere, represented mainly by their mining subclass. In the future, mining landscapes will continue to be the background in the KLTS and the environment-forming within Kryvorizhzhia.

ALTITUDE DIFFERENTIATION AND DIVERSITY OF THE MINING LANDSCAPES OF KRYVORIZHZHIA

3.1. The history of study of the mining landscapes of Kryvorizhzhia

For the first time within the boundaries of Kryvorizhzhia, landscape science research was conducted by L. M. Bulava, who noted that "technogenic landscape formation takes place on disturbed lands - a set of correlated processes (transformation of rocks and original forms of relief, "completion" of biota and soil), as a result of which the integrity of the disturbed part of the landscape sphere is restored, the vertical and spatial morphological structure of technogenic landscapes is gradually formed" [3].

I. S. Paranko studied the geological aspects of Kryvorizhzhia and proved that Kryvorizhzhia is an ecological risk zone due to the development of technogenic fracturing of rocks, which leads to a decrease in the seismic resistance of the territory, as well as a violation of the monolithicity of the massifs of Precambrian rocks [87].

V.L. Kazakov described the post-technogenic landforms of the mining landscapes of Kryvorizhzhia and showed that the process of their self-development begins after dumping the tailings and working out the quarries. V.L. Kazakov was the first to present the geomorphological characteristics of sinkhole zones, individual quarries and dumps of the KLTS [52].

V. P. Palienko established that 29% of the territory of Kryvyi Rih is occupied by landscape and technical complexes - urban, mining, reservoirs and sites of industrial enterprises [84].

A. V. Zberovskyi [42] and O. E. Lapshyna [74] were engaged in the research of climatic factors in the iron ore quarries of Kryvorizhzhia. The influence of hydrological factors on the self-flooding of depleted quarries was investigated by L. Y. Zolotariova [43] and the workers of the Dnipropetrovsk geophysical expedition "Dniprogeofizyka". Geobotanical and floristic researches aimed to study the plant grouping formed on the mining landscapes of Kryvorizhzhia, their species composition, herbarium of plants. The study of successions, the process of ruderalization, conditions for biological reclamation were studied by M. G. Smetana [101], Y. V. Malenko [76] and V. V. Kucherevskyi [73], S.V. Yarkov [116].

The active development of the mining industry contributed to the area growth of mining developments throughout the territory of Kryvorizhzhia. At the initial stages, since the capacity of overburden rocks did not exceed 1–9 m from the surface of the ore body, the open method of mining was mainly used. The introduction of the first lifting equipment into operation led to an increase in the depth of quarries and, accordingly, to the expansion of the dump area [27].

In the 50s and 60s of the XX century the main mining and beneficiation plants were built and their number increases in the future, in particular at the beginning of the 21st century. Industrial enterprises and the mining landscapes belonging to them now form the background of the powerful KLTS (Fig. 3.1). According to the calculations of V. L. Kazakov, within the boundaries of the KLTS, the total area of mining landscapes is 17.1 thousand hectares, the area of quarries - more than 4.2 thousand hectares, the area of dumps - 7.0 thousand hectares, the area of extractive sludge storages - 5.5 thousand hectares, the area of mine sinkholes and displacement zones - 3.4 thousand hectares [50]. This variety of landscape structures made it possible to classify them [87]. A detailed description of the taxonomic system of mining landscapes is given in the next subsection.

Fig. 3.1. The KLTS Northern Mining and Processing Plant

3.2. Diversity of mining landscapes of Kryvorizhzhia

The formation and development of mining landscapes is caused by the interaction of landscape-creating factors: technological methods and development of minerals and background natural conditions - the location of the development area and the background landscape environment.

Various derivative processes and phenomena (shifts, screes, landslides, etc.) also cause the formation of landscape complexes of various ranks - from tracts and plots to localities [27].

Taxonomic system of mining landscapes by G.I. Denysyk and G.M. Zadorozhnia was taken as a basis when researching the Kryvyi Rih mining landscapes [27] (Fig. 3.2). The types of mining landscapes of Kryvorizhzhia were also graphically classified and it was determined that the most common mining landscape complex of Kryvorizhzhia is the quarry and dump one (Figs. 3.3, 3.4).

The quarry and dump landscape complex is represented by a quarry and a dump, which are compared with each other unequally. Their mutual location, interaction and diversity are determined by the mineral extraction system and the feature of their occurrence [63]. Quarry-dump complexes are combined, mixed and distant.

Combined quarry-dump landscape complexes represent a paragenetic system, in which the slope of the dump often passes into the wall of the quarry or is located close to the dump. Between the quarry and the dump, there is an active exchange of mineral and biogenic substances, the circulation and temperature regime of the air is formed.

As an example, the quarry-dump complex named after K. Liebknecht on territory of Kryvorizhzhia, was studied.

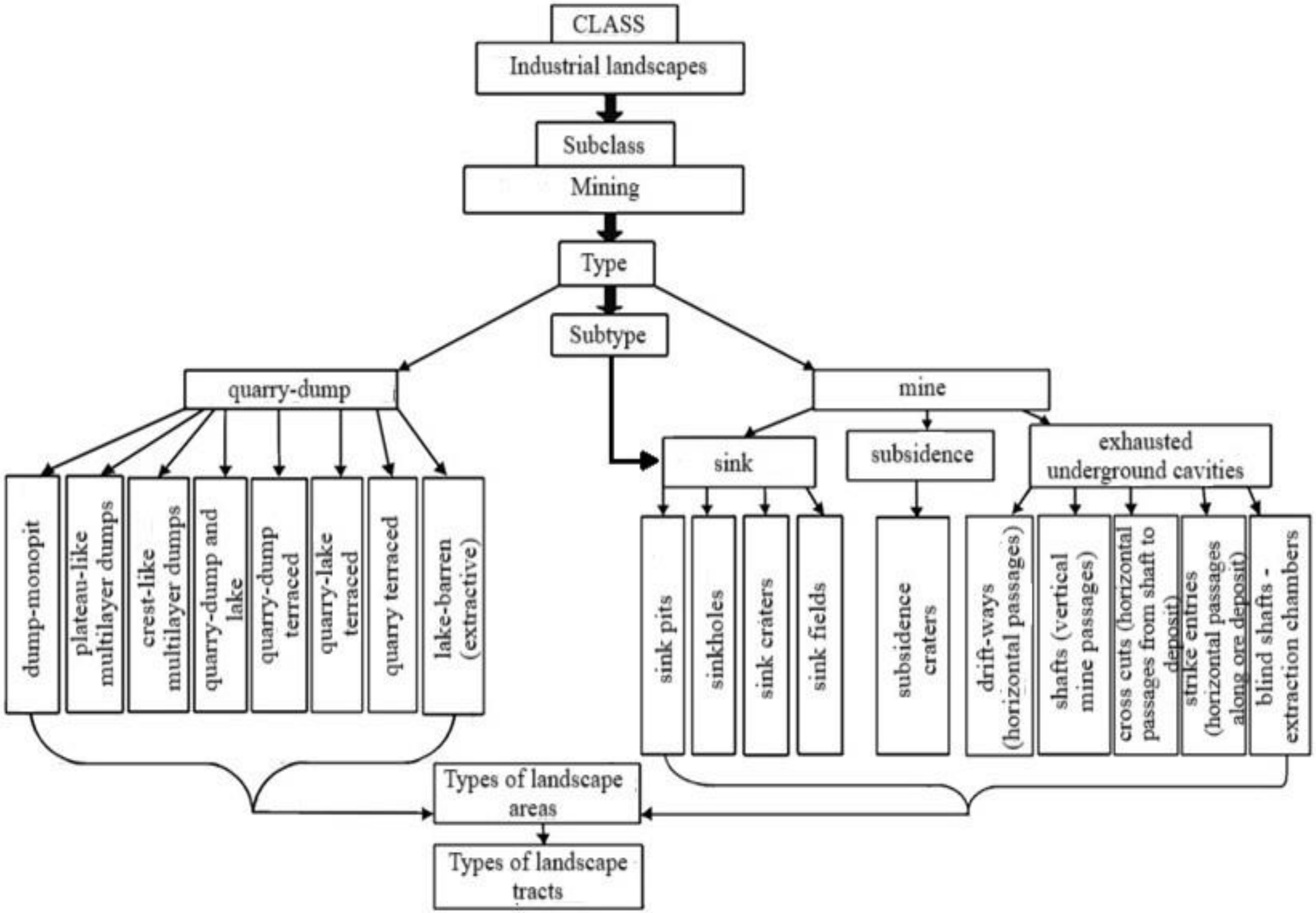

Fig. 3.2. Taxonomic system of mining landscapes [27].

ML types
of Kryvyi Rih landscape-technogenic system

1. Quarry-dump landscape complexes

- ○ Dump and monopit types of terrain
  - ◇ shallow excavations
- ○ plateau-like multi-stage dump type of terrains
  - ◇ multy-stage dumps
- ○ Crest-like multy-stage dump type of terrains
  - ◇ Raise dump «technogenic valleys»
- ○ Quarry-dump-lake type of terrains
  - ◇ Karst sinkhole «blue lakes»
- ○ Quarry-dump-stage type of terrains
- ○ Quarry-lake-stage type of terrains
  - ◇ Deep reservoirs, deep quarry-staged excavations
- ○ Quarry-stage type of terrains
  - ◇ Shifts, screes, landslides

2. Mine complexes

- ○ Mine-sinkhole type of terrains
  - ◇ Sinkhole craters
- ○ Mine-subsident type of terrains
  - ◇ Drift-ways, mine shafts, crosscuts, strike entries, blind shafts with areas, blind shafts with horizons, transitory pits, mining chambers
- ○ Lake-barren type of terrains
  - ◇ Slime storage

Fig. 3.3. Diversity of types of mining landscapes of the KLTS.

Distant quarry and dump complexes do not have direct connections in the exchange of matter and energy between their components. Quarries and dumps can be located at a distance of several, sometimes 10–15 km from each other. The formation of such complex is caused by a combined mineral development system.

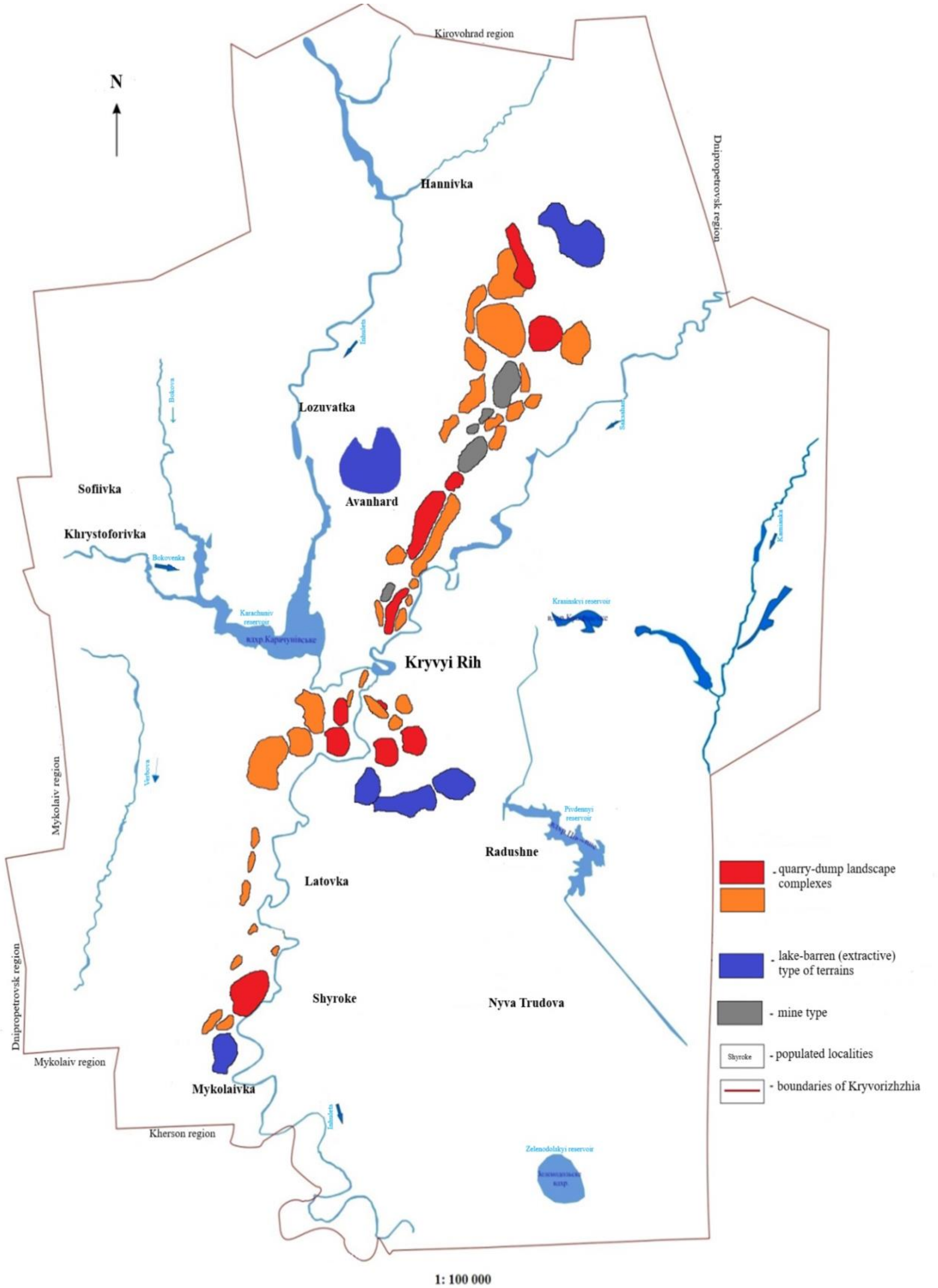

Fig. 3.4. Spatial location of the main types of mining landscapes of Kryvorizhzhia

Mixed quarry and dump complexes are formed in the process of storage of overburden rocks and various wastes in the exhausted quarry space. Researchers [7, 63] distinguish two subtypes in the structure of quarry-dump type landscapes: reclaimed and non-reclaimed (self-regulated).

The subtype of non-reclaimed quarry-dump landscapes is characterized by newly dumped or partially overgrown dumps, more rarely by quarries that stand out against the background of adjacent landscapes. On the territory of Kryvorizhzhia, unreclaimed quarry and dump landscapes are represented by two types of mining areas - "stony badland" and tailing storage wasteland.

The "rocky badland" terrain type is represented mainly by the original slopes of river valleys, gullies, ravines, "mountains", less frequently - a terraced complex, where the development of minerals is carried out in an open and closed way. From other types of mining landscapes, rocky badland differs by significant height dismemberment (up to 60 m), the presence of rocky dumps with terraced slopes, which often form rocks of different ages. The stony badland is divided into *granitic* and *ferruginous by the composition of rocks.*

The granite rocky badland on the territory of Kryvorizhzhia is formed with the help of above-ground mining of granite of the Ukrainian Crystalline Shield and the stacking of spent rocks into plateau-like dumps with terraced slopes.

Subtypes of reclaimed dump landscapes are formed in the process of carrying out works to restore the fertility of mining landscapes. The reclamation works involved in mining landscapes are described in the next section.

Dump-monopit type of area created as a result of anthropogenic denudation- shallow (10–25 m) pits filled with detrital material. They arise in the process of mining iron ore, which lies close to the surface. For the most part, these are the quarries that were the first on the territory of Kryvorizhzhia, and operated from the 1880s to the 1930s.

These are quarry-dump complexes of ore management named after S. Kolachevskyi, the Shmakov quarry, where the dump has not been preserved, and the quarry and dump complex of the joint-stock company "Kryvorizkyi Ore Plant" is located as a dump-single pit type in the central and southern part of Kryvorizhzhia.

Plateau-like multi-stage dump type of area was formed due to road or railway dumping of waste rocks. Multi-stage dumps were formed, with leveled and plateau-like surfaces. According to the available rocks, multi-stage dumps are divided into rocky, loose and mixed [27].

Rock dumps are characterized by the presence of rock fragments, namely granites, slates, quartzites and brown ironstone. As a rule, such dumps are loose, gravitational processes develop here and there is a complete absence of vegetation. They are widespread throughout the territory of Kryvorizhzhia. The rock dumps, which were active from 1960 to 1990, include the quarry dump of the Northern former ore management (further OM) named after Kirov, tailings of former mines named after Valiavka, Illich, Skelevatskyi dump of the Novokryvorizkyi mining and processing plant (hereinafter NkMPP) "ArcelorMittal Kryvyi Rih", Shymakivskyi dump of quarry No. 3 of NkMPP "ArcelorMittal Kryvyi Rih", Eastern Hannivskyi dump of the Northern mining and processing plant (hereinafter NMPP), dump in the displacement zone of the mine named after Ordzhonikidze of the Central Mining and Processing Plant (hereinafter CMPP). Also among the active ones, which have been operating since 1960 and up to the present day, there is dump No. 1 of the quarry of the Inhulets Mining and Preparation Plant (hereinafter IMPP) and dump No. 2 of the quarry of IMPP.

Loose dumps are created by dumping loose rocks, mostly loose and permeable, composed mainly of limestone, clay, marl, and loam. Loose dumps are characterized by significant turfing and the active development of herbaceous and woody vegetation.

Loose dumps include the dump of the Kochubeiv mine, the dump of the OM named after S. Kolachevskyi, the dump of the Oleksandriivskyi mine within the former Gvardiiska mine, the "Kryvbaszalizrudkom" dump, the dumps of the Northern quarry of the Starodobrovolske OM, the dumps of the southern quarries of the Starodobrovolske OM, the Northern dump of the Zhovtnevyi granite quarry, the dumps of the Northern Vizyrka, Southern Vizyrka, Western Vizyrka quarries of the former Inhuletskyi OM.

Mixed dumps are formed due to the presence of both rocky and loose rocks. These include: small-area iron ore quarry dumps in the Northern Chervona ravine of the former OM named after Lenin, Dubova Balka OM dump, Shymakiv mine quarry dump, Leninskyi dump of the former OM named after Lenin, the western dumps of the Hleiuvatskyi quarry of the CMPP, the Novobilshovytski dumps of the Hleiuvatskyi quarry of the CMPP, the dumps of the former OM named after Komintern, the southern dump of the Zhovtnevyi granite quarry, the dumps of the Halkovskyi and Saksahanskyi mines, the Burshchitskyi dump of the NkMPP "ArcelorMittal Kryvyi Rih", the dump of the Sovietsky quarry of the former OM named after Illich, Right-bank dump of the Southern Mining and Processing Plant (hereinafter SMPP), dump of quarry No. 2 of the CMPP, dump No. 6 of the quarry No. 2 of the CMPP, dump of the Gleiuvatskyi quarry of the CMPP. All dumps are inactive, the period of their activity was in 1890–1990.

The crest-like multi-stage dump terrain type is formed thanks to the specialized dumping of dumps, namely the cyclic flow technology, when "crests" are formed on the surface of the dumps. On the dumps there are formed "technogenic valleys" through the ridges. Dumps are favorable for the formation of vegetation. They are concentrated in the central part of Kryvorizhzhia [27].

Quarry-dump-lake terrain type. With the development of the mining industry, the depth of iron ore extraction increases, the abandoned pits eventually fill with water, forming "blue lakes". The depth of the quarries reaches 40 m, the height of the dumps - from 5 to 10 m. The slopes of the inactive dumps are well covered with grass and tree plants. The landscape processes are actively developing on the dumps, among which gravity and fluvial processes are observed, and where limestone is, karst types of relief are formed. The quarry-dump-lake type of mining landscapes is limited to the southern part of Kryvorizhzhia.

The quarry-dump-terraced type of terrain is characterized by the considerable depth of the pits and the height of the dumps. Iron ore is extracted using specialized equipment for overburden works, pits are not flooded due to constant pumping of groundwater. Gravity and fluvial relief developed here. The quarry-dump-terraced type of mining landscapes is widespread in the central part of Kryvorizhzhia.

Quarry-lake-terraced terrain type is formed as a result of the flooding of deep, previously exhausted quarry pits. The depth of such pits is up to 30 m. There are about

20 pit reservoirs on the territory of the Kryvyi Rih Landscape and Technical System. Vegetation, in particular tree, forms near water bodies. There are two types of quarry-lake-terraced landscape complexes on the territory of the KLTS - iron ore, which includes the Radianskyi quarry, and granite, which includes the Zhovtnevyi and Karachuniv granite quarries.

The quarry-terraced type forms a modern powerful zone, where all active quarries (up to 420 m deep, more than 4 km long) are concentrated in Kryvorizhzhia. Such landscape processes as screes, landslides, and shifts are manifested in these quarries. No vegetation was found. This type includes the exhausted quarry named after K. Liebknecht. Now the quarry of OM named after K. Liebknekht is inactive, it was exploited in period from the 1950s to the 1960s, it is not flooded, because groundwater is being pumped out. The vegetation is ruderal, the bottom of the quarry is covered with tree vegetation. The quarry-terraced type includes active quarries: NkMPP quarry No. 1, NkMPP quarry No. 2, NkMPP quarry No. 3, SMPP quarry, Gleiuvatskyi quarry (CMPP), Pervomaiskyi quarry (NMPP), Hannivskyi quarry (NMPP), Inhuletskyi quarry (IMPP).

The largest quarry in its area is SMPP. The length of the quarry is more than 3 km, the width is 2.5 km, and the depth reaches 400 m. The deepest quarry in Ukraine is Inhuletskyi, the depth of which reaches 420 m.

The lake-barren type of terrain was formed in the locations of sludge storages in Kryvorizhzhia. Sludge storages are hydraulic dumps, which are composed of watered sludge (pulp - a mixture of crushed ore extraction waste with water). They are formed by sludge flow through channels and pipes, and in the future water saturation is maintained artificially. Hydraulic dumps are composed of dry rock mixture, the height of which is 100–150 m, the surface area of the plane is from 700 to 1200 ha. There are 12 sludge storage facilities on the territory of Kryvorizhzhia. There are millions of cubic meters of technogenic sands at the sludge storage facilities. With strong winds, dust from the sand rises and spreads over a long distance, polluting the air, soil and water bodies. Sludge storage facilities are located along the entire territory of Kryvorizhzhia.

Mining type of mining landscapes was formed, respectively, as a result of the closed development of iron ore deposits. It is divided into two types: mine-sinkhole and mine-subsidence types of terrain.

The mine-sinkhole subtype arises as a result of underground mining of iron ore using the technology of subsurface displacement [40]. It is widespread in the northern and central part of Kryvorizhzhia. It has a complex structure. Landscape-creating processes and phenomena take place intensively on this subtype of terrain. The sinkhole zones are characterized by a significant height difference (the depth of the pit reaches 200 m), the vegetation is poor due to harsh environmental conditions. Reservoirs are formed on the territories of failure zones.

The mine-subsidence subtype arises as a result of brown iron ore mining and is associated with the geological and geomorphological features of the territory.

Mine cavities belong to the class of industrial landscapes, subclass of mining, type of underground mine landscapes:

– tunnels (horizontal passages);
– mine shafts (vertical passages);
– crosscuts (horizontal runs from the shaft to the deposit);
– strike drives (horizontal passages along the ore deposit);
– blind shafts with sections, horizons, transitional pits (vertical-stepped passages for passing ore down);
– extractive chambers (volumetric rounded shape).

Shafts are vertically located cavities in rocks representing the geological section of Kryvorizhzhia in places of iron ore mining. The diameter is from 2-3 m to 5- 6 m, and the depth in iron ore mines reaches 1000-1300 m (the maximum depth of the Batkivshchyna mine is 1522 m). The walls of the mine shafts are reinforced with metal and concrete.

Shaft wells are formed as a result of iron ore exploration, their diameter is 10–30 cm, depth – 2–3 km or more.

Vertical shaft wells are vertical stepped passages for passing iron ore vertically.

Tunnels are usually intended for mine maintenance and are located close to driftways. The tunnels are laid at an angle to the surface of the earth to facilitate the removal of iron ore from the mine.

Mining chambers-blocks - formed as a result of the fact that iron ores are often concentrated in the rocks in so-called lenses or "pillars". The sizes of the cloisters are diverse, they can be up to 160 m in diameter and more and several hundred meters long.

Mine shafts are represented by horizontal workings with a small (3–5 m) slope. They are used to form underground labyrinth of passages of iron ore deposits, developed by the mine method.

Strike drives are horizontal runs along the ore deposit. They serve for the exploration of ore bodies, their better knowledge and further rational development.

Today, the average depth of the quarries in Kryvbas is up to 400 m (SMPP quarry), the height of dumps and dams is up to 100 m (dumps of the Hannivskyi quarry, Voikivskyi, Mykolaivskyi tailings), the depth of the mines is up to 1400 m ("Kryvorizka" mine , "Yuvileina") [47].

3.3. General peculiarities of altitudinal differentiation of the Kryvyi Rih landscape

Altitude differentiation clearly separates and closely interrelates zonal, azonal, and marginal features of the nature and landscapes of the plains. Altitude differentiation of plain landscapes is divided into highland and lowland types [58]. The main factors that serve to distinguish the edges are longitudinal-climatic and geological-geomorphological conditions that affect the nature of the soil cover, vegetation and other components of landscapes. With the help of the interaction of flows of matter and energy, direct and reverse paradynamic connections, the intensity of which depends on the absolute and relative elevations, *altitudinal landscape complexes* are formed [58]. That is, the landscape complex is formed as a result of time and the action of endogenous and exogenous factors: lithological-geomorphological, climatic, hydrological, biotic, anthropogenic. Differentiation of climatic conditions, flora and fauna diversity, watercourses depend on the geomorphological features of the territory and topography [109]. Altitude differentiation on the plains, in particular in the Kryvorizhzhia region, is characterized only by intrazonal changes, and is considered due to the existence of altitudinal-landscape stages, levels and tiers.

The altitudinal level is an intrazonal paradynamic system of the regional level, which is distinguished by changes in absolute and relative heights within the plains, which are divided into highlands and lowlands. The degrees of altitudinal differentiation appear in the form of a set of physical and geographical regions and districts, which are united by the common height and the dynamics of landscape-creating processes [57].

The altitudinal landscape level is divided into *altitudinal landscape levels*. They arise due to complex paradynamic systems, namely types of localities united by common absolute heights, geological and geomorphological structure, depth of groundwater, relative homogeneity of soil cover, macroclimate, and the direction of landscape-forming processes [56].

Altitude-landscape stages are formed due to paradynamic systems of localities and tracts, which have the same hypsometric markings, one type of location, lithogenic base, and invariance.

Kryvorizhzhia is located within the Dnieper altitudinal and landscape grade. Its surface has absolute altitudes (+20–180 m), covers the territory of the Dnieper Highlands and the Black Sea Lowlands. From a tectonic point of view, the Dnieper altitudinal and landscape stage belongs to the Ukrainian crystalline shield, gneisses, granites, magmatites and quartzites lie in its foundation.

On the territory of the Dnieper Highlands, which covers the northern and central parts of the territory of Kryvorizhyzhia, there are quaternary loams 3–25 m thick, and below them are Neogene clays, sands, fracture limestones 5–11 m thick. Neogene deposits lie on Precambrian crystalline rocks (granites), which come to the surface in river valleys. There is also a developed truss-beam system, widespread landslides, passable valleys, cones of removal.

The Black Sea lowland, which covers the south of Kryvorizhzhia, is characterized by sedimentary rocks of the quaternary age: clays, sands, and sandstones with patches of marls and limestones. Loess rocks are the most common among quaternary deposits within the southern part of Kryvorizhzhia.

The territory of the Dnieper altitudinal and landscape stage is diverse with minerals: iron (Kryvorizkyi iron ore basin), manganese (Nikopol manganese basin) ores, kaolin, graphite, brown coal and others. There are numerous rivers here, which are tributaries of the Dnieper, which form rapids and rapid streams in places where crystalline rocks emerge. In the past, steppe landscapes were widespread on the territory of the Dnieper altitudinal landscape stage.

Within the forest-steppe strip of the East European plain, three altitudinal landscape levels are distinguished: the lower or "young" accumulative, the middle or typical denudation-accumulative and the upper or "old" denudation. These levels have the following absolute altitudes: lower – 150–180 m, middle – 180–250 m, upper – more than 250 m [9].

In the natural zones of the forest-steppe and steppe, 6 types of terrain are distinguished: floodplain, supraflood-terrace, plakorn, last-watershed, riverine and low-mountain. Subsequently, the inter-river undrained, hilly-ridge and tovtr types of terrains were distinguished [91].

The altitudinal differentiation of mining landscapes is more expedient to study by the types of localities, where an active process of denudation and accumulation takes place in each type of locality. Depending on the speed of the denudation-accumulation processes, a microstrip is formed within each type of terrain .

The selection of microstrips is based on pronounced geomorphological processes closely related to their location within the types of localities. Each anthropogenic type of locality is characterized by its own set of geomorphological processes, which occur faster in some areas, slower in others, and sometimes only accumulation processes occur. When one process is replaced by another, microstrips are formed in which there are transitions. Also, the increase in the number of tracts within individual microstrips is primarily influenced by the shape of the relief, human economic activity, the peculiarity of the soil cover, vegetation and animal life [9].

It is also advisable to divide microstrips in anthropogenic types of terrain into upper, middle and lower.

Upper microstrip is characteristic of tracts of the upper slopes of terricones, mounds, tracts of dumps and embankments of overburden rocks, where there is rock that crumbles and migrates down the slope. In the mature stage, the microstrip is overgrown with vegetation.

The middle microstrip is determined by tracts of the quarry slopes, where denudation occurs in the upper and middle parts of the microstrip, and accumulation occurs in the lower part. There is no vegetation on this microstrip, or it is just emerging.

The lower microstrip is represented by areas where matter (rock) accumulates, namely at the bottoms of quarries, lakes that arise in quarries. On this microstrip, there are cones of removal of substances, groundwater lies close, compared to other microstrips, humidity is much higher, wetlands and vegetation are present.

The basis for the formation of microstrip is the slope. According to three indicators - the shape of the slope, the history and conditions of the formation of the slope and the nature of the slope processes - the slopes are divided into straight, convex and concave. And they are also divided into additional options: convex to the bottom, straight, convex-concave, stepped and wavy (Fig. 3.5)

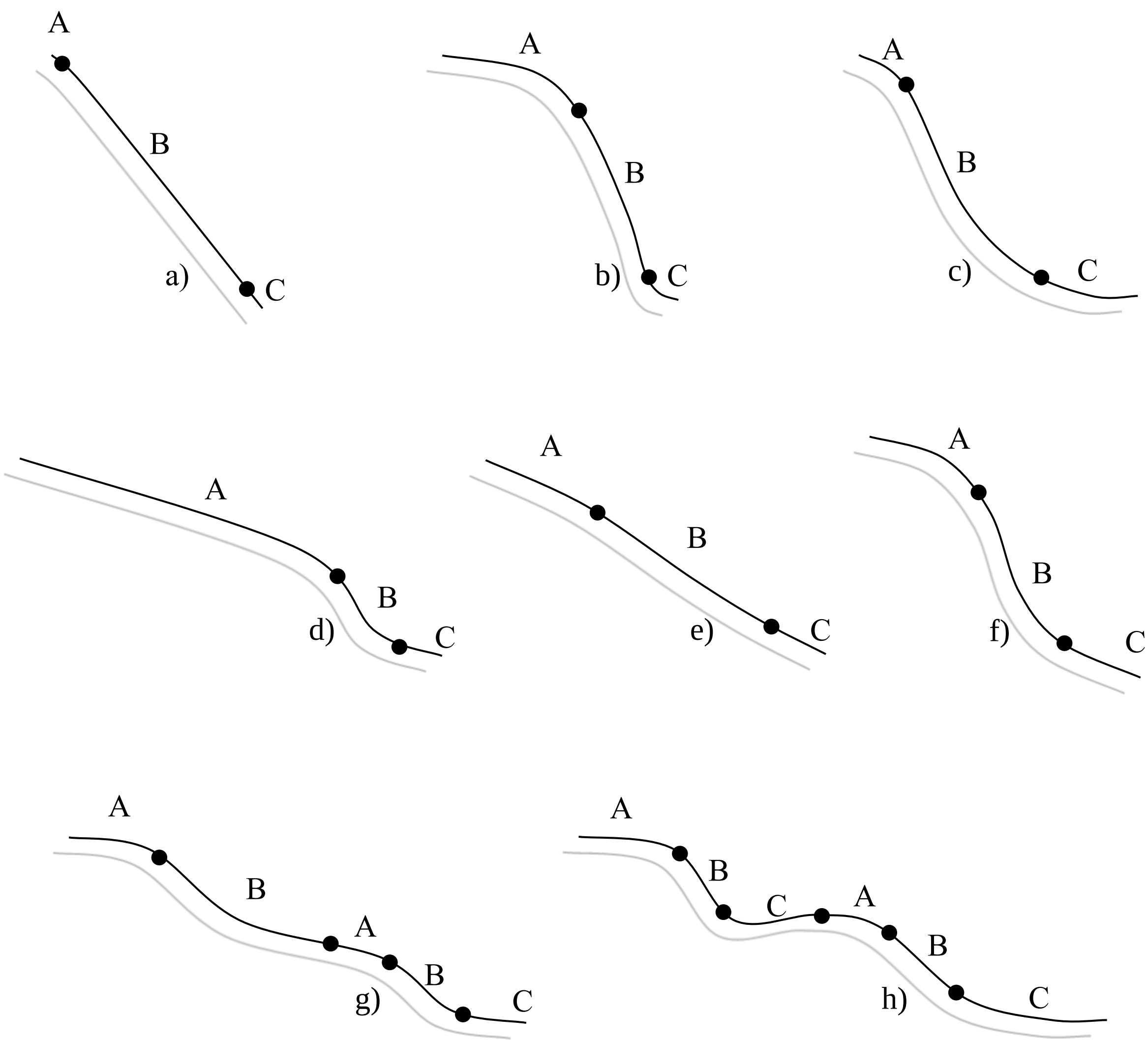

Fig. 3.5. Morphological variants of sloping microstrip according to [7]

Microbelts: A ─ upper, erosion-denudation microstrip; B ─ middle, transit microstrip; C ─ downslope, accumulative or foot microstrip.

Morphology of slopes: a) – straight; b) – convex; c) concave; d) – convex to the sole; e) – straight (inclined); f) – convex-concave; g) - stepped; h) - wavy;

● – boundaries between microstrips

Straight slopes are characterized by an intensive process of collapse and shedding on the upper microstrip, and a washout line is observed on the middle microstrip. These slopes are characteristic of such terrain types as rocky badland and monopit type terrains. Straight sloping and convex slopes belong to the single-pit and pit-hilly-lake types of terrain (Fig. 3.6). Slopes convex to the bottom belong to trench-swamp wastelands. The greatest function is performed by the upper microbelt, where the substance is washed to the sole. Slopes with a concave and convex-concave profile are formed in single-pit and pit-hilly-lake terrain types. Slopes with wavy or stepped transverse sections belong to the subsidence-terrace-fall type of terrain.

Fig. 3.6. The flooded quarry of NkMPP

3.4. Altitudinal differentiation of quarry and dump complexes of mining landscapes of Kryvorizhzhia

Many scientists studied anthropogenic terrain types, in particular mining landscapes [20, 32, 50, 57, 80, 87, 105]. In their studies, the researchers singled out the most diverse forms of anthropogenic relief, where altitudinal differentiation is clearly visible. It was determined the fact that under the influence of the mining industry there is a change in the relief in the vertical and horizontal directions, which contributes to the formation of a diversity of landscapes. The altitude differentiation of quarries and dumps within the borders of Ukraine is characterized in more detail in the works of O. A. Medvedeva, V. L. Kazakova [51], E. A. Ivanov [48] and S. V. Yarkova [28].

The mining industry has formed landscapes on the territory of Kryvorizhzhia that are completely not typical for it. Instead of plain landscapes, the so-called "technogenic low-mountain relief" was formed - dumps and "technogenic depressions" - quarries, which are widely represented here at the beginning of the 21st century and often are factors in the development of altitudinal differentiation of the landscape in separate districts of Kryvorizhzhia.

Altitudinal differentiation of the quarry-lake-terraced type of mining landscapes (on the example of the Zhovtnevyi granite quarry). Quarries occupy an important place in the anthropogenic landscapes of Kryvorizhzhia. The concept of "quarry" is an open excavation of significant transverse dimensions, which is exploited for the purpose of extracting ore, coal, building materials, etc. [14]. In general, a quarry is a negative relief form of technogenic origin, where active mineral extraction takes place. V.L. Kazakov classified quarries according to such features as structure and complexity, depth, shape, location, closure, and type of mineral raw materials extracted in the quarry [32]. It is worth noting that the quarries are divided into shallow (depth up to 50 m), medium deep (depth 50–150 m), deep (depth 150–250 m) and ultra-deep (depth from 250 m).

The altitudinal differentiation and diversity of mining landscapes can be considered in more detail, taking as a basis several quarries of the territory: Zhovtnevyi and Karachuniv granite quarries.

The Karachuniv granite quarry (Fig. 3.7) is located within the boundaries of the Central City District of the Dnipropetrovsk Region. The area of the quarry is 26.9 km². The Karachuniv quarry is a part of the floodplain terrace of the Inhulets River, the absolute height of which is 200–220 m. The geological structure of the Karachuniv deposit is determined by its location in the zone of the complex of crystalline rocks of the Ukrainian Crystalline Massif. Quaternary sediments, represented by loams, clays and sands, which are found on the entire area, take part in its structure. Below the quaternary sediments are products of weathered crystalline rocks - primary granites. Granite, feldspar and sand were mined in the quarry.

In the past, the Karachuniv quarry belonged to the Karachuniv stone-crushing plant, which belongs to JSC "Kryvorizkyi Granite Quarry". The climate is moderately continental. The minimum temperature in January is – 15°C, the average temperature in July is +23.1°C, the average annual temperature is +23°C. The greatest amount of precipitation falls in June-July - up to 65 mm, the least in January-February - 28 mm.

Fig. 3.7. Spatial location of the Karachuniv granite quarry

Fig. 3.8. The deluged bowl of the Karachuniv granite quarry

The granites of the Karachuniv quarry are mined for the production of rubble stone, construction breakstone, breakstone for the ballast layer of railways, asphalt-concrete mixtures and road construction. The currently operating quarry is a hexagonal expiration, stretched from north to south (Fig. 3.7). Its maximum width is 700 m, and its length is 1,400 m. The altitude of the quarry site above the river level is 10– 15 m. The quarry is developed in five ledges, through 15 m each one, that is, with absolute height marks - 200 m, 195 m, 190 м, 175 m. The quarry-dump type of landscape prevails here, which is represented by the stony badland terrain type. In the landscape organization (Fig. 3.9) there are two types of structures distinguished: pit landscape plots and dump landscape plots. Pit tracts are characterized by significant vertical dismemberment, the presence of steep stony and multi-step slopes with poor vegetation cover, etc [66].

In general, the phenomenon of altitudinal differentiation manifests itself in the presence of accumulative-denudation processes, taking into account which the following altitudinal-landscape microstrips can be distinguished.

Lower accumulative microstrip. The bottom of the granite quarry looks like a plain, almost flat area without vegetation. Locally only remains of stone blocks and breakstone flooded with water are found.

Middle accumulative-denudation microstrip. Tracts of overburden are located on the floodplain terrace of the Inhulets River and form two layers. The first layer - with absolute marks of 200 m and relative marks of 0 - 8 m – looks like a bulk shaft, composed of the remains of the soil cover, sand and clay. The vegetation here is dominated by weed groups with individual specimens of tree species: poplars, birches, acacias, etc.

The second layer is on the level 230 m has a ledge height of 10 м. It composed of granites, fragments of crystalline rocks. Tracts of overburden rocks also separate the quarry from the Inhulets River. The overburden rocks are piled in a 3–8-high dam. The first layer of the dam is composed of rocks, which protects the dam from erosion. The upper layer is composed of granites and loess loams. The dam is densely overgrown with vegetation. Representatives of ruderal vegetation are widespread here - field sow thistle, couch-grass, absinth sage *(Artemisia absinthium L.)*, spurge vine (*Euphorbia virgata WK)*. Poplar, birch, and acacia represent here the tree species.

Tracts of quarry slopes differ among themselves in height, steepness, and vegetation depending on their exposure. These differences are caused not so much by the distribution of heat and moisture, but by the features of the mining process. Thus, the northern slopes of the quarry are rather steep (up to 80°) "walls". They consist of granite rocks and are devoid of vegetation. Since there is no sediment accumulation here due to the steepness, and therefore there are no favorable conditions for the growth of vegetation. The western and eastern slopes of the quarry are stepped terraces. There are six of them in the western part. These are low (2– 6 m) terraces with a width of 60 m. The upper, edge areas of the slopes of each terrace are densely overgrown with tree vegetation: willow, birch, poplar. On the middle and lower parts of the slopes of the terraces, only single species of these trees are found.

Fig. 3.9. Altitude differentiation and diversity of mining landscapes of Karachuniv granite quarry

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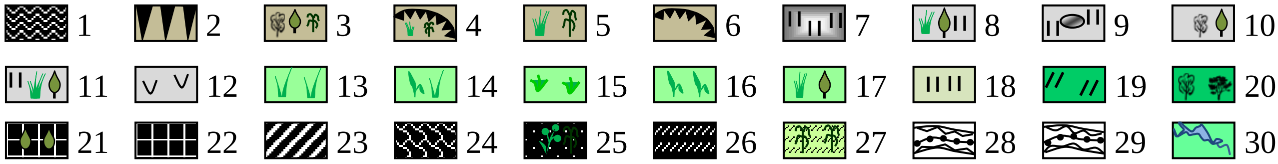

Industrial landscapes : ***Quarry and dump.*** A granite variant of the rocky badland terrain type. *Tracts* : 1 – a flat, monolithic bottom of a granite quarry without vegetation, occupied by a lake reservoir; 2 – steep (up to 80°) granite "walls" of quarries without vegetation; 3 – high (10-15 m) granite slopes of quarries, with a steepness of 60-70 ° , overgrown with birch, willow, and poplar; 4 – terraced working granite ledges, partially overgrown with shrubs; 5 – low (2– 6 m) granite "walls" of quarries, overgrown with birch, willow, sycamore; 6 – steep (60-80 °) granite-loam working ledges of overburden; 7 – hilly granite-loam dumps overgrown with ruderal vegetation; 8 – micro-bumpy loamy-granite-sand surfaces with a predominance of weed associations, overgrown locally with trees and bushes; 9 – stony wastelands with sparse ruderal vegetation; 10 – a high (3 – 8 m) dam made of overburden granite-loam rocks, overgrown with poplar, birch and acacia; 11 -high (3 – 8 m) dam made of overburden granite-loam rocks, overgrown with various herbs and shrubs; 12 – microbumpy surface of granite-loam dumps without vegetation;

Agricultural landscapes. *Floodplains* Meadow and pasture . *Tracts:* 13 – micro-bumpy wet surfaces of a low floodplain with sedge vegetation; 14 – redundantly waterlogged, partially waterlogged areas of the low floodplain, overgrown with reeds and sedge vegetation; 15 – grass-herbaceous wet meadows of a low floodplain; 16 – waterlogged, partially waterlogged areas of a low floodplain, overgrown with reeds; 17 – micro-bumpy surface of the middle floodplain, overgrown with meadow vegetation and willow trees; *Supraflood-terraced.* Meadow and pasture . *Tracts:* 18 – the gently undulating surface of the first terrace with black soils, occupied by various herbaceous vegetation under hayfields. *Slopes* Meadow and pasture . *Tracts:* 19 – various grass-cereal vegetation on sloping loess slopes with black soils.

Forest landscapes. *Floodplains* *Conventionally natural*. *Tracts.* 20 – willow grove and common alder on gently sloping surfaces of the high floodplain; *Supraflood-terraced. Tracts* 21 – acacia, sycamore and poplar bushes on the gently undulating surface of the first terrace with black soil.

Residential landscapes. 22 – the gently undulating surface of the first floodplain terrace, occupied for individual development; 23 – garden plots on the gently undulating surface of the first floodplain terrace.

Road landscapes. Tracts. 24 – sloping slopes of the railway embankment overgrown with ruderal vegetation; 25 -sloping slopes of the railway embankment, overgrown with ruderal vegetation, rare sycamore and acacia trees; 26 steep slopes of the railway embankment overgrown with ruderal vegetation; 27 steep slopes of the railway embankment, overgrown with ruderal vegetation and single sycamore trees; 28 – railway track on the embankment bridge; 29 – railway track on a concrete bridge with reinforced concrete supports.

Water landscapes. 30 – riberbed of the Ingulets River; 31 – reservoirs with a depth of 1.5–2 m in waterlogged areas of the floodplain.

Other marks: Borders. 32 – tract; types of localities: 33 – floodplain and supraflood-terrace; 34 – floodplain and slope; 35 – the direction of the river Ingulets

This scarcity of the vegetation cover as it moves down the slope is explained by the fact that the middle and lower parts of the slopes are characterized by erosive activity, especially where the basis of the slope is loose rocks (clay, granite, sand). Deluvial plumes are often observed along such slopes.

The eastern slopes are three carved terraces with a height of 10– 15 m. Their steepness is 50–70°, plants settle here. Black poplar, warty birch *(B. verrucosa Ehrh.)*, grey willow, seabuckthorn *(Hippophaë rhamnides L.)* have adapted to the specific conditions of disturbed areas quite well. Erosion processes are also quite active on these slopes.

Tracts of terraced working granite ledges are located in the southern part of the quarry. These are carved terraces, the upper parts of which are composed of overburden rocks, and the lower parts are made of granite. These tracts are not covered with vegetation for the reason of active mining here.

In the northern part of the industrial area there are spent quarries. They look like a chain of water complexes stretched from west to east, formed at the place of mineral deposits. Each reservoir has an oval shape (Fig. 3.10).

Fig. 3.10. Reservoir of the Karachuniv granite quarry

There are the tracts of overburden rocks around of these water complexes, which almost merged with the environment. Their industrial past is evidenced only by the rugged relief and steep granite "walls" on the slopes of the nearby quarries. Tracts of overburden rocks are overgrown with dense vegetation, which is dominated by motley grasses and cereal and weed associations. The slopes of the upper opening ledge, which is clearly separated, are overgrown with wild raspberries *(Rubus idaeus L.)*. Wild apple and black cherry trees grow on the slopes, and willow, birch, sycamore maple, and poplar trees grow closer to the water.

Upper denudation microstrip. It includes tracts of dumps located on the periphery of the industrial site. On the flat-undulating surface of the second floodplain terrace of the Inhulets River, these tracts form a chain of chaotically piled hills and ridges. The relative height of such ridges and hills is 50– 120 m, and the steepness of the slopes reaches 35–50°. Interridge depressions are often occupied by small lakes overgrown with sedge and reeds.

Dumps are piled in two tiers: the first – up to 240 m absolute altitude mark, the second – up to the mark 260 m above. The relief-forming rocks of the tracts are the remains of granites and loess-like loams. The plant cover of the ancient dumps is quite diverse. The grass cover is dominated by weeds: absinth sage, couch grass, garden milkweed, field horsetail, field sow thistle. The tree species and shrubs prevailing here are warty birch, aspen, poplar, goat willow, and white acacia.

Landscape diversity on the natural site is characterized by the presence of 3 classes of anthropogenic landscapes, 2 natural types of terrain and one anthropogenic (rocky badland), 34 types of tracts. Indicators of chorological and typological diversity (Table 3.1) indicate that chorological diversity prevails on the natural site (indicator - 0.351). So, a natural area is characterized not so much by the variety of landscapes, but by variegation, the frequent alternation of the same types of landscapes. The high indicators of landscape diversity of the entire nature area are determined by the indicators of the stony badland type of terrain.

Table 3.1

Indicators of modern and restored (pre-agricultural) chorological and typological landscape diversity of the natural site
Karachuniv granite quarry

	Altitude and landscape levels							
	Lower accumulative							
	Types of localities							
	Floodplain		Supraflood-terrace		Rocky badland		Totally on a field area	
	1	2	1	2	1	2	1	2
S ha	26	65.7	50	128	117.7	-	193.7	193.7
N	12	10	11	9	46	-	68	19
m	6	3	6	4	23	-	34	7
CD_1	2,2	6.57	4.5	14.2	25	-	2.9	10.2
CD_2	0.46	0.15	0.22	0.07	0.39	-	0.351	0.099
TD	0.25	0.05	0.12	0.031	0.195	-	0.175	0.036

TD – indicators of typological diversity of landscapes; m – number of types of landscapes; CD_1, CD_2 – indicators of chorological diversity; CD_1 – average area of one contour of LC (landscape complexes); CD_2 – the number of LC contours per unit area; S is the area of the territory under investigation; N is the number of landscape contours.

The Zhovtnevyi granite quarry is located in the Pokrovskyi district of Kryvyi Rih city, to the east of the Kres village, and 150 m from the river Saksahan, and has the following geographic coordinates: 47°59'17"N 33°27'49"E. (Fig. 3.11).

From 1944 to 1990, the eponimous granite deposit was developed by the open method in the Zhovtnevyi granite quarry. Since 1960, the Kryvorizkyi granite deposits were united into one enterprise - the Kryvorizkyi Granite Quarry. In turn, its production divisions were the Kolomoievskyi and Zhovtnevyi quarries, as well as the Karachuniv stone-crushing plant. [66]. However, as a result of the bankruptcy of OJSC "Kryvorizkyi Granite Quarry", in 1990, the Zhovtnevyi Granite Quarry was removed from the state reserves of minerals.

Fig. 3.11. Territorial location of the Zhovtnevyi granite quarry*

* Compiled on the basis of [123] with additions by the author

According to the geological section of the quarry, Precambrian light-gray granites, with admixtures of feldspar and kaolin. In the upper tier, there are quaternary deposits, which are represented by loams, clays, and sands, which are located over the entire area of the quarry (Fig. 3.12).

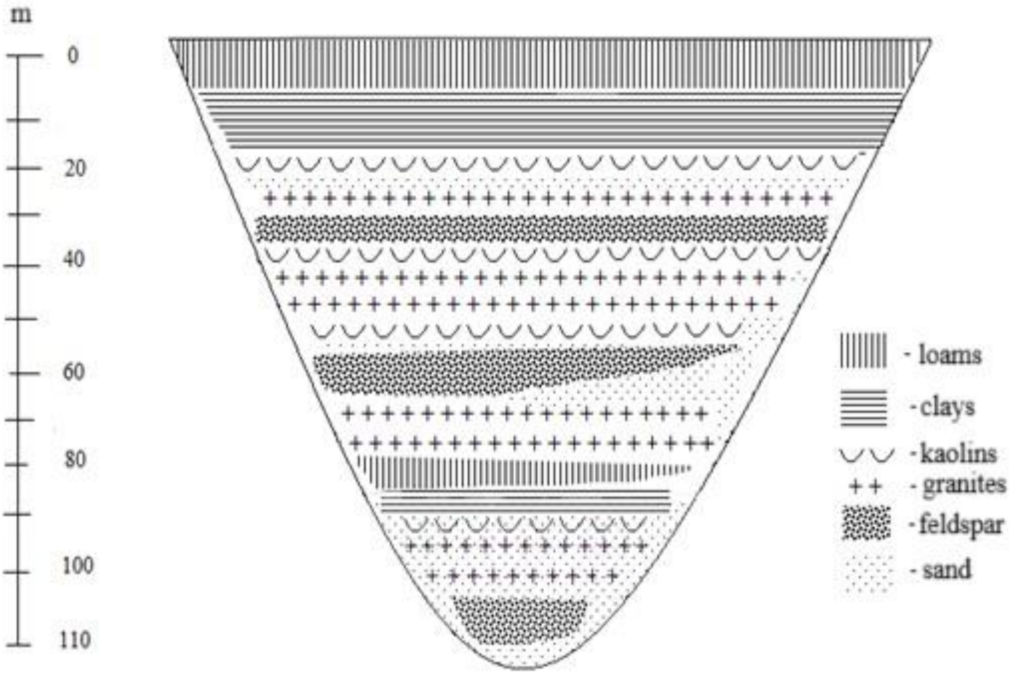

Fig. 3.12. Geological structure of the Zhovtnevyi granite quarry

Granite extraction at the Zhovtnevyi quarry was carried out for the production of construction rubble, rubble for the ballast layer of railways, asphalt concrete mixtures, for road works, etc.

In the course of granite extraction, 5 quarry terraces were formed in the quarry. Natural exogenous factors became the driving force for the slopes of the quarry, and this caused the migration of rock fragments to the bottom of the quarry. When granite was extracted and transported, a loop-like tracks of the Zhovtnevyi granite quarry was formed (Fig. 3.13).

The morphometric characteristics of the quarry at the end of 1990 were the following: length - 0.6 km, maximum width - 0.45 km, depth - 110 m, contour length along the edge - 1.8 m, area - 0.22 km. sq. (22.25 ha). The pit has a typical structure - the bottom (flooded) and sides. The sides consist of berms - ledges with a height of 10–12 m [12]. In 1990, it was stopped extracting of granite, which led to rapid flooding of the quarry bowl with fissure groundwaters. In 2003, the depth of the technogenic lake was 28.5 m, and at the end of 2018, the depth reached 40 m [12].

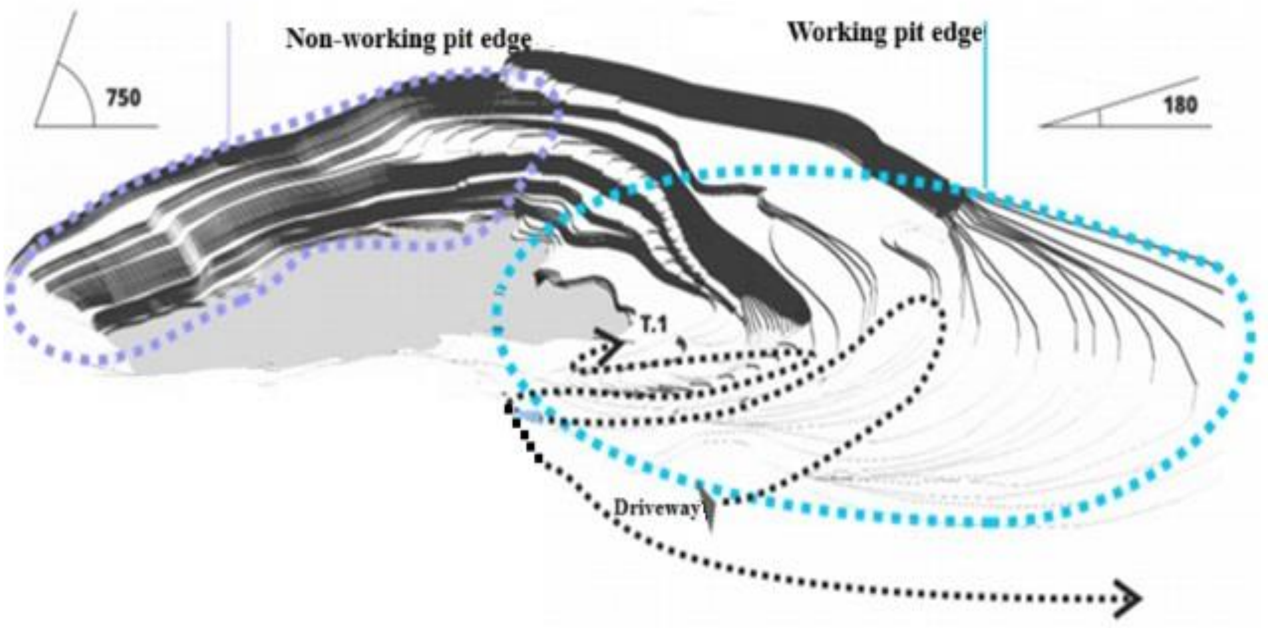

Fig. 3.13. Model of loop-shaped tracks of
Zhovtnevyi granite quarry [94]

The climate of the location of the quarry is moderately continental. The average temperature in January is -6ºC, the average temperature in July is +23ºC, and the average annual temperature is +10ºC. The largest amount of precipitation falls in June-July is up to 65 mm, the smallest is in February - March (28 mm), the annual amount of precipitation is up to 483 mm .

The Zhovtnevyi granite quarry belongs to the quarry-dump type of landscape, the landscape structure of which is dominated by the quarry-lake-terrace type of localities (Fig. 3.14, 3.15)

Fig. 3.14. Landscape organization of the territory of the Zhovtnevyi granite quarry*

* Adapted from [123] with additions by the author

Fig. 3.15. Reservoir of the Zhovtnevyi granite quarry

The quarry is a terraced excavation, with a significant vertical ruggedness, the presence of steep slopes of the terraces, the flat surfaces of which are partially covered with various herbaceous and tree vegetation (Fig. 3.16).

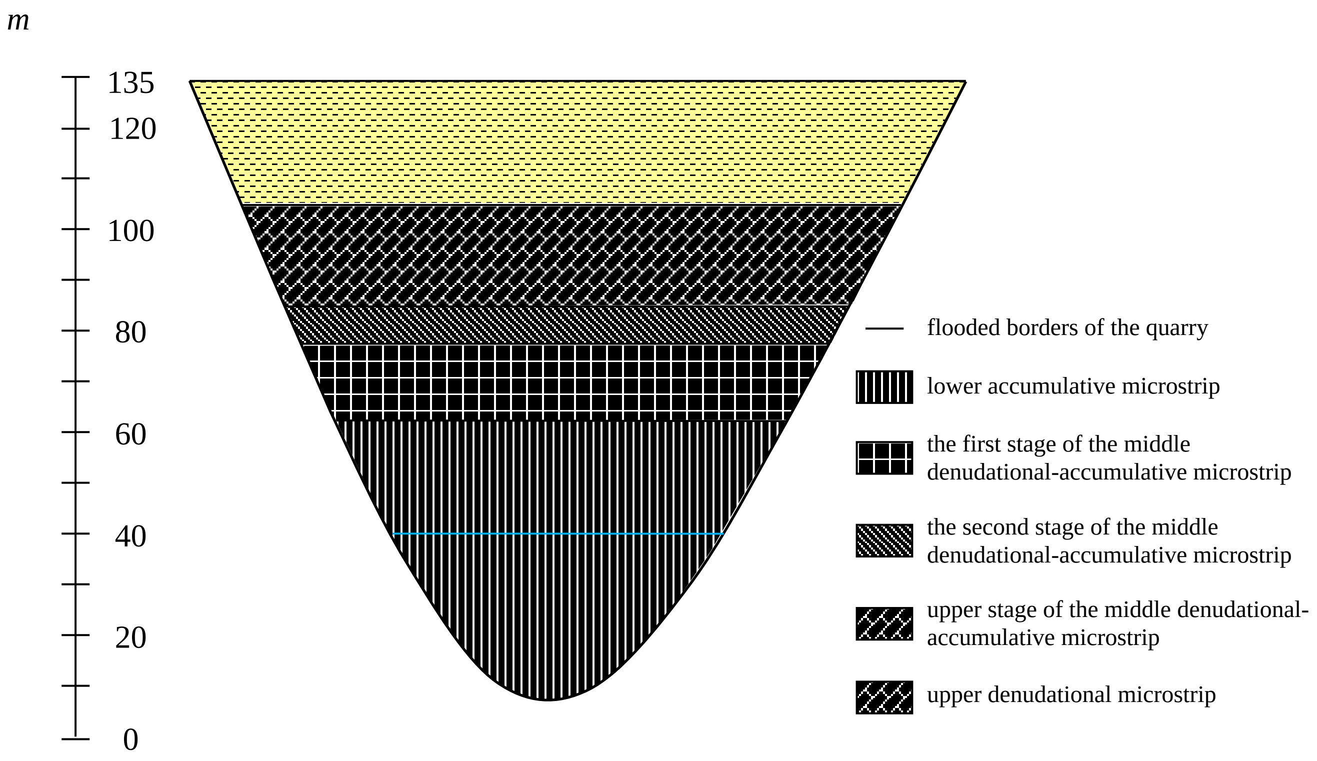

Fig. 3.16. Altitude-landscape microstrips of the Zhovtnevyi granite quarry

Within the limits of the Zhovtnevyi granite quarry, the following altitudinal landscape microstrips can be distinguished (Fig. 3.17).

The upper denudation microstrip is formed by tracts within the overburden, which are on the trajectory of the post-mining system. There are small mounds up to 25 m high. The relief-forming rocks of the tracts are remnants of granite, kaolin and feldspar. Inherent plant cover – old man's pepper, cotton thistle, hoary plantain, caseweed, absinth sage, couch grass. Tree species are represented with white acacia and cotton poplar. The absolute heights of the upper denudation microstrip range from 110 m to 135 m.

The middle accumulative-denudation microstrip is represented by two layers and the top of the quarry. The first layer with absolute marks of 65-80 m and is represented by quarry terraces. The second layer occupies a height of 80–95 m.

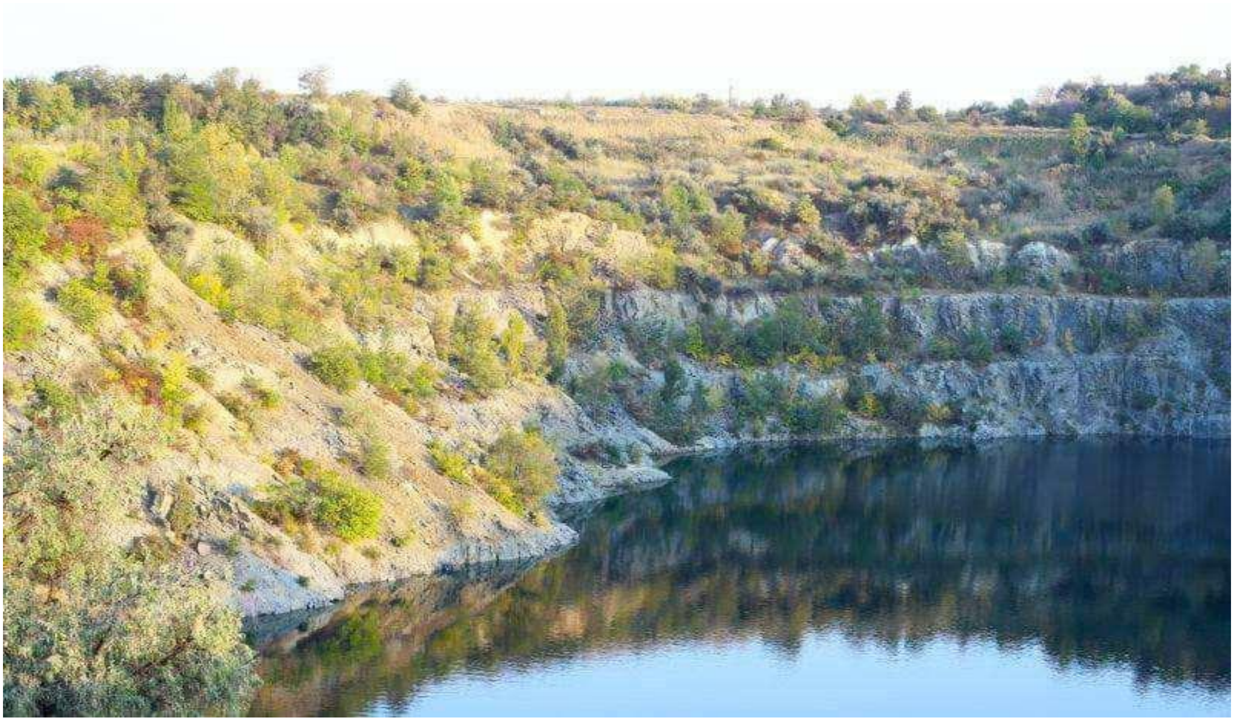

Fig. 3.17. Altitude-landscape microstrips of the Zhovtnevyi granite quarry

The two layers in the geological structure are composed of light gray granites, with admixtures of feldspar, kaolin and fragments of crystalline rocks. On the first level, plant diversity is rather poor, which is explained by active denudation processes. Absinth sage, Tatarian brassica, and knot grass prevail here. On the second layer, mainly tree-like vegetation grows: cotton poplar, dog rose, field elm, silver berry, Tatarian maple. Among the forbs, steppe bluegrass, couch grass, Austrian wormwood, and Hungarian vetch predominate. Third layer (quarry peak) composed of kaolin and loess-like loams. The vegetation cover is represented mainly by ruderal vegetation – field sow thistle, absinth sage, couch grass, and spurge. Tree species, there are represented with Canadian poplar, field elm, narrow-leaved olive, and white poplar.

Thus, the tracts of the quarry slopes of the middle accumulative-denudation microstrip differ in height, steepness, and vegetation cover. It depends on the mineral extraction process, heat and moisture distribution.

The lower accumulative microstrip is the bottom of granite quarry, which looks like a flat area. The bottom is covered with stone blocks, crushed stone, flooded with water. The reservoir contains aquatic vegetation and some types of algae. Biota there is represented with crustaceans and fish (roach, redfin, perch). On the upper layer of the lower microstrip, which contacts with the reservoir, moisture-loving plants grow - snap willow, common reed grass, narrow-leaved catoptric. Water reserves are replenished at the expense of underground water.

The relative heights of the lower accumulative microstrip range from 0 to 65 m. The vegetation group changes with height: tree vegetation is characteristic of the upper denudation microstrip of the quarry, while the vegetation of the lower accumulative microstrip of the quarry is represented by moisture-loving species and forbs. This is explained by the influence of such factors as climate, topography, moisture exchange, biochemical migration, the arrival of solar energy and the release of substances from the ecotope.

The 2019-2020 field studies of the elevational differentiation of the quarry and dump complexes of the Zhovtnevyi granite quarry are shown in chart 3.2. and fig. 3.17, 3.19. The research was carried out with the help of the following devices: anemometer, barometer, measuring stick - ruler, hygrometer, navigator (Fig. 3.18).

Fig. 3.18. Measuring devices for the study of the Zhovtnevyi granite quarry

Fig. 3.19. Vegetation cover on the territory of the Zhovtnevyi granite quarry

Table 3.2

Variation of temperature, atmospheric pressure, humidity and wind direction with height within the boundaries of the Zhovtnevyi Granite Quarry

No	Name points	Depth, m	Temperature t, ºC	Atmospheric pressure, Pa	Humidity, %	Direction of the wind
1	The lower accumulative strip	65	+22, 2	995	71	E
2	Average accumulative-denudation strip	80-110	+ 23.5	998	66	E
2a	First layer	80	+23.5	998	64	E
2b	Second layer	95	+23.7	999	58	NE
2c	Quarry top	110	+24.2	1001	56	E
3	Upper denudation strip	135	+24.8	1003	54	E

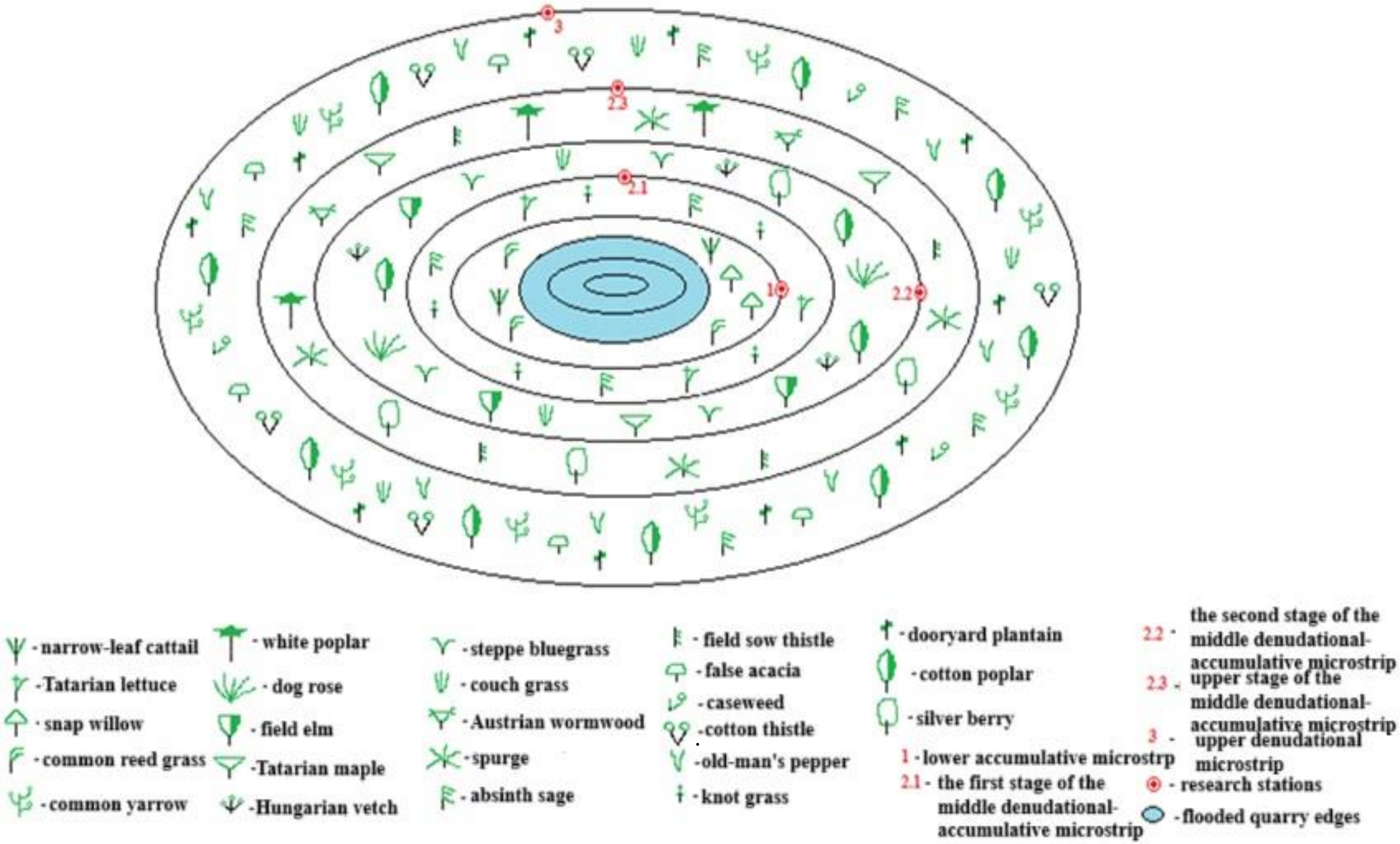

Fig. 3.20. Research points of the vegetation cover of the altitudinal landscape strips of the Zhovtnevyi granite quarry

Taking into account presented in the chart 3.2 and fig. 3.20 data, it can be concluded that with the height of the microstrips of the Zhovtnevyi granite quarry, *the air temperature* increased and reached the maximum mark of +24.8ºC (point 3). The minimum temperature was +22.2ºC (point 1). *Atmospheric pressure* was a maximum of 1003 Pa on the upper denudation microstrip (point 3). The minimum indicator of 995 Pa was recorded on the lower accumulative microstrip (point 1). The maximum *air humidity* was 71% on the lower accumulative microstrip (point 1). Lower air humidity was found on the upper denudation microstrip of 54% (point 1).

The direction and strength of the wind changed with height. At the depth of the Zhovtnevyi granite quarry, the wind strength was determined at 2 points, the wind direction changed from north to the north-east. In the quarry-dumping complex, the climatic characteristics change, which significantly affect the plant diversity in the high-landscape microstrips. First of all, it is affected by the presence of a lake at the bottom of the pit, due to which the humidity coefficient increases, and the temperature on the lower accumulative microstrip is lower than on the upper denudation one, which is due to smaller amount of incoming solar energy.

Vegetation cover of the territory of the Zhovtnevyi quarry is insignificant - most of it grows tree-shrub vegetation, grass is also present. There is hydrophilous vegetation on the lower accumulative microstrip. In the middle denudation-accumulative microstrip, the conditions for the germination of vegetation are tougher [66]. This is explained by the presence of gravitational processes: the overburden falls, and it is washed to the bottom. The fauna world is quite poor, mostly birds prevail, lizards and crickets are present in the warm season - this is caused by the unfavorable conditions for living in this area.

Altitude differentiation of the plateau-like, multi-tiered dump type of mining landscapes (on the example of the Burshchit dump).

The plateau-like, multi-tiered fallout type of terrain is characteristic of the entire territory of Kryvorizhzhia. Formed by railway or road dumping, due to which multi-tiered dumps were formed, with a leveled and plateau-like surface. On the territory of Kryvorizhzhia there are rocky, loose and mixed dumps. The composition of rock dumps is characterized by hard and coarse-grained rocks: quartzite, schist, blocks of brown ironstone, granite. Loose dumps have more loose types of rocks, namely: limestones, marls, clays, loams and sands. And the mixed type of dumps, respectively, includes a mixture of all the above-mentioned breeds. In general, the term "dump" is found in the scientific literature as an embankment on the earth's surface from loose rocks obtained during the development of mineral deposits , tailings of enrichment factories [14].

The Burshchit dump was formed by loose overburden rocks, which are characteristic of the Cenozoic [67]. It belongs to the multi-tiered plateau-like type (Fig. 3.21).

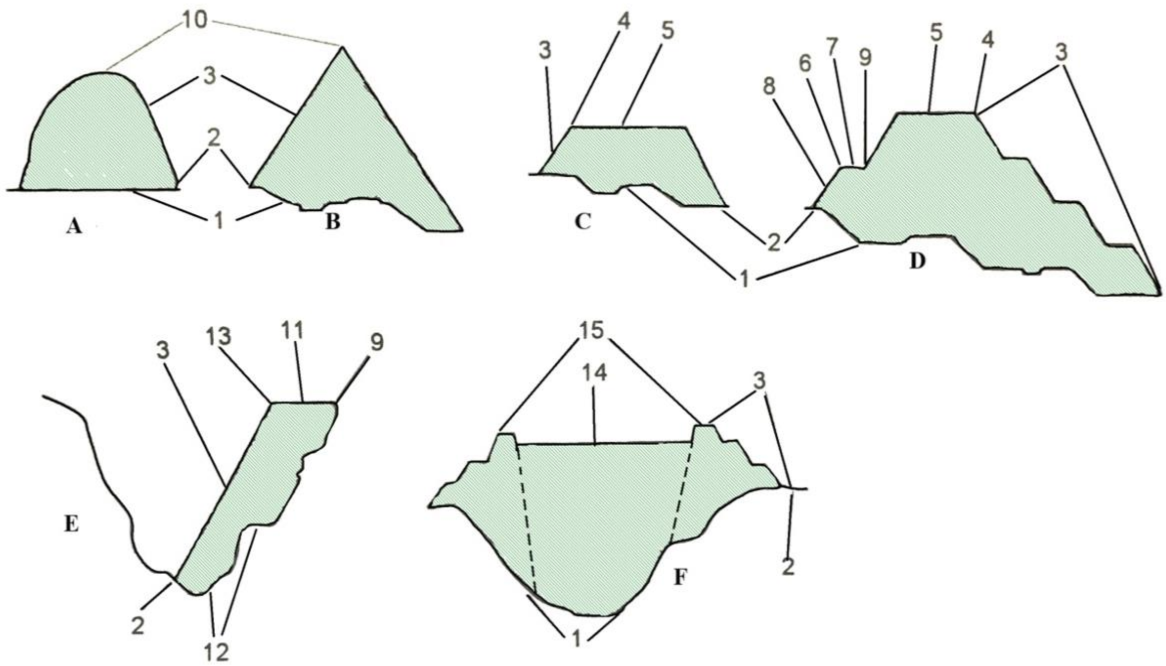

Fig. 3.21. Morphology of Kryvorizhzhia dumps [38]

Morphological types of dumps: A – crest-ridge-like; B – waste pile; C – single-tier plateau-like; D – multi-tiered plateau-like; E - sheltered filled; F is a multi-tiered plateau-like sludge storage.

Morphological elements of dumps: 1 – bottom; 2 – foot; 3 – slope; 4 – edge of the plateau; 5 – the surface of the plateau; 6 – edge of the tier; 7 – platform (surface) of the tier; 8 – slope of the tier; 9 – rear suture; 10 – top; 11 – filling surface; 12 – contact surface; 13 – the edge of the filling surface; 14 – the surface of the sludge storage body; 15 – a dam with a platform and edges.

The Burshchit dump is located in the Inhulets district, Kryvyi Rih, near the villages of Hdantsivka and Shevchenkovo. It belongs to the valley of the Inhulets River and has the following coordinates: 47°52'23''N, 33°20'0''E. Belongs to the Novokryvorizkyi mining and beneficiation plant.

The height of the Burshchit dump is 80 m, the steepness of the slopes is 35–45º (Fig. 3.22).

Fig. 3.22. Territorial location of the Burshchit dump*
* Adapted from [123] with additions by the author.

The climate for the location of the dump is moderate-continental. The average temperature in January is -5 ºC, the average temperature in July is -+22 ºC, the average annual temperature is +9 ºC. The highest amount of precipitation falls in June-July - up to 65 mm, the lowest -in February-March - 28 mm, the annual amount of precipitation is up to 483 mm.

The lower accumulative, middle accumulative-denudation, and upper denudation microstrips are traced in the height differentiation of the dump (Fig. 3.23).

Fig. 3.23. Altitude-landscape microstrips of Burshchit dump

The results of the research conducted on June 15, 2018 and 2019 show that the altitudinal differentiation of the vegetation cover of mining landscape complexes is clearly manifested (Fig. 3.24).

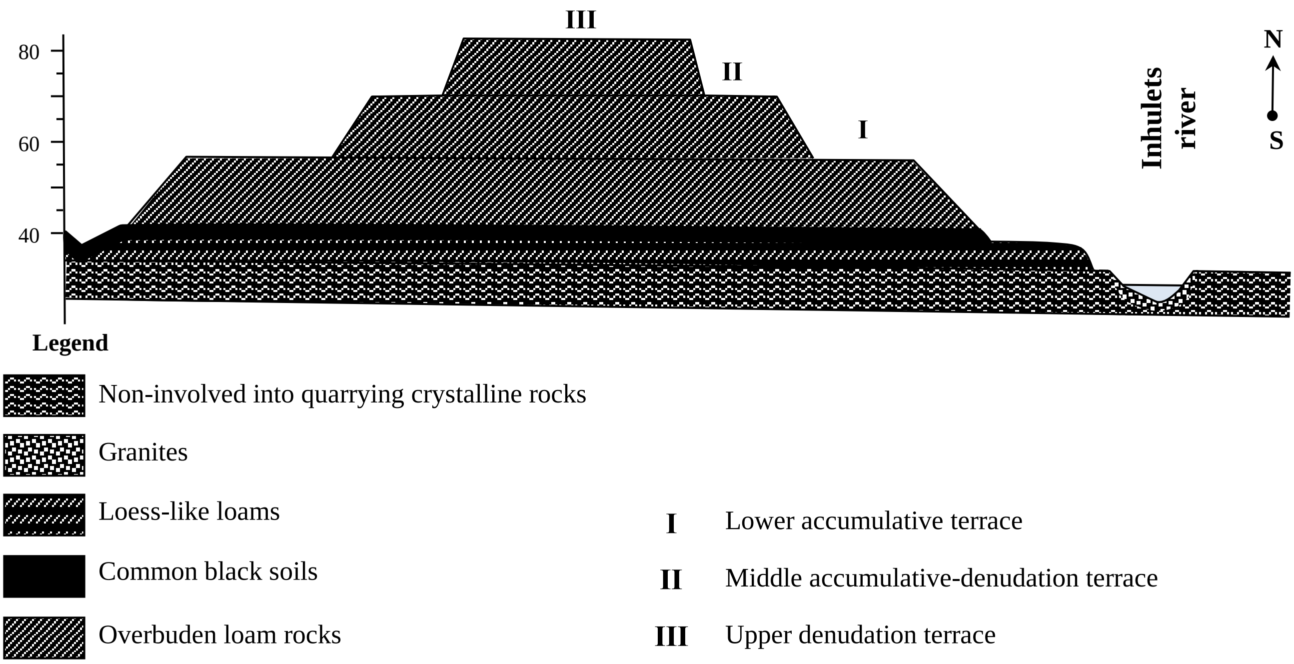

Fig. 3.24. Geological structure and terraces of the Burshchit dump

It was established that in the lower accumulative strip (point 1), namely at the foot of the dump (35 m), the air temperature was +26 ºC, the atmospheric pressure was 1010 Pa, the humidity was 56%, and the wind direction was north (Table 3.3) .

Table 3.3

Change in temperature, atmospheric pressure, humidity, and wind direction with height at the Burshchit dump

No	Name points	Altitude	Angle of inclination in degrees	Temperature t, °C	Atmospheric pressure, Pa	Humidity.%	Geographic coordinates	Direction of the wind
1	Riverbed of Inhulets	23	8	+26	1010	56	47º52´34″N 33º19´34″E	North
2	The foot of the dump	35	11	+26.2	1009	55	47º52´29″N 33º19´14″E	North-west
3	Lower accumulative strip	53	35	+27, 3	1003	53	47º52´29″N 33º19´44″E	North
4	Average accumulative denudacion strip	55	35	+27.2	1002	52	47º52´27″N 33º19´49″E	North
5	Upper accumulative strip	60	45	+ 27	1000	52	47º52´24″N 33º19´52″E	North
6	Top of dump	80	90	+ 25.3	997	49	47º52´34″N 23º19´33″E	North

In the process of field research on the Burshchit dump, high-landscape microstrips were identified. The research was conducted during June 2018–2019 (Fig. 3.25, 3.26).

Fig. 3.25. Study of altitudinal differentiation of the Burshchit dump

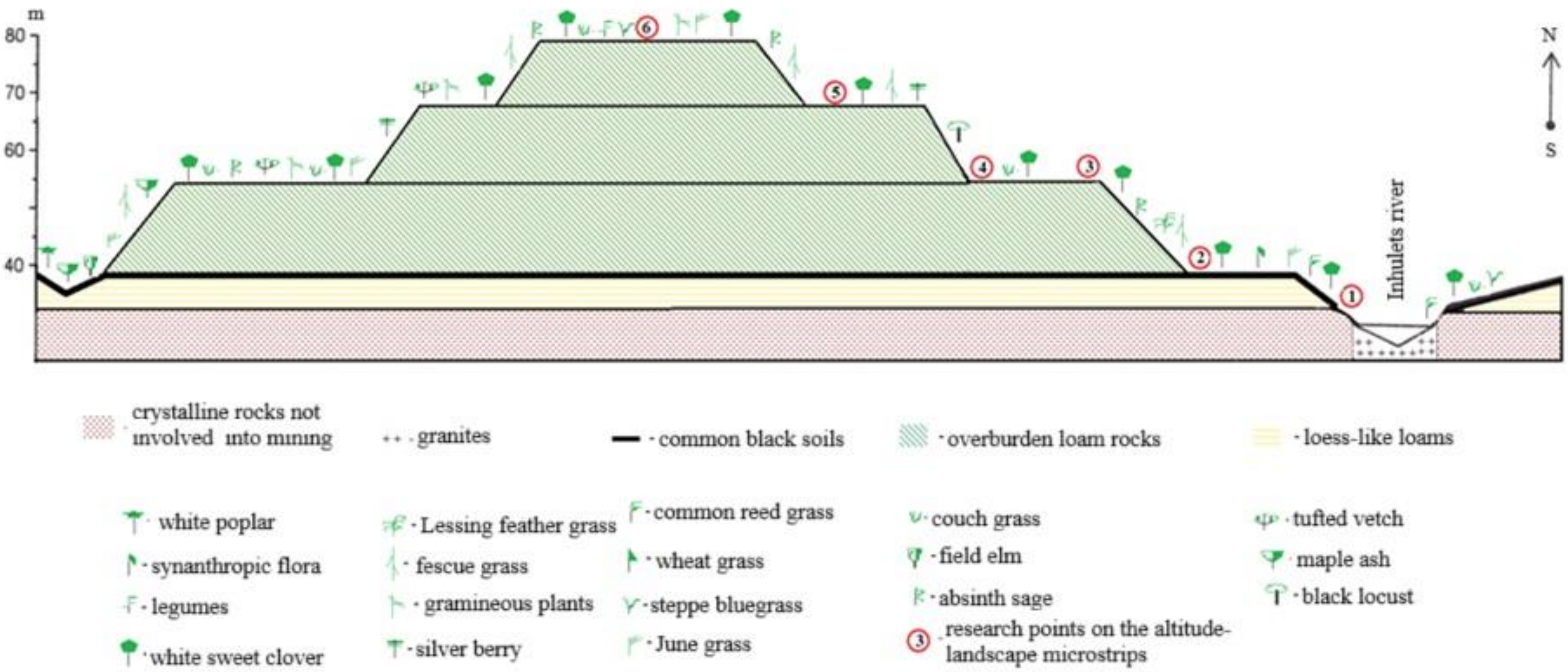

Fig. 3.26. Altitude differentiation of vegetation cover and measurement points of temperature, atmospheric pressure, wind direction, and air humidity on the Burshchit dump.

Altitude-landscape microstrips:

– the lower accumulative microstrip is characterized by crystalline rocks that are not involved into development.

– the middle accumulative-denudation microstrip is represented by loess-like loams, and there are granites near the terrace of the Ingulets River.

– the upper denudation microstrip, which corresponds to the upper above-ground part of the dump, is composed of overburden loamy rocks.

The Burshchit dump is now fully rehabilitated, the plant groups here are diverse:

– at the foot of the dump, the lower accumulative microstrip is characterized by white poplar, field elm, maple ash; among the herbaceous plants there are white sweet clover, tufted vetch, wormwood, wheatgrass;

– to the middle accumulative-denudation microstrip, narrow-leaved hawkmoth, fescue, and cereals grow;

– the following plants are characteristic of the upper denudation microstrip: sedge, white sweet clover, June grass, grease [23].

The vegetation group changes with height: at the foot of the dump there is typical tree vegetation, the upper denudation strip of the dump is motley grass.

It was revealed that in the lower accumulative strip (point 1), namely at the foot of the dump (35 m), the air temperature was +26 ºC, the atmospheric pressure was 1010 Pa, the humidity was 56%, and the wind direction was north (Table 3.3).

With the rise to the Burshchit dump, *the air temperature* increased and reached the maximum mark at 27.2 ºC (point 4), on middle denudation-accumulative microstrip at a dump on height of 55 m, the temperature decreased, the minimum temperature was +25.3 ºC at a height of 80 m (point 6).

Atmospheric pressure reached a maximum of 1010 Pa at the foot of the dump on the lower denudation microstrip (point 1), and then began to decrease gradually with height. The minimum indicator of 997 Pa was recorded on the upper denudation microstrip, namely on the top of the dump (point 6).

The maximum *air humidity* was 56% at the lower accumulative microstrip (point 1), near the Inhulets riverbed. Less moisture in the air was admitted in the upper denudation microstrip at an altitude of 80 m (point 6).

The direction and strength of the wind changed with height. At the height of the Burshchit dump, the wind strength was determined at 5 points, its direction changed from north to the north-west. At the top of the dump (point 6) it is cool and windy.

The differentiation of indicators with height is due to the fact that the air is heated not by the sun rays, but by the earth surface heated by them, therefore the temperature decreases with height, and the atmospheric pressure on a separate dump also decreases with height [115]. The steepness of the dump slopes and the prevailing winds also play an important role.

In general, the altitudinal differentiation of the mining landscapes of Kryvorizhzhia is expedient and necessary to be studied within the limits of altitudinal stages, altitudinal landscape levels and types of localities. Using these height structures, 3 altitudinal landscape levels are distinguished: accumulative (lower young), denudation-accumulative (average, or typical), denudation (upper, or old). They are characteristic of almost all types of quarry and dump complexes, and therefore they can be used in the process of developing typical projects for the optimization of mining and industrial landscapes of Kryvorizhzhia. When studying the types of localities on the territory of Kryvorizhzhia, it was established that the most common are the quarry-terrace and plateau-like multi-tiered dump types of localities (Fig. 3.27).

Altitude differentiation of each of the established terrain types is also heterogeneous. Microstrips are clearly distinguished here - areas with different rates of denudation-accumulation processes. It is appropriate to distinguish the upper denudation, middle accumulative-denudation and lower accumulative microstrips. The altitudinal tiers are traced within the altitudinal microstrips. It is necessary and better to isolate the altitudinal tiers only in deep (150-250 m) and ultra-deep (more than 250 m) quarries and high (more than 30 m) dumps and the edges of sludge storages. This is confirmed by detailed studies of the natural conditions of six quarries of various types of minerals, eight dumps of various rocks and four sludge storages within the boundaries of Kryvorizhzhia.

Fig. 3.27. Burshchit dump in the valley of the Inhulets river

USE OF ALTITUDE DIFFERENTIATION AND DIVERSITY OF MINING LANDSCAPES OF KRYVORIZHZHIA IN THE PROCESS OF THEIR RATIONAL USE

4.1. Optimization measures to improve the rational use of altitudinal differentiation and the diversity of mining landscapes

Optimization of mining landscapes means a system of scientifically based measures aimed at achieving high productivity, rational use and protection of landscape complexes [9]. Kryvorizhzhia is a territory that has experienced the powerful impact of mining activities, as a result of which various landscape complexes have been formed, which cause the development of various derivative phenomena and processes, sometimes catastrophic ones.

It is no longer possible to reproduce the natural state of landscape complexes of Kryvorizhzhia, and it is also impractical from an economic point of view. However, the measures need to be developed to help to organize the structure of mining landscapes in a way to avoid harming the environment and to have benefits. First of all, the design works on the creation of mining landscape complexes and their reclamation should be clearly planned taking into account the features of height differentiation and the diversity of the present-day nature of Kryvorizhzhia. One of the most important tasks is the restoration of the territory after industrial activity, prevention of degradation of mining landscapes and their return to long-term and effective use.

Optimization measures for mining landscapes involve substantiating the ways of their implementation, identifying natural and socio-economic limitations, determining a certain type of nature use and the consequences of human activity.

According to E.A. Ivanov [95], mining landscapes after the completion of mineral development can be optimized in various directions: ensuring the most efficient performance of certain production functions by mining landscapes; creation of recreational areas, nature-oriented facilities with an increase in landscape and biotic diversity.

The main components of optimization of mining landscapes are their reclamation and revitalization (Fig. 4.1).

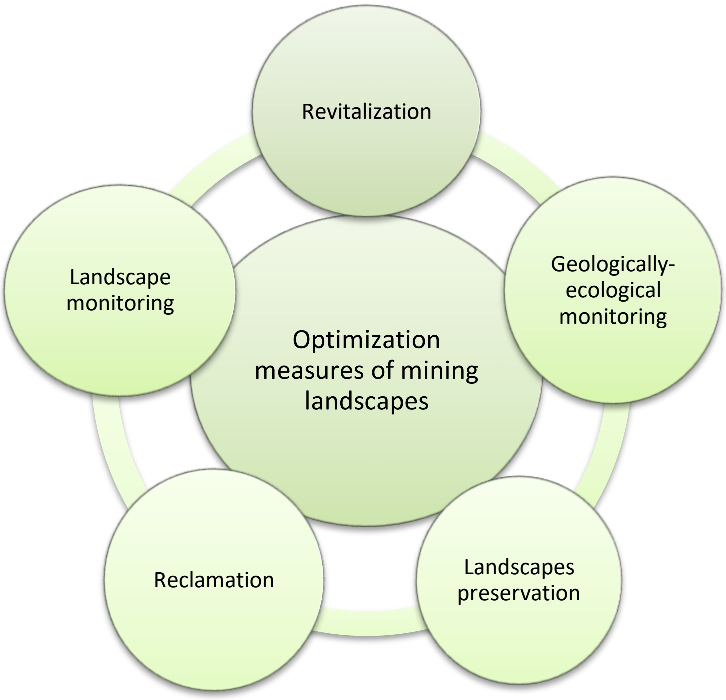

Fig. 4.1. Optimization measures to improve mining landscapes of Kryvorizhzhia

Reclamation (lat. re. - a prefix meaning reverse or repeated action, and cultivatio - cultivation, introduction, breeding; reuse) of mining landscapes - an attempt to implement a complicated complex of engineering, mining, reclamation, biotic, sanitary and hygienic and other measures, which are aimed at returning territories disturbed by industry to various types of nature use (agricultural, forestry, recreational) [28].

Each mining enterprise must create a project for the reclamation of disturbed mining and industrial landscapes before start of mineral development.

Reclamation is subject to all mining complexes where there is a change in the thickness of sediments, relief, soil and plant cover. As a rule, reclamation is carried out during the liquidation of a mining enterprise and permanent (decommissioned) systems that remained from the enterprise.

The objects of reclamation are pits, dumps, settling pits, tailings, as well as territories that were disturbed during the extraction and beneficiation of minerals (depressions, sinkholes, etc.). The technological process that occurs during the development of mineral deposits leads to the removal of rocks of various composition, genesis, lithology and properties to the earth surface. It frequently occurs that the rocks that are mined contain toxins which are dangerous for soils and plants. Sometimes toxins are formed in the process of oxidation of deposits on the earth surface, therefore it is quite important to determine the possibilities and directions of optimization of mining landscapes [98]. Within the boundaries of Kryvorizhzhia, reclamation prevails, which takes place in two stages: mining and biotic.

The mining technical stage is land preparation, relief surface planning, application of fertile soils on the surface of a certain mining facility, reclamation works, etc. As an example, backfilling of pit No. 2 of the Central Mining and Processing Plant (CMPP) (Fig. 4.2).

The biotic stage of reclamation involves a certain set of agrotechnical and phytomelioration measures aimed at restoring the habitat of living organisms and the economic productivity of land (Fig. 4.3)

Fig. 4.2. Mining engineering works at pit No. 2 of the CMPP

Fig. 4.3. Carrying out the biotic stage of reclamation at pit No. 3 of the Inhulets Mining and Processing Plant

Reclamation is combined with *phytomelioration*, which is a set of optimal measures aimed at improving the fertility of reclaimed lands by growing grassy, shrubby, and woody reclamation crops [98]. Phytomelioration differs from biological reclamation, as it can use the natural self-recovery potential of vegetation in order to optimize mining landscapes, and can be carried out without prior mining technical reclamation.

Reclamation in the territory of Kryvorizhzhia is mostly carried out on quarry-dump type areas.

In 1963, I. A. Dobrovolskyi and V. M. Danko made the first attempts to optimize waste landscape complexes on the territory of Kryvorizhzhia. The researchers tried to select plant species with different life forms that would be able to grow on the overburden of the dumps. In the 1970s, the Kryvyi Rih Botanical Garden was created, which continued this line of activity, and also studied the ecological conditions of plant germination and the climatic characteristics of the territory.

Phytoremediation on quarry and dump complexes was carried out by various methods - from manual planting of seeds and seedlings to sowing with the help of helicopters (Fig. 4.4).

However, the first attempts at phytoremediation were ineffective and cost much. In the 21st century the researchers came to the conclusion that the reclamation was the most effective on stony dumps that were planted with Crimean pine. After a successful experiment, researchers began to develop strategies, directions and models of reclamation of disturbed lands not only on the territory of Kryvorizhzhia, but also in Ukraine (M. E. Bereskevych, M. T. Masyuk, I. P. Chaban, V. L. Zabaluyev and A A. Mytsyk).

Fig. 4.4. Manual planting of seedlings at the iron ore dump of the Pershotravnevyi quarry of PJSC "Northern Mining and Processing Plant"

Today the six most common areas of reclamation of the mining landscapes of Kryvorizhzhia are known: agricultural (creation and development of agrocenoses), forestry (creation of forest plantations), water management (use of quarry and technogenic excavations for reservoirs), recreational (we have proposed a project of recreational reclamation of the Karachunivskyi quarry-dump complex (Fig. 4.5)), sanitary and hygienic (suspension of the negative impact of disturbed lands on the environment) and construction (development of construction). In the process of reclamation, the following models are the most common:

– *universal* - creation of a fertile layer of soil on the surface of the dump, the thickness of which reaches 1.2–1.5 m. This model is the most popular and well-known;

– *hydromelioration* - carried out on two levels. The first layer is a layer of non-saline clay (25–30 cm), the second layer is a layer with rocks of light granulometric composition (30–50 cm), which absorbs atmospheric precipitation quite well;

– *geomelioration* - implemented on geological deposits with unfavorable properties for plants. Mountain rocks are covered first with loess-like loams - 50-80 cm, and then with a fertile soil layer - 50-70 cm. Loams contain calcium carbonate, which is a protector against harmful substances [28];

– *local* - agricultural measures are carried out, which are aimed at fertilizing for a certain cultural plant.

However, scientists, having analyzed the accomplished reclamations, claim that the existing methods of reclamation have a number of shortcomings that inhibit the improvement of disturbed lands, including:

– ignoring the syngenesis of the plant cover;

– the complete arrangement of the meso-relief and the reduction of the area of the dump slopes leads to compaction and reduces the filtering activity of rocks, which in turn leads to the strengthening of erosion processes; by the ceasing of agrotechnical support, there is competition between natural zonal and azonal development processes, which leads to the development of erosion and gravitational processes on the dump;

– it is better to apply a comprehensive approach to the reclamation of landfills in general;

– lack of funds for reclamation measures both at the dumps and in general for the mining landscapes of Kryvorizhzhia.

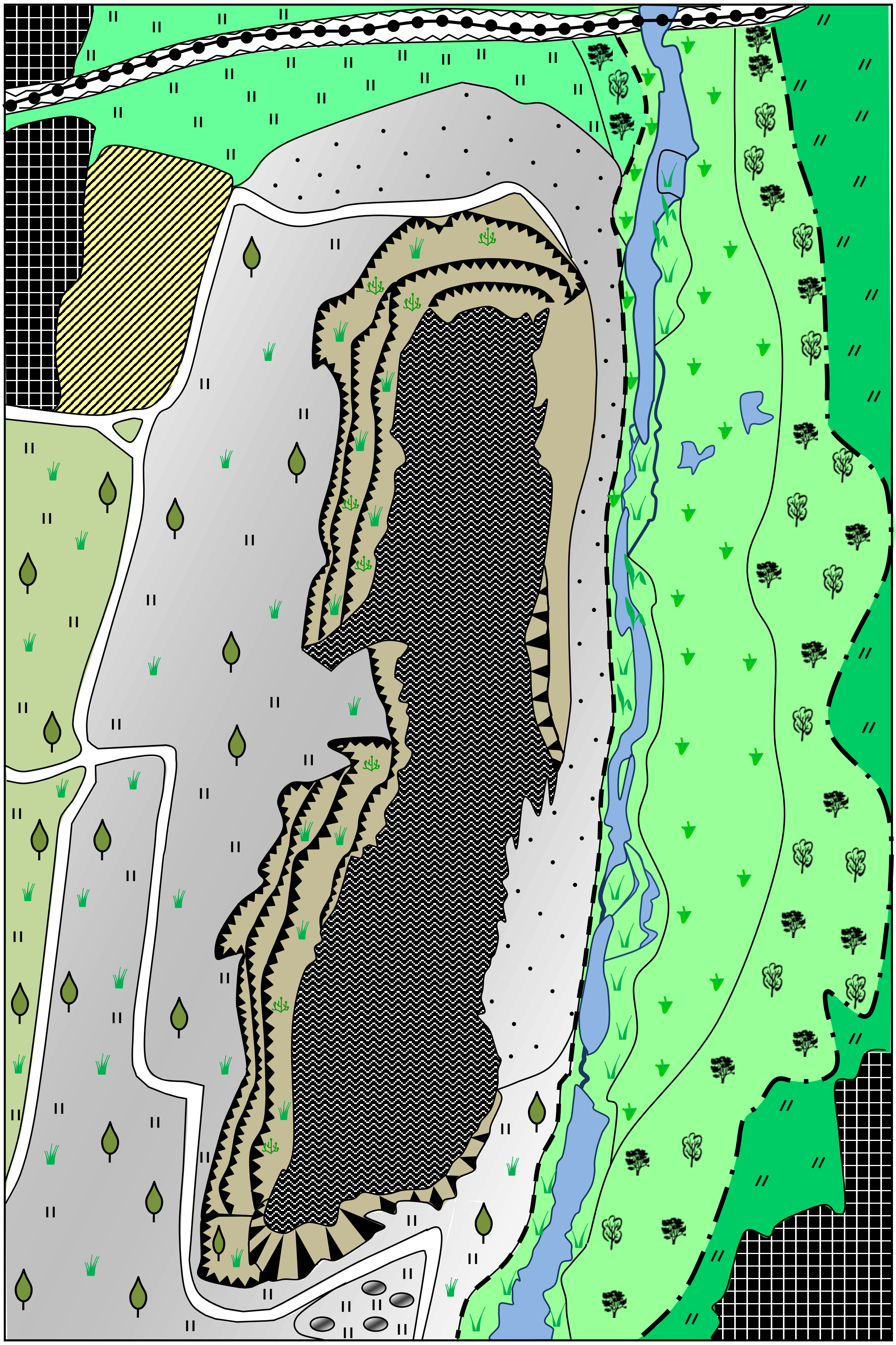

Fig. 4.5. Recreational landscapes of Karachunivskyi mining of granite (reclamation project)

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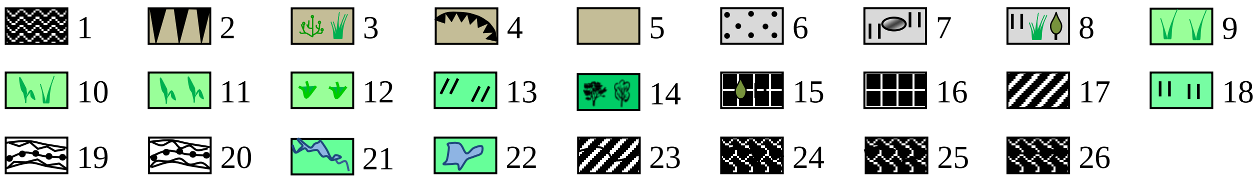

Industrial landscapes : *Quarry and dump.* A granite variant of the rocky badland terrain type . *Tracts* : 1 – a reservoir of 10-15 deep on the quarry site, which is used for recreational purposes and water sport trainings; 2 – steep (up to 80°) granite "walls" of quarries without vegetation; 3 – high (10-15 m) granite slopes of quarries, with a steepness of 60-70 ° , planted with decorative vegetation; 4 – terraced working granite ledges planted with decorative vegetation; 5 – low (2– 6 м) granite "walls" of quarries, without vegetation; 6 – bulk sandy beach; 7 – a flower bed (alpine hill) on the site of stony wastelands; 8 – a recreation park on the planned surface of the dump with paved paths and attractions.

Agricultural landscapes. *Floodplains* Meadow and pasture . *Tracts:* 9 – micro-bumpy moist surfaces of a low floodplain with sedge vegetation; 10 – waterlogged, partially swampy areas of the low floodplain, overgrown with reeds and sedge vegetation; 11 – waterlogged, partially swampy areas of a low floodplain, overgrown with reeds; 12 – cereal and herbaceous hay meadows; *Slopes* Meadow and pasture . *Tracts:* 13 – various grass-cereal vegetation on sloping loess slopes.

Forest landscapes. *Floodplains* *Conventionally natural*. *Tracts* 14 – willows and black alders on cultivated slightly sloping surfaces of the high floodplain; *Supraflood-terraced.* *Tracts* 15 – recreation park on the gently undulating surface of the first terrace.

Residential landscapes. 16 – the gently undulating surface of the first floodplain terrace, occupied for individual development; 17 – garden plots on the gently undulating surface of the first floodplain terrace.

Road landscapes. Tracts 18 – sloping slopes of the railway embankment overgrown with ruderal vegetation; 19 – railway track on the embankment bridge; 20 – railway track on a concrete bridge with reinforced concrete supports.

Water landscapes. 21 – the channel of the Inhulets River; 22 – reservoirs with a depth of 1.5–2 m in waterlogged areas of the floodplain.

Other marks: Borders. 23 – tract; types of localities: 24 – floodplain and supraflood-terrace; 25 – floodplain and slope; 26 – the direction of the flow of the Inhulets River.

Revitalization (lat. re - a prefix meaning reverse or repeated action, and vita - life; return of life) *is* a new direction in the optimization of disturbed lands of mining landscapes. For the last years, scientists have increasingly paid attention to this direction. Revitalization is used to improve the direction of restoration of disturbed lands of mining landscapes [95].

E. A. Ivanov [47] notes that, in general, the choice of an option for optimizing mining landscapes depends on the complexity of their structure, the intensity of destructive processes, and the amount of project financing. A significant area of Kryvorizhzhia is occupied by mining landscapes, so revitalization requires a large amount of money and time. Unfortunately, revitalization in Ukraine is implemented weakly.

Examples of revitalization. In Poland, the "Jeziorko" recreation area was created in the Grybuv commune at the site of the underground sulfur smelter with the support of the funds of the National Nature Protection Fund and Water Management of the Republic of Poland. More than 50% of mining enterprises in the European Union have been liquidated and preserved, a significant part is used for the disposal of industrial and household waste [95, p. 187].

The next important measure is *geological and ecological monitoring*, which is carried out by summarizing the results of the study of the ecological state of mining landscapes, forecasting the development of negative processes in mining landscapes and the occurrence of natural and technogenic emergency situations.

Landscape monitoring involves a system of observation and control of the state of mining landscapes and their morphological parts both during exploitation and in the post-exploitation period with the aim of their evaluation, forecasting and substantiation of rational use [27, p.137].

One of the areas of improvement of mining landscapes is *preservation.* For the first time, the preservation of mining landscapes in Kryvorizhzhia was carried out in 1998. The preservation allows to unite functionally and territorially mining landscapes with other groups of anthropogenic landscapes, which, regardless of their origin, are centers of concentration of individual geocomponents - with planted forests, forest belts, reservoirs, parks and forest park zones, etc. Together, this provides grounds for including mining landscapes into regional eco-complexes.

Preservation of territories allows to solve the problem of restoration of territories that have been technologically altered by mining operations comprehensively. As noted H.M. Zadorozhnia [27], the main principles for preservation of territories dominated by mining landscapes are:

– the preservation is carried out only in the territories that have a self-renewal tendency;

– in order to introduce the preservation system, it is necessary to carry out a global geoecological and landscape inventory of landscapes, to establish their ecological condition and level of preservation;

– availability of a developed program and strategy for the operation of a landscape reserve with mining landscapes.

During iron ore mining, different types of reclamation are often closely intertwined in the same area. So, quarries and ditches are flooded by water, and the banks are forested. As a result, a peculiar lower accumulative altitudinal landscape level of anthropogenic origin is created with a reclaimed lake-park landscape type.

Underground mining led to the creation of large-scale excavations, galleries, tunnels, which are now used mainly as landfills. For the rational use of the territory, such underground productions can be turned into commercial premises, where it is possible to place industrial enterprises, laboratories, archives, warehouses, etc.

4.2. Structural and geographical optimization features of the current state of mining landscapes of Kryvorizhzhia

In the process of field research, and basing on domestic and foreign experience in the construction of cultural landscapes, it becomes clear that in addition to narrowly focused reclamation, optimization of mining landscapes can also be carried out in broader aspects, in particular - cultivation.

Cultivation is a set of transformative measures aimed at: 1) improving the quality of the human environment and other subjects; 2) anthropogenic regulation of functional processes within optimized landscapes; 3) increasing the dynamic stability of cultural landscapes; 4) the aesthetic attractiveness of the cultural landscape; 5) optimal fulfillment of production and social functions by cultural landscapes [28].

In particular, there are 8 potential types for cultivation of mining landscapes within Kryvbas territory:

1) steppe preservation - creation of protected tracts on loose loamy substrates - steppe sanctuaries and nature reserves;

2) pasture cultivation – the creation of productive land on the dumps, both with and without technical reclamation of dump surfaces;

3) forestry cultivation – creation of forests to prevent pollination and water erosion of dumps and slag storages;

4) recreational cultivation – creation of forest park zones for active recreation in the conditions of a quarry-dumping intersecting area;

5) water management cultivation – creation of reservoirs in exhausted small quarries for fish breeding or recreation;

6) field agricultural cultivation, which is carried out after technical reclamation of dumps and small quarries with further development of cottage, greenhouse and garden farms, planting gardens;

7) settlement cultivation – building of housing estates on reclaimed dumps and tailings storage facilities, which are the closest to modern centers of urbanization;

8) industrial cultivation – construction and organization of new industries on the

surface of dumps or tailings storage facilities, filling of spent quarries with dumps, creation of landfills [28, p. 138].

Cultivation can be carried out in *three* stages: I stage (preparatory) – evaluation of objects for a certain type of cultivation; II stage (planning) – design works; The II stage (implementation) is putting the project into practice [28].

The following recommendations should be adhared to when optimizing the disturbed lands of Kryvorizhzhia*:*

– to prohibit economic activity on the territory of the dump: restoration of backfill works and removal of garbage, burning, which can cause a fire, livestock pasturing;

– to create more environmental protection objects (sanctuary of local importance). A vivid example is the Vizyrka sanctuary (Fig. 4.6). This is the largest landscape reserve in Kryvorizhzhia. Its territory is more than 121 hectares. Created at the end of 2001 at the initiative of PrJSC "Inhulets Mining and Processing Plant (InMPP)" and Dnipropetrovsk University of Environmental Problems and Ecology of the National Academy of Sciences of Ukraine;

– to find the ways to create recreation areas without resource costs;

– use industrial facilities for the development of industrial tourism.

Fig. 4.6. The sanctuary "Vizyrka" of InMPP

The improvement of mining landscapes also includes conservation - "non-interference" in the course of the processes of their natural self-development. This direction is based on ideas about the stability of internal inter-component connections in landscapes, if they exist according to the principles of self-development. One of the goals of conservation of mining landscapes is the need to preserve the oldest (over 50 years) or cognitively interesting objects as monuments of science and technology for industrial tourism (Fig. 4.7).

Fig. 4.7. Landscape organization of the territory"Vizyrka" of InMPP

4.3. New perspective directions regarding the rational use of altitudinal differentiation and the diversity of mining landscapes of Kryvorizhzhia

The new directions for rational use of the mining landscapes of Kryvbas include museification, revalorization, substantiation of the tourist and industrial heritage of Kryvorizhzhia, as well as the creation of various structures on quarry and dump complexes.

A significant number of liquidated objects of the mining industry are concentrated in the territory of Kryvorizhyzhia. There is a problem in museification and revalorization of important mining objects in the form of tourist routes, places of professional studies, student practices, etc.

Museification is a set of scientifically based measures to bring monuments of historical and cultural heritage into a state suitable for sightseeing and cultural and educational use. In the mining industry, such attractions can be both individual mining enterprises or their historical departments, and mining territories in general [95]. In particular, a number of mining museums have been created in the USA (California, Colorado, Kentucky, Michigan, New Mexico, etc.). This includes museums of the oil and gas, gold ore, and iron ore industries. Also, such museums are characteristic of many European countries (Great Britain, Germany, Poland, etc.) [95].

Museification only begins to develop in Ukraine thanks to the detailed study by scientists the history of mineral development. There are several museums of the history of the mining industry within Kryvorizhzhia, in particular the Museum of History of the National Mining University, the Lysychansk Museum of the History of Mining, the Museum of the Krasnolymanska Mine.

The mining and mineralogical museum of the Kryvyi Rih Technical University and the labor glory museum of the Southern Mining and Processing Plant (SMPP), which was founded in 2015 are particularly interesting. The labor glory museum of the SMPP has already presented over 1,500 exhibits. There are models of various equipment, factories, and enterprises among them. It is possible to trace the evolution of industrial equipment and mining machinery, looking at the exhibits. Museum visitors also have the opportunity to see a 3D projection of the quarry, which represents the specifics of mining operations. On the monitors you can see an online picture with explosions in the quarry and the work of mining equipment. The museum has a model of the largest quarry of SMPP, the depth of which today is more than 400 m. The model shows the quarry terraces in detail (Fig. 4.8). In addition, SMPP installed an observation platform at the quarry, where all visitors can view the size of the quarry and the process of iron ore extraction (Fig. 4.9).

Fig. 4.8. SMPP quarry model in the SMPP labor glory museum

Tour guides conduct the most interesting excursions for schoolchildren, adults and foreigners at such an observation deck.

It is worth noting that "open-air museums" (scansen) occupy a special place among modern scientific and technical museums. These museums, created on actual mining facilities and settlements, preserve particularly valuable fragments of the cultural landscape and industrial heritage. The first two prototypes of open-air museums are known in Ukraine - the Museum of Industrial Culture of Podilskyi Polissia and the Museum of the Oil Industry of Galicia [28]. Unfortunately, there are no open-air museums on the territory of Kryvyi Rih, there is a historical scansen-museum in the park named after F. Mershavtsev.

Fig. 4.9. Observation deck at the quarry of SMPP

(Destroyed in 2022 as a result of shelling of the deposit by the Russians).

Revalorization (French revalorization - value, artificial price increase) implies the reassessment of the value of a geographical object, the reinterpretation of its historical and cultural heritage. This approach makes it possible to restore a space, place or object of historical significance.

Practically, revalorization is carried out on the objects of the mining industry, especially with the remains of industrial buildings that have scientific, technological and social, historical and architectural significance. As a rule, objects of mining heritage are transformed into modern shopping complexes, sports or cultural objects.

In order to carry out museification and revalorization of mining objects, first of all, a combination of scientific-engineering and humanitarian knowledge, mostly geo-construction technologies, is required.

In Ukraine, the mining heritage is being protected through the museification of underground structures, the creation of museums and geotourist routes. An important component of the museification of underground structures is the restoration of mining workings that form routes with the preservation of historical features of ancient mining structures and technologies [28].

On the mining landscapes of Kryvorizhzhia, revalorization can be introduced also, in particular on quarry complexes.

Studying the elevation and landscape levels, it was concluded that the quarries have a significant potential for revalorization into various structures that will serve in entertainment, historical-cultural and cognitive processes. Such research is covered thoroughly in the scientific work of M. O. Rudenko, where the architectural and planning organization of public buildings and structures on the territory of reclaimed quarries of Kryvorizhzhia is proposed [94].

The idea of building various facilities on the territory of quarries was suggested at the end of the 20th century. Currently, the world has already a practice in construction reclamation and later development of quarries [94]. Public buildings formed on the territory of quarries can belong to the following typological groups of buildings: physical culture and sports and entertainment buildings, show-buildings, cultural and educational buildings, scientific research buildings. A separate group includes the arrangement of recreational park areas in quarries with additional functions (open-air cinemas, exhibitions, etc.). Depending on the typology of the object, as well as geometric and other parameters of the quarry, its location in relation to the city, the city center, recreational areas, investment opportunities and customer wishes, etc., corresponding scheme for the organization of the building in space is also chosen [94]. It can be a terraced house, complete or partial covering of the quarry with a dome, partial or complete filling of it with an amphitheater, adjacent to the slope, separate location of the house at the bottom of the quarry, which includes one building, a complex of buildings and open-air areas. There is possible realization for the construction of physical culture and sports and entertainment facilities. It is known the world experience about such buildings, in particular: the municipal stadium, located in the city of Braha, and the entertainment complex "Sunway Lagoon" in the center of the capital of Malaysia - Kuala Lumpur. Both objects are located in construction material quarries with an area of more than 10,000 m^2.

Municipal Stadium of Braha or "Estádio Municipal de Braga" (Port. Estádio Municipal de Braga) is a stadium in the city of Braha, in the North of Portugal. The stadium was built specially for the European Football Championship 2004. According to the budget, it is one of the most expensive Portuguese stadiums – it cost more than 83 million euros [94].

On the territory of Kryvorizhzhia, quarries can also be used in construction. As an example, the Zhovtnevyi granite quarry has quarry terraces and is located close to public transport stops, including the metrotram. Office or even administrative buildings can be placed here. Taking into account the fact that the quarry is now a spontaneous meeting and training place for the cycling club, a bicycle track and a sports facility can be arranged within the quarry complex. In addition, the reservoir in the quarry can contribute to the development of water recreational and tourist activities, which are quite popular today.

The next important factor in the rational use of altitudinal differentiation and diversity of mining landscapes is the development of industrial tourism.

Kryvyi Rih has a significant number of various industrial facilities, which contributes to the development of industrial tourism. There are 45 iron ore mining mines, 41 quarries, 89 dumps, 26 sinkhole zones and landslide zones in mine fields, 15 slurry storage facilities, 27 speleological objects (opened old tunnels, shafts, mines, gas tunnels, sinkhole pits, etc.), 6 energy enterprises, 5 metallurgical enterprises, 28 machine-building enterprises, 5 chemical enterprises, 14 construction enterprises, 9 woodworking enterprises, 5 light and 12 food industry enterprises (Table 4.4).

Extreme tourism is gradually developing on the territory of Kryvyi Rih. According to V. L. Kazakov, extreme tourism here can be divided into 9 types: hiking tourism; mountain tourism; rock climbing; speleological tourism; cycling tourism; mining tourism; diving; para- and hang-gliding [54].

Table 4.4

Industrial facilities of Kryvyi Rih [88]

<table>
<tr><td rowspan="12">The area of Kryvyi Rih is 425 ^{km2}
Mining landscapes make up 48.8% of the territory
The industrial heritage includes more than 800 industrial facilities, old railways, hydraulic structures, etc.</td><td>45 working iron ore mines</td></tr>
<tr><td>41 quarries</td></tr>
<tr><td>89 dumps</td></tr>
<tr><td>26 sinkhole zones in the fields of underground mines</td></tr>
<tr><td>15 sludge storage facilities and mining ore plants</td></tr>
<tr><td>34 speleological objects: 12 open mine shafts, 3 shafts, 11 tunnels, 2 underground workings, etc.</td></tr>
<tr><td>6 energy enterprises</td></tr>
<tr><td>5 metallurgical enterprises</td></tr>
<tr><td>28 machine-building plants</td></tr>
<tr><td>5 chemical plants</td></tr>
<tr><td>14 special enterprises</td></tr>
<tr><td>9 woodworking enterprises</td></tr>
</table>

Such objects of mining landscapes as the quarry and dump complex of JSC " Kryvbaszalizrudkom", the sinkhole (formed in the 90s of the XX century), the SMPP dump (Burshchytskyi, created during the 1950-1980s of the XX century), flooded quarry of OM named after Illich (Radianskyi, years of exploitation - 1970-1980s of 20th century), railway bridge across the Inhulets river named after M.A. Beleliubskyi (built in 1884), the valley of the Inhulets River, rock outputs of the Kryvyi Rih chain along the Inhulets River serve for the development of various extreme excursions.

In the course of the educational and landscape excursion, you can get acquainted with the quarry and dump landscapes of Kryvbas through their overview, the history of creation and the peculiarities of operation, and also see the differentiation of mining landscapes from a height.

An extreme sports excursion allows you to get known the quarry and dump landscapes of Kryvbas in detail through direct "contact": climbing to the upper plateau of the dump, descending steep slopes; crossing to the opposite side of the river via a suspension bridge; inspection of the sinkhole; overview of the current state of the Inhulets river valley; comparison of the vegetation cover of natural rock outputs of the Kryvyi Rih chain with the reclaimed dump and the formation of the appropriate vegetation cover on it; survey of mineral shifts of rocks in the quarry and study of altitudinal and landscape microstrips.

The informative and entertaining excursion is mostly aimed at recreation in non-standard places, in particular in the Zhovtnevyi granite quarry. It is possible to conduct a brief informative excursion on the territory of the "Vizyrka" nature sanctuary, etc. [27].

As mentioned above, the Zhovtnevyi granite quarry is an object of tourist and recreational activity, but now the quarry is in neglected condition, its degradation is gradually taking place. Local residents, resting here, leave garbage and correspondingly they reduce the attractiveness of a quarry in recreational and tourist activities. An important factor that inhibits the development of tourism in the career is the lack of recreational infrastructure.

Taking into account the above-mentioned factors, the prospects for the development of the Zhovtnevyi granite quarry may be as follows:

– to level, arrange the bottom and walls of the quarry, and fill the bottom with sand-clay material with the help of technical reclamation;

– to create a beach for comfortable rest of tourists;

– to organize the infrastructure of the quarry territory, namely the road and parking for motor transport and to develop strategies for the development of recreation centers;

– to plant trees and grassy vegetation with the help of biotic reclamation.

The suggested measures will contribute to the development of mining landscapes and their control in order to prevent the emergency situations of a natural and technogenic nature (Fig. 4.10).

Therefore, the territory of Kryvyi Rih needs to be comprehensively restored, but this is not yet possible yet. The main obstacle -is financial one. In the practice of nature management and in the development of measures aimed at optimizing the landscape and ecological situation in Kryvorizhzhia, it is necessary to take into account anthropogenic altitudinal differentiation and the diversity of landscape complexes caused by it. Applying this approach, it is possible to carry out not only the reclamation of abandoned mining areas, traditional for the region, but also to start a large-scale cultivation of Kryvorizhzhia in general. However, in modern conditions, in the absence of the necessary funding, it is advisable to start only with the cultivation of waste landscape complexes, mainly loose and mixed breeds. The priority is the middle denudation-accumulative strip. In the present and future cultivation of mining landscapes, conservation, preservation, eight types of cultivation and partial reclamation carried out in the past should prevail.

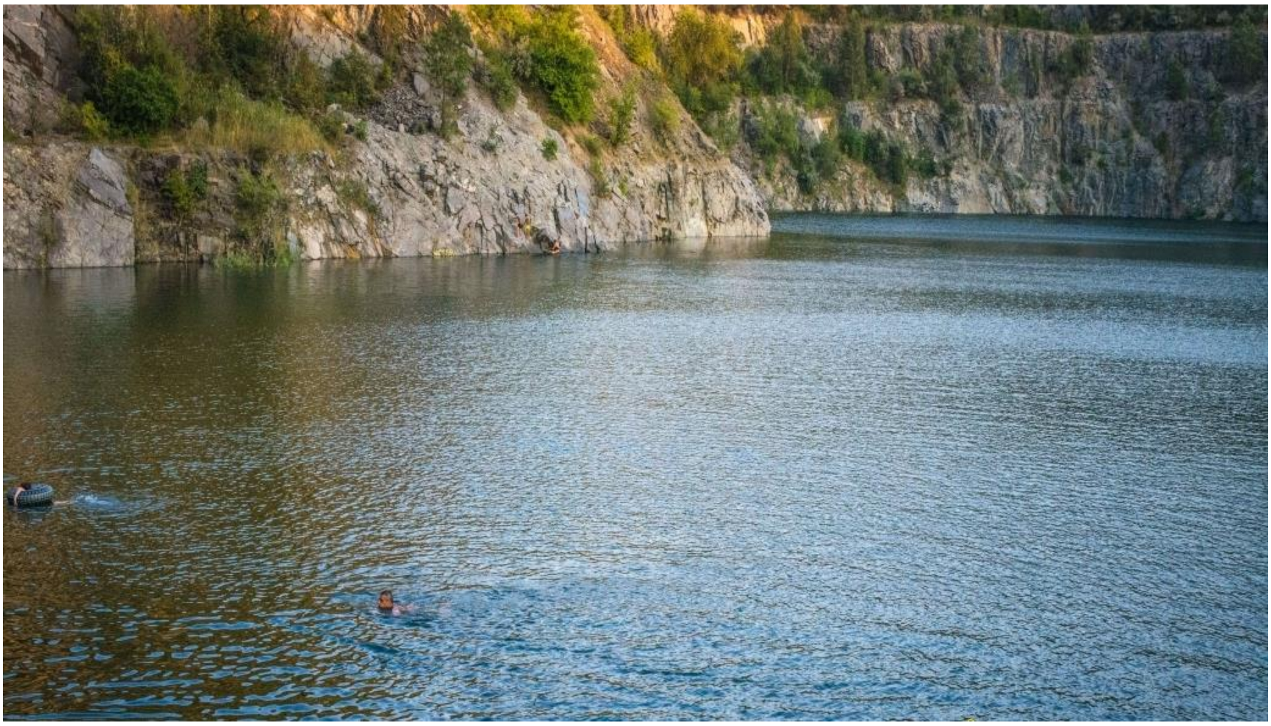

Fig. 4.10. The Zhovtnevyi granite quarry a tourist and recreational facility of KLTS

POSTFACE

The study of landscapes of technogenesis zones in order to optimize their functioning and minimize the negative processes developing within them is a topical direction of modern constructive geography and anthropogenic landscape science. The research of altitudinal differentiation and diversity of landscape complexes of technogenesis zones is of particular importance in the process of this study. They were studied separately for the most part, which does not meet the demands of practice and does not provide an opportunity to plan measures of rational nature management realistically. The altitudinal differentiation of the landscapes of technogenesis zones, especially their mining landscapes, increases the intensity of energy and weight exchange, stimulates the development of landscape complexes and, as a result, contributes to the increase of landscape diversity. Such dependence is typical for landscape complexes of natural, natural-anthropogenic and anthropogenic (especially technogenic) origin. The study of altitudinal differentiation and diversity of landscape complexes in technogenesis zones can be carried out using the methods of classical and anthropogenic landscape science.

Kryvorizhzhia is one of the unique zones of technogenesis of Ukraine, where the altitude differentiation of landscape complexes and their diversity is an excellent testing ground for learning the interrelationships between them and substantiating measures to optimize adverse processes. In the history of the development and study of the mining landscapes of Kryvorizhzhia, three stages are distinguished: artisanal development and development of natural resources (IV century BC - XVII century) - descriptions and development of individual geocomponents, which were of direct importance for human lives, prevailed; research of natural resources for the purposes of their initial industrial development (XVIII - first half of the XX century), which made it possible to form an industrial ground for start intensive extraction of minerals; of active industrial development (the second half of the 20th century - the beginning of the 21st century) - the development of one of the largest landscape systems not only in Ukraine, but also in the world. In just 150 years, a new, complex and dynamic landscape structure was formed within Kryvorizhzhia, with an obvious predominant industrial, mostly mining landscapes, which, together with residential landscapes, form the modern landscape background of Kryvorizhzhia. Among anthropogenic, industrial, especially mining and residential landscapes, they are distinguished by the altitude differentiation of landscape complexes and their diversity, which is also characteristic of Kryvorizhzhia.

The unique nature of the region natural resources and the intensity of their economic development contributed also to the substantial growth of altitudinal differentiation and diversity of mining landscapes of Kryvorizhzhia. About 18 billion tons of iron ores alone, significant reserves of crystalline rocks (granites, gneisses, etc.), kaolins, clays, etc. are concentrated here. Iron ore Kryvbas stretches from northeast to southwest for 96 km.

The systematization of landscape complexes and the calculation of indicators of topological and chorological landscape diversity make it possible to conclude that the modern landscape diversity of Kryvorizhzhia exceeds the indicators of natural landscape complexes restored for this region by 3.7-5.1 times. Altitude differentiation of territories occupied by mining developments increased by 2.1 -2.7 times. A unique for the steppe zone of Ukraine, a low-mountain mining landscape was formed with an altitude difference of up to 620-650 m and underground workings to a depth of more than 1200 m. Territories with a more dismembered topography (if there are 3-4 types of terrain on the natural site) have higher indicators of landscape diversity than territories that have a significant area, but are represented by one type of terrain.

The altitudinal differentiation of mining landscapes of Kryvorizhzhia is expedient and necessary to be studied within the limits of altitudinal degrees, altitudinal landscape levels and types of localities. Using these altitude structures, 3 altitudinal landscape levels are distinguished: accumulative (lower young), denudation-accumulative (medium, or typical), denudation (upper, or old). They are characteristic of almost all types of quarry and dump complexes, and therefore they can be used in the process of developing typical projects for the optimization of mining and industrial landscapes of Kryvorizhzhia. Studying the types of localities on the territory of

Kryvorizhzhia, it was established that the most common are the quarry-terrace and plateau -like multi-tiered dump types of localities.

Altitude differentiation of each of the determined terrain type is also heterogeneous. Microstrips are clearly distinguished here - areas with different rates of denudation-accumulation processes. It is appropriate to distinguish the upper denudation, middle accumulative-denudation and lower accumulative microstrips. The high tiers are observed within the altitude microstrips. It is necessary and better to isolate the tiers only in deep (150-250 m) and ultra-deep (more than 250 m) quarries and high (more than 30 m) dumps and edges of sludge storage facilities. This is proved by detailed studies of the natural conditions of six quarries of various types of minerals, eight dumps of various rocks and four slurry storage facilities within the boundaries of Kryvorizhzhia.

The mining landscapes of Kryvorizhzhia are not always rationally located at the natural altitudinal levels. During the development of minerals, the peculiarities and consequences of the formation of their altitudinal differentiation, and, accordingly, their diversity, were taken into account even less. The proposed ways of optimization allow to model rationally and design newly created landscape complexes and to combine them harmoniously with existing ones. Since the 60s of the XX century and until the beginning of the 21st century among the measures aimed at improving the state of mining landscapes, reclamation with subsequent forestry, less often recreational and agricultural development prevailed everywhere. In addition to reclamation, cultivation of mining landscapes (steppe, pasture, forestry, residential, water management and industrial) is expedient and promising. One of the new and promising directions of optimization of mining landscapes is revitalization, which has not been implemented yet in the territory of Kryvorizhzhia due to financial insolvency. This does not make it impossible to carry out optimization measures everywhere. Suggested measures of rational use and protection of mining landscapes should be carried out more actively on their tailing sludge storage, quarry and landscape complexes suitable for the formation of protected and recreational landscapes.

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ABSTRACT

Koptieva T.S. **Altitudinal differentiation and diversity of mining landscapes of Kryvorizhzhia.**

On the basis of the improved theoretical and methodological foundations of constructive geography and anthropogenic landscape science, the problem of scientific substantiation of the use of altitudinal differentiation formed by the mining industry of Kryvyi Rih and the diversity of landscapes of the region caused by it is considered for their rational modern and future use and protection.

On the territory of Kryvorizhzhia, the mining industry has been operating for about 150 years and during this period of time transformed natural landscapes into anthropogenic ones. Every year, their area increases, mainly due to the mining landscapes, which occupy almost 40 thousand hectares and are leading in the landscape structure of Kryvbas. As a result, the territory of Kryvorizhzhia is sufficiently representative for the study of both altitudinal differentiation and the diversity of mining landscapes.

The purpose of the study is to identify interdependence and relationships between landscape diversity and altitudinal differentiation of the mining landscapes of Kryvorizhzhia for the needs of their rational use.

The phenomenon of altitude differentiation combines the properties of vertical and horizontal differentiation of natural components and landscape complexes. This phenomenon can be compared with altitudinal zonality in the mountains, but on the plains it is characterized only by intrazonal changes and manifests itself due to the presence of altitudinal-landscape steps, levels, and tiers. Altitude differentiation determines a number of important processes and phenomena, among which there is an increase of the landscape diversity. Under landscape diversity, it is appropriate to understand the multiplicity of landscape complexes actually present on the earth surface. Study of the diversity of mining landscapes involves the identification of landscape complexes of different hierarchical levels in any territory for scientific,

educational and economic purposes, and is also necessary for recommendations on their use for various economic needs, tourism and recreation, the creation of protected fund objects.

Ukrainian scientists became interested in landscape diversity only at the end of the 20th century, and the study of the diversity of mining landscapes - at the beginning of the 21st century. Analytical review of natural-geographical and landscape studies on the studied issues makes it possible to conclude the fact that more attention was paid to the horizontal differentiation and diversity of mining landscapes and to the altitudinal differentiation and diversity of their natural (natural and anthropogenic) components. Altitude differentiation and diversity of mining landscapes were not reflected in scientific developments, and, accordingly, in practical recommendations for their rational use.

Among the main areas of research into altitudinal differentiation and diversity of mining landscapes of a separate region of Ukraine - Kryvorizhzhia, landscape-dynamic, landscape-geochemical, landscape-biocenotic and landscape-ecological, as well as the principles and methods inherent in them, are appropriate and optimal.

The presence of large reserves of iron ore (more than 18 billion tons), favorable natural conditions and the demands of practice led to the formation of a powerful technogenic zone on the territory of Kryvorizhzhia. In the process of its development, three stages are clearly distinguished: artisanal developments (IV century BC – XVII); initial industrial development (XVIII – first half of XX century) and active industrial development (second half of XX – the beginning of XXI century). They are different in terms of time, but they really reflect the features of the formation of the most powerful Kryvyi Rih Landscape and Technical System (KLTS) in Ukraine and Europe. Territorially, the KLTS extends sublatitudinally from north to south for 96 km, from west to east for 62 km, and occupies an area of 4.1 thousand km^2, which is 0.67% of the territory of Ukraine. The modern landscape structure of Kryvyi Rih is represented by various anthropogenic landscapes, among which the most common are agricultural, residential and industrial.

In the structure of the Kryvorizka landscape-technical system, industrial landscapes prevail everywhere, represented mainly by their mining subclass. In the future, mining landscapes will continue to be the background in KLTS and the environment-forming within Kryvorizhzhia.

The altitudinal differentiation of mining landscapes of Kryvorizhzhia was studied at three altitudinal landscape levels: accumulative (lower), denudation-accumulative (middle), denudation (upper). They are characteristic of almost all types of quarry and dump complexes, and therefore these levels must be taken into account in the process of developing typical projects for the optimization of mining landscapes in Kryvorizhzhia. When studying the types of localities on the territory of Kryvorizhzhia, it was established that the most common are the quarry-terrace and plateau-like multi-tiered dump types of localities. Within their boundaries, it is advisable to distinguish the upper denudation, middle accumulative-denudation and lower accumulative microstrips. Within the altitudinal microstrips, altitudinal layers are traced. It is necessary and better to isolate the layers only in deep (150-250 m) and ultra-deep (more than 250 m) quarries and high (more than 30 m) dumps and sides of sludge storage facilities. This is confirmed by detailed studies of altitude differentiation of six quarries of various types of minerals, eight dumps of various rocks and four slurry storage facilities within Kryvorizhzhia.

The systematization of landscape complexes and the calculation of indicators of topological and chorological landscape diversity make it possible to conclude that the modern landscape diversity of Kryvorizhzhia exceeds the indicators of natural landscape complexes restored for this region by 3.7-5.1 times. Altitude differentiation of territories occupied by mining developments increased by 2.1 -2.7 times. A unique for the steppe zone of Ukraine, a low-mountain mining landscape was formed with a height difference of up to 620-650 m and underground workings to a depth of more than 1200 m. Territories with a more dismembered topography (if there are 3-4 types of terrain on the natural site) have higher indicators of landscape diversity than territories that have a significant area, but are represented by one type of terrain.

In the practice of nature management and in the development of measures aimed at optimizing the landscape and ecological situation in Kryvorizhzhia, it is necessary to take into account anthropogenic altitudinal differentiation and the diversity of landscape complexes caused by it. With this approach, it is possible to carry out not only the reclamation of abandoned mining areas, traditional for the region, but also to start a large-scale cultivation of Kryvorizhzhia in general.

Proposed ways of optimization allow to model rationally and design newly created landscape complexes and to combine them harmoniously with existing ones. Since the 60s of the XX century and until the beginning of the 21st century among the measures aimed at improving the state of mining landscapes, reclamation with subsequent forestry, less often recreational and agricultural development prevailed everywhere. In addition to reclamation, cultivation of mining and industrial landscapes (steppe legacy, pasture, forestry, residential, water management and industrial) is expedient and promising. One of the new and promising directions of optimization of mining landscapes is revitalization, which has not yet been implemented in the territory of Kryvorizhzhia due to financial incapacity. This does not make it possible to carry out optimization measures everywhere. More actively proposed measures for the rational use and protection of mining landscapes should be carried out on their dump and sludge storage landscape complexes and quarries, which are suitable for the formation of protected and recreational landscapes.

Key words: Kryvorizhzhia, altitudinal differentiation, landscape diversity, mining landscape, quarry, dump, altitudinal landscape level, terrain type, rational nature management.

АНОТАЦІЯ

Коптєва Т.С. **Висотна диференціація та різноманіття гірничопромислових ландшафтів Криворіжжя.**

На основі удосконалених теоретико - методологічних засад конструктивної географії і антропогенного ландшафтознавства розглянута проблема наукового обґрунтування використання сформованих гірничодобувною промисловістю Криворіжжя висотної диференціації та зумовленою нею різноманіття ландшафтів регіону для їх раціонального сучасного й майбутнього використання та охорони.

На території Криворіжжя гірничодобувна промисловість функціонує близько 150 років і за цей проміжок часу трансформувала натуральні ландшафти в антропогенні. З кожним роком їх площа збільшується, переважно, завдяки гірничопромисловим ландшафтам, які займають майже 40 тис. га і є провідними у ландшафтній структурі Кривбасу. Як наслідок територія Криворіжжя достатньо репрезентативна для дослідження як висотної диференціації, так і різноманіття гірничопромислових ландшафтів.

Мета дослідження полягає у виявленні взаємозалежності та взаємозв’язків між ландшафтним різноманіття і висотною диференціацією гірничопромислових ландшафтів Криворіжжя для потреб їх раціонального використання.

Явище висотної диференціації об’єднує в собі властивості вертикальної і горизонтальної диференціації природних компонентів і ландшафтних комплексів. Це явище можна порівняти з висотною поясністю в горах, однак на рівнинах воно характеризується лише внутрішньозональними змінами і проявляється через наявність висотно – ландшафтних ступенів, рівнів і ярусів. Висотна диференціація зумовлює низку важливих процесів і явищ, серед яких – збільшення ландшафтного різноманіття. Під ландшафтних різноманіттям доцільно розуміти реально наявну на земній поверхні множинність ландшафтних комплексів. Пізнання різноманіття гірничопромислових ландшафтів передбачає виявлення ландшафтних комплексів різних ієрархічних рівнів на будь-якій території з науковою, навчальною та господарською метою, а також є необхідним для рекомендацій щодо їхнього використання для різних господарських потреб, туризму і рекреації, створення об'єктів заповідного фонду.

Науковців України ландшафтне різноманіття зацікавило лише наприкінці XX ст., а дослідження різноманіття гірничопромислових ландшафтів – на початку XXI ст. Аналітичний огляд природничо – географічних і ландшафтознавчих напрацювань з досліджуваної проблематики дає можливість зробити висновок, що більше уваги приділялось горизонтальній диференціації і різноманіттю гірничопромислових ландшафтів та висотній диференціації і різноманіттю їх природних (натуральних і антропогенних) компонентів. Висотна диференціація і різноманіття гірничопромислових ландшафтів не знайшли відображення у наукових розробках, а, відповідно, й практичних рекомендацій щодо їх раціонального використання.

Із основних напрямів дослідження висотної диференціації та різноманіття гірничопромислових ландшафтів окремого регіону України – Криворіжжя, доцільними і оптимальними є ландшафтно-динамічний, ландшафтно-геохімічний, ландшафтно-біоценотичний і ландшафтно-екологічний, а також притаманні їм принципи і методи.

Наявність великих запасів залізних руд (більше 18 млрд. т.), сприятливі природні умови і запити практики призвели до формування потужної техногенної зони на території Криворіжжя. У процесі її розвитку чітко виокремлюються три етапи: кустарних розробок (IV ст. до н.е. – XVII ст.); початкового промислового освоєння (XVIII – перша половина XX ст.) і активного промислового освоєння (друга половина XX – початок XXI ст.). Вони різні за проміжками часу, однак реально відображають особливості становлення найпотужнішої в Україні та Європі Криворізької ландшафтно-технічної системи (КЛТС). Територіально КЛТС субширотно простягається з півночі на південь на 96 км, із заходу на схід – на 62 км, і займає площу 4,1 тис. км^2, що складає 0,67%

території України. Сучасна ландшафтна структура Криворіжжя представлена різноманітними антропогенними ландшафтами, серед яких найбільш розповсюджені сільськогосподарські, селитебні та промислові.

У структурі Криворізької ландшафтно – технічної системи повсемісно переважають промислові ландшафти представлені, переважно, їх гірничопромисловим підкласом. Гірничопромислові ландшафти і у майбутньому будуть фоновими у КЛТС та середовищеформуючими у межах Криворіжжя.

Висотну диференціацію гірничопромислових ландшафтів Криворіжжя досліджено на трьох висотно-ландшафтних рівнях: акумулятивному (нижній), денудаційно-акумулятивному (середній), денудаційному (верхній). Вони характерні майже для всіх типів кар’єрно-відвальних комплексів, а тому ці рівні необхідно враховувати у процесі розробки типових проектів оптимізації гірничопромислових ландшафтів Криворіжжя. При дослідженні типів місцевостей на території Криворіжжя встановлено, що найбільш поширеними є кар’єрно-терасовий і платоподібний багатоярусний відвальний типи місцевостей. У їх межах доцільно виділяти верхню денудаційну, середню акумулятивно-денудаційну і нижню акумулятивну мікросмуги. У межах висотних мікросмуг прослідковуються висотні яруси. Останні необхідно і краще виділяти лише на глибоких (150-250 м) і надглибоких (більше 250 м) кар’єрах та високих (більше 30 м) відвалах та бортах шламосховищ. Це підтверджується проведеними детальними дослідженнями висотної диференціації шести кар’єрів різних видів корисних копалин, восьми відвалів різноманітних порід та чотирьох шламосховищ у межах Криворіжжя.

Систематизація ландшафтних комплексів та обчислення показників топологічного і хорологічного ландшафтного різноманіття дають можливість зробити висновок, що сучасне ландшафтне різноманіття Криворіжжя переважає у 3,7 – 5,1 рази показники відновлених для цього регіону натуральних ландшафтних комплексів. Висотна диференціація територій зайнятих гірничопромисловими розробками зросла у 2,1 - 2,7 рази. Сформувався унікальний для степової зони України гірничопромисловий низькогірний ландшафт з перепадом висот до 620-650 м та підземними виробками до глибини більше 1200 м. Території з більш розчленованим рельєфом (за наявності на натурній ділянці 3-4 типів місцевостей) мають вищі показники ландшафтного різноманіття, ніж території, що мають значну площу, однак представлені одним типом місцевостей.

У практиці природокористування і при розробці заходів, направлених на оптимізацію ландшафтно-екологічної ситуації в Криворіжжі необхідно враховувати антропогенну висотну диференціацію і зумовлене нею різноманіття ландшафтних комплексів. При такому підході можливо проводити не лише традиційну для регіону рекультивацію відпрацьованих гірничопромислових територій, але й розпочати широкомасштабне окультурення Криворіжжя загалом.

Запропоновані шляхи оптимізації дозволяють раціонально моделювати і проектувати новостворені ландшафтні комплекси та гармонійно їх поєднувати з наявними. З 60-х років XX ст. і до початку XXI ст. серед заходів спрямованих на поліпшення стану гірничопромислових ландшафтів повсюдно переважала рекультивація з наступним лісогосподарським, рідше рекреаційним та сільськогосподарським освоєнням. Крім рекультивації доцільним і перспективним є окультурення гірничопромислових ландшафтів (степове заповідання, пасовищне, лісогосподарське, селитебне, водогосподарське та промислове). Одним із нових і перспективних напрямів оптимізації гірничопромислових ландшафтів є ревіталізація, яка поки що не запроваджується на території Криворіжжя у зв'язку із фінансовою неспроможністю. Остання не дає можливості проводити оптимізаційні заходи повсемісно. Активніше запропоновані заходи раціонального використання й охорони гірничопромислових ландшафтів необхідно проводити на їх відвальних і шламосховищних ландшафтних комплексах та кар'єрних , що придатні до формування заповідних і рекреаційних ландшафтів.

Ключові слова: Криворіжжя, висотна диференціація, ландшафтне різноманіття, гірничопромисловий ландшафт, кар’єр, відвал, висотно-ландшафтний рівень, тип місцевості, раціональне природокористування.

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Scientific publication

Koptieva Tetiana Serhiivna

Altitudinal differentiation and diversity of mining landscapes of Kryvorizhzhia

Monograph

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Phone: 0(800) 33-00-90, (096) 97-30-934, (093) 89-13-852
e-mail: info@tvoru.com.ua
http://www/tvoru.com.ua

Koptieva Tetiana Serhiivna - Ph. D. in the field of study 10 Natural sciences, speciality 103 Earth sciences, associate professor of the Socio-economic studies and geography Chair of H.S. Skovoroda Kharkiv National Pedagogical University. Scientific profession - geographer. Field of activity - natural (physics, historical, anthropogenic) geography, rational use of natural resources, ecology, touristic and recreational activity and landscape study. The author of more than 60 scientific publications: 2 collective monograph, 1 coauthor textbook, 10 specialized articles among them.