

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

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

Journ. Geol. Geograph.
Geology,
29(3), 447–459.

doi: [10.15421/112040](https://doi.org/10.15421/112040)

Ulyana I. Bornyak, Antonina V. Ivanina, Halina I. Hotsanyk, Ihor V. Shaynoha

Journ. Geol. Geograph. Geoecology, 29(3), 447–459.

Urban complex of geotourist sites of the city of Lviv (Western Ukraine)

Ulyana I. Bornyak, Antonina V. Ivanina, Halina I. Hotsanyk, Ihor V. Shaynoha

Ivan Franko National University of Lviv, Lviv, Ukraine,
u.bornyak@ukr.net, ant_iv@ukr.net, hotsanyuk@ukr.net

Received: 02.01.2020

Received in revised form: 05.02.2020

Accepted: 14.04.2020

Abstract. Lviv is a city with a centuries-old history that is easy to adapt to introduce a new direction in tourism for Ukraine - urban geotourism. Urban geotourism is an innovative form of tourism, the basis of which is the use of objects of modern cities for the promotion of geology, educational activities and tourism business needs. Lviv is a city with high geotourist potential due to its unique geomorphological, geological position, well-developed

tourist infrastructure, good information support and a large concentration of unique easily accessible diverse geo-tourist objects. The study of urban geosites for the needs of geotourism, the study of potential objects illuminating the interconnection of geology and architecture in the development of the historical urban landscape in Lviv have only just begun. Currently, there is a summarized short characteristic of the urbanistic complex of Lviv's geotourist sites and their classification was developed. They are divided into two supergroups (natural, anthropogenic), four groups (natural formations, natural processes, geotourism trails, natural-cultural, mining), two subgroups (polytypic, monotypic), 11 types and 19 categories. The geotourist sites of Lviv have scientific, cognitive, cultural-aesthetic value, are easily accessible, important for the educational process and in the case of their popularization will become attractive geo-tourist attractions. They are an important link for restoring Earth's history, exhibiting the geological structure of Lviv's territory, demonstrating new approaches to geotourism that combine nature, history and culture. Their study will allow the geomorphological and geological features of the city to be shown, allow us to get acquainted with the history of geological development, and help draw attention to the stone material used in the organization of urban space. Combining stone monuments with the cultural and tourist aspect is a great approach for disseminating geological knowledge.

Keywords: geotourism, urban geotourism, geotourism sites, natural and anthropogenic sites, Lviv

Урбаністичний комплекс геотуристичних об'єктів міста Львова (Західна Україна)

У. І. Борняк, А. В. Іваніна, Г. І. Гоцанюк, І. В. Шайнога

Львівський національний університет імені Івана Франка, Львів, Україна,
u.bornyak@ukr.net, ant_iv@ukr.net, hotsanyuk@ukr.net

Анотація. Львів – місто з давньою історією, яке легко пристосувати для запровадження нового для України напрямку – міського геотуризму, або урбангеотуризму. Міський геотурізм – це інноваційна форма туризму, основою якого є використання об'єктів сучасних міст для популяризації геології, просвітницької діяльності і потреб туристичного бізнесу. Львів – місто з високим геотуристичним потенціалом завдяки унікальній геоморфологічній, геологічній позиції, добре розвиненій туристичній інфраструктурі, хорошему інформаційному забезпеченню і значній концентрації унікальних легкодоступних різноманітних геотуристичних об'єктів. Вивчення урбаністичних сайтів для потреб геотуризму, дослідження потенційних об'єктів, що висвітлюють взаємозв'язок геології та архітектури у розвитку історичного міського ландшафту у Львові лише започатковане. Наразі наведена узагальнена стисла характеристика урбаністичного комплексу геотуристичних об'єктів Львова і розроблено їхню класифікацію. Вони поділені на дві надгрупи (природні, антропогенні), чотири групи (природні утворення, природні процеси, геотуристичні траси, природно-культурні, гірничопромислові), дві підгрупи (політипні, монотипні), 11 типів і 19 категорій. Геотуристичні об'єкти Львова мають наукову, пізнавальну, культурно-естетичну цінність, легкодоступні, важливі для навчального процесу і в разі їх популяризації стануть привабливими геотуристичними атракціями. Вони є важливою ланкою для відновлення історії Землі, експонування геологічної будови львівської території, демонструють нові підходи до геотуризму, що поєднують природу, історію та культуру. Їхнє вивчення дозволить показати геоморфологічні та геологічні особливості міста, ознайомитися з історією геологічного розвитку, привернути увагу до кам'яного матеріалу, що використовували при організації міського простору. Сполучення кам'яних пам'яток з культурно-туристичним аспектом є відмінним підходом для поширення геологічних знань.

Ключові слова: геотурізм, міський геотурізм, геотуристичні об'єкти, природні та антропогенні сайти, Львів

Introduction. Geological tourism (geotourism) is a new direction for tourist activity. The definition: «geotourism is the provision of such services and educational support, so that, in addition to aesthetic impressions, tourists have the opportunity to gain knowledge about the features of the geological structure of the territory» was first cited by British scientist Thomas Jose in 1995. (Slomka, Kicińska-Świederska, 2004), and in 2004 the term «geotourism» was officially approved by the National Geographic Union. In the early twenty-first century geotourism has received international publicity (Migoń, 2012; Ross, Dowling, Newsome, 2006; Wimbledon, SmithMeyer, Erikstad, Brilha, van den Ancker, 2013 and others) and gained popularity in Ukraine (Denysyk, Strashevskaya, Korinnyj, 2014; Khomenko, Isakov, Manyuk, 2018; Manyuk, 2015; Malska, Zin'ko, Shevchuk, 2014 etc.). The main purpose of geotourism is to promote and introduce into the tourism industry geotourism objects (or geotourism attractions) - geological objects and phenomena that are of interest to tourists. The objects of geotourism are diverse (Denysyk, Strashevskaya, Korinnyj, 2014; Grytsenko, Korniyets, Rusko, Yarozshuk, 2001 and others). These are geologic landmarks that are protected and are in the list of a geological heritage; geoparks nature conservation areas with a high concentration of interesting abiotic formations; geosites without protection, but which are important for demonstrating features of the geological structure of local areas of the Earth; objects that have arisen as a result of human activity (man-made landforms, works of material culture, museums and other exhibitions), etc.

For the successful implementation of geotourism activities, it is important, first of all, that there are territories with high geotourism potential with numerous and varied geological features (which are attractive, have scientific, cognitive value, capable of forming world-view principles and aesthetically pleasing); second, appropriate management and, third, infrastructure. All these requirements are met by the urbanized territories of large cities, in which it is easy to introduce new types of tourism for Ukraine - urban geotourism. Urban geotourism is an innovative form of geotourism, the basis of which is to use the objects of modern cities to promote geology, educational activities and tourism business needs. This area of geotourism in the world has only just begun to evolve. Among the main tasks of urban tourism is to identify, study and characterize interesting geoattractions in cities and develop geotrails. Such research is currently only being undertaken in some major cities: London, Lisbon (Rodrigues, Machado, Freire, 2011), Rome (Del Monte, Fredi, Pica, Vergari, 2013); and small

towns (Górska-Zabielska, Zabielski, 2017) in Europe; Sao Paulo (Brazil) (Del Lama, Bacci, Martins, Garcia, Dehira, 2015), Mexico City (Mexico) (Palacio-Prieto, 2015) etc.

Lviv is a city with an ancient history and rich architectural heritage, known primarily for its historical and cultural values. The historical architectural and urban development complex of Lviv (central part of Lviv with the ensemble of St. George's Cathedral and mountain Vysokiy Zamok) with an area of about 120 hectares and a buffer zone (2441 hectares) has been on the UNESCO World Heritage List since 1998 (www.unesco.org). Characteristics of the territory of the ensemble, interactive maps, coordinates of historical sites, etc. are listed on the website of the Lviv City Council (www.lviv.travel).

But only a few people know that there are numerous and varied urban geosites within Lviv, reflecting its natural and natural-cultural heritage, showing the connection between geology, geomorphology and urban development, and which are interesting geo-tourist objects. These are landscapes with a great variety of natural conditions, contrast, with differentiated relief, caused by the peculiarities of the geological structure, numerous expositions of different geological periods layering sediments, springs, paleontological objects, etc.

The natural heritage of Lviv is unique, due to its specific tectonic and geomorphological position. It is located at the conjunction of two big geomorphological regions: Podilskyi and Volyn-Malopoliskyi. Within the limits of Lviv, the Podilskyi geomorphological region is represented by structural-denudation of residual heights with absolute markings of 330- 390 m of Roztochchya, Lviv Opillya and the Davidovsky horseback of Rozotsko Obil subregion. The hypsometrically low (absolute marks 220-270 m) accumulation-denudation height of the Pasmovy (Gryadove) Pobuzhzhya of Small Polissia is the part of the Volyn-Malopolska region (Matolych, Kovalchuk, Ivanov, 2009). Through the highest points of Roztochchya, Lviv Opillya and the Davidovsky horseback, Lviv crosses the Great European watershed, dividing the river basins, some of which flow into the Baltic and the other into the Black Sea.

Intectonically, these geomorphological units correspond to the following tectonic blocks: the Buskomitted block (the Pasmovy (Gryadove) Pobuzhzhya) of the Eastern European Platform and two raised Roztochchya and Lviv (probably the Western European Platform) blocks (Derzhavna geologichna karta Ukrainy, 2004): The raised blocks are separated from the lowered by a steep erosion-

tectonic ledge 120- 135 m high; differing geological structure, stratigraphic completeness, the thickness, age, the composition of rocks and fossils.

The geological structure of Lviv was studied by A. Alt, M. Lomnitsky (Lomnicki, 1884), O. Vyalov, I. Venglinsky, V. Horetsky (Venglinskyi, Goretskyi, 1979), L. Kudrin (Kudrin, 1966), I. Kruglov, O. Kruglov (handwriting), P. Voloshin and others. The term «urban geotourism» was introduced recently, but interesting geological sites and the first trails for getting acquainted with the geology of Lviv were described in the 1960s. (Vyalov, Goretskyj, Kudrin, Pasternak, 1954; Baby nec, Burov, Vyalov et al., 1958). On the territory of Lviv, there are rocks of different age: Cretaceous (Maastrichtian), Neogene and Quaternary. In the Busk block, the Maastrichtian deposits of the Cretaceous are with disconformities covered by Quaternary sediments. In the raised tectonic blocks, the sequence is generally more complete, heavier, composed by Cretaceous carbonate rocks, Neogene terrigenous-carbonate deposits of Langhian and, possibly, Serravallian (a common thickness of 60- 114 m) with (bottom-up) Baraniv, Znesen, Naraiv, Ratyn, Ternopil, Bugle layers (Andreeva-Grigorovich, Gruzman, Kulchytsky, Ivanina et al., 1997; Hozhyk, Semenenko, Polietaiev et al. in., 2012) and Quaternary sediments with thickness of 0.5- 9.0 m.

The modern natural-landscape of Lviv is caused not only by the peculiarities of the deep structural-tectonic and geological structure but also by the management of people. Due to economic activity, natural landscapes have seriously changed. Throughout the territory, there are mining sites. They are the former stone quarries formed during the open cast extraction of sand, sandstone, gypsum, marls, limestone .

All this indicates that Lviv, the tourist mecca of Ukraine, is also a geo-tourist cluster, a city with significant natural potential, with many interesting geo-attractions on its territory. But at present, the study of the territory of Lviv for the needs of geotourism and the formation of an information-analytical and empirical database has only just begun.

The main tasks of this stage of research are:

- identification, study, preparation and selection of interesting geo-attractions;
- systematization and creation of the classification of geo-tourist objects of Lviv;
- a brief description of the geo-tourism potential of Lviv.

Materials and methods of investigations. The varied and numerous natural formations (geological or geomorphological objects that were naturally formed

and which are the subject of tourists' interest) and anthropogenic geotouristic attractions (landforms that are the result of an engineering-geological activity, works of material culture, museum exhibitions, etc.) of Lviv city provide the main research material.

An overview of the techniques and sequence of operations for the detection, study, evaluation of geotourist sites is presented in Wimbledon, Smith Meyer, Erikstad, Brilha, van den Ancker, 2013; Denysyk, Strashevskaya, Korinnyj, 2014; Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018 etc. For now, let's just highlight the main elements. The algorithm for estimating the geotourism potential of the territories is generally recognized and includes: geological study, conservation assessment, identification of major natural and anthropogenic attractions and their passport description, the definition of classifiers and creation of classification systems of geotourism objects, assessment of geo-diversity, development of routes of geo-tourist excursions, determination of tourist and socio-economic factors, creation of infrastructure, assessment of the profitability of geotourism and more.

The definition of geoattractions and assessment of their geotourist attractiveness were performed in stages. In the first stage, the study and detection of objects used a traditional set of methods: observation, description, photographic documentation and all existing geological methods: stratigraphic, geochronological, paleontological, paleoecological, sedimentological, lithological, geomorphological, structural mapping and so on. In the second stage during the evaluation and selection of representative objects the method of the systematic review and comparative evaluation of geo-tourist sites (Wimbledon, Smith Meyer, Erikstad, Brilha, van den Ancker, 2013; Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018)) was the main one.

The first attempts to assess the geo-tourism potential of Lviv in general and its individual parts (the Regional Landscape Park Znesinnia) were made in 2017 (Voloshyn, Slyvko, Knysh, Kremin, Bubniak, 2017; Ivanina, Pidlisna, 2017) and 2018 (Ivanina, Hotsanyuk, Spilnyk, Pidlisna, Pidlisna, Pidlisna 2018; Ivanina, Bornyak, 2018). These works are the basis for identifying and characterizing primarily geosites. But unlike natural areas (geoparks, national parks, etc.), the list of geo-tourist sites of cities is much wider. It includes anthropogenic geo-attractions, the vast majority of which exist only within urban areas.

Results. One of the most complex and least developed methodological issues is the systematization of urban geotourism objects, their division into groups, categories and the creation of an effective classifica-

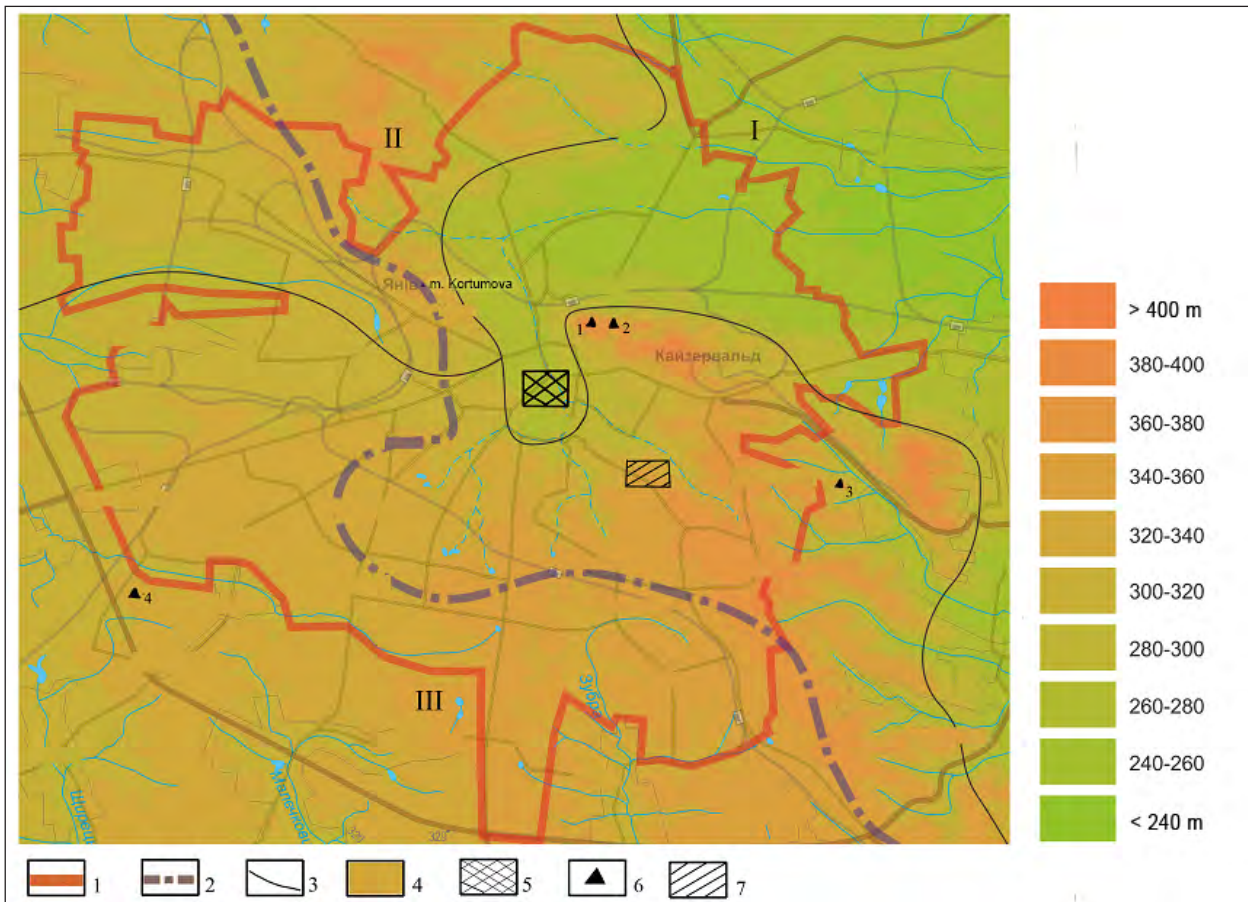


Fig. 1. Schematic geomorphological scheme of Lviv, by <https://uk.wikipedia> with changes. III geomorphological elements: I Pasmovy (Gryadove) Pobuzhzhya; II Roztochchya; III –Lviv Opillya. 1 the borders of Lviv, 2 the line of the Great European watershed; 3 boundaries of geomorphological elements; 4 absolute height; 5 the central part of Lviv with a significant concentration of geotourist sites; 6 geosites with legal status (1 Gora Vysokiy Zamok; 2 Gora Leva; 3 Medova (‘Honey’) Cave; 4 Kortumova Gora); 7 Lychakiv Cemetery.

tion system, which would be based on several classification features and, most fully, reflect the variety of geo-attractions. The process of systematization of Lviv city tourism geoattractions has only just begun. There are currently some classification systems that are geared to streamline our knowledge about natural geological objects only. They are based on different approaches to understanding the subject of research and apply different systems of classifiers. According to the authors, the most objective classifications, are characterized in Gritsenko et al., 1995, 2001; Bezvinnyj, et al., 2006; Wimbledon, Gerasimenko, and Ishchenko, 1999, which were taken as the basis for the development of the first urban geotourism sites classification system by A. V. Ivanina for the Park Znesinnia (Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018). But the diversity of Lviv’s geo-attractions turned out to be much larger. Therefore, we propose an updated, improved and modernized classification system of urban geotourist sites of Lviv with the allocation of supergroups, groups, subgroups, types and categories (Table 1).

It is built on a hierarchical basis, composed of smaller units subordinate to larger ones. All objects by origin are grouped into two large supergroups: natural (natural geologic objects of inanimate nature) and anthropogenic geotourist attractions created by human activity. There are groups defined in subgroups: natural objects and natural processes are highlighted among natural geo-objects. Among the anthropogenic attractions are two groups: natural-cultural and mining objects. The subgroups that are subordinate to the groups are defined by the degree of validity. These are polytypic, or complex (landmarks that combine features of two or more types of geological attractions) and monotypic, defined by one feature. Subgroups on a subject basis are divided into types. In the subgroups of natural sites are distinguished the following types: stratigraphic (typical, or standard, sections exhibit a sequence of layers and characterize the

Table 1. Classification of geotourist sites in Lviv

Supergroup	Group	Subgroup	Type	Category	Number of objects	
Natural	Natural formations	Polytypic	Geomorphological, stratigraphic	Typical sections, erosion remnants	Two	
			Geomorphological, stratigraphic, speleological	Supporting section, erosion remnants, cave	One	
		Monotypic	Stratigraphic		Typical sections	Three
					Supporting section	One
			Paleontological	Location of fossils	One	
			Geomorphological	Erosion remnants	One	
			Hydrogeological	Springs	Many	
		Natural processes				At the detection stage
Anthropogenic	Natural-cultural		Stone for building needs	Stonewalls of sacred and residential buildings	Many	
				Monument stone	Many	
				Capstone	Many	
				Finishing stone	Many	
				Brooke	Many	
		Urban Fossils	Fossils in wall and pavement stone	At the detection stage		
		Museum exhibitions	Specialized geological museums	Four		
			Museum exhibits made of natural stone	At the detection stage		
		Historic and architectural sites	Buildings associated with well-known geologists or geological events	At the detection stage		
		Mining			Sand quarry	Many

history of the geological development of a certain section of the crust; supporting sequences of the stratigraphic units of the local stratigraphic scale, which determine the station’s volume, age and structure; paleontological (unique sites of fossils); hydrogeological (springs), geomorphological (erosional remnants), speleological (caves of natural karst origin). Within the group of natural-cultural objects are identified the following types: stone for building purposes (wall stone of sacral and residential buildings, stone of monuments and tombstones, facing and finishing stone, paving stone). In the mining group, there are categories: former quarries (artificially created object for the industrial development of the territory and open pit mining of sand, gypsum or marl) and quarry - mining facilities for open pit mining of rock-solid rocks and rocks sandstone.

Geotourist sites were evaluated by criteria that determine the object’s rating. For the general characterization of Lviv’s geotourist sites, the following classifiers are used: legal status (international, national, regional, local

landmarks or no legal status), conservation (critical, recommended for improving geological study), level of protection (especially strict security mode, limited security mode with no recommendation for mass tourism, limited security mode with a recommendation for mass tourism, no need for protection), significance (global, supra-regional, regional, local); type of use (scientific reference, scientific and educational reference, scientific and tourist (importance for geotourism only), tourist (importance for tourism in general), priority (best, unique, first, model, standard), attraction (high, medium, low), geotourism value (high, medium, low), etc.

Below is a brief summary of the characteristics of Lviv’s geo-tourist sites.

There are numerous geological formations in Lviv. These are outcrops of rocks of different ages springs, erosion remnants hills. Among the geotourist sites that are classified as natural supergroups, the most valuable and attractive for the tourism are 10 geosites, four of which are (Gora Vysokiy Zamok, Gora Leva, Kortumova Gora, Gora Ratyn with

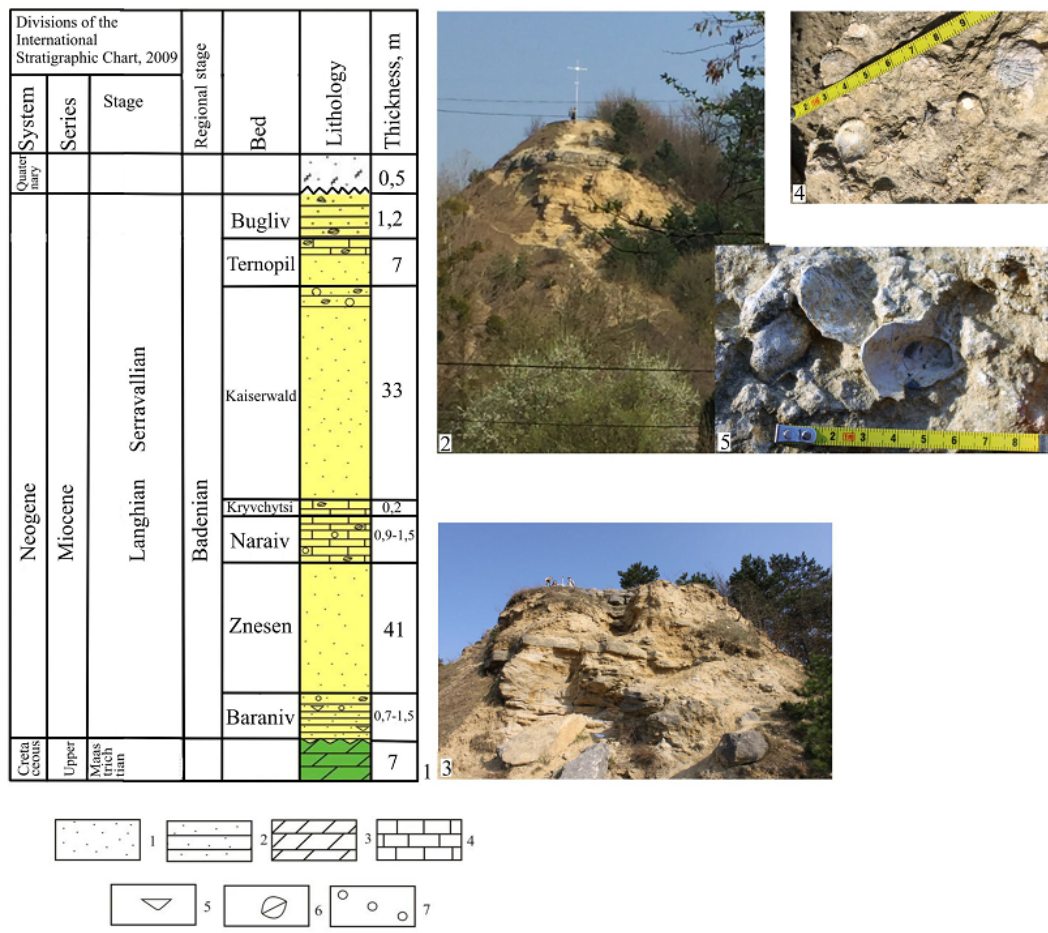


Fig. 2. Geological landmark Gora Leva: 1 – schematic stratigraphic column; 2 – general view of the mountain; 3 – outcrops of sandstone at the top of the sequence; 4, 5 – bivalve mollusc fossils. At the stratigraphic column: 14 – rocks: 1 – sand; 2 – sandstones; 3 – marls; 4 – limestone; fossils: 5 – litotamnium algae; 6 – bivalves; 7 – brachiopods.

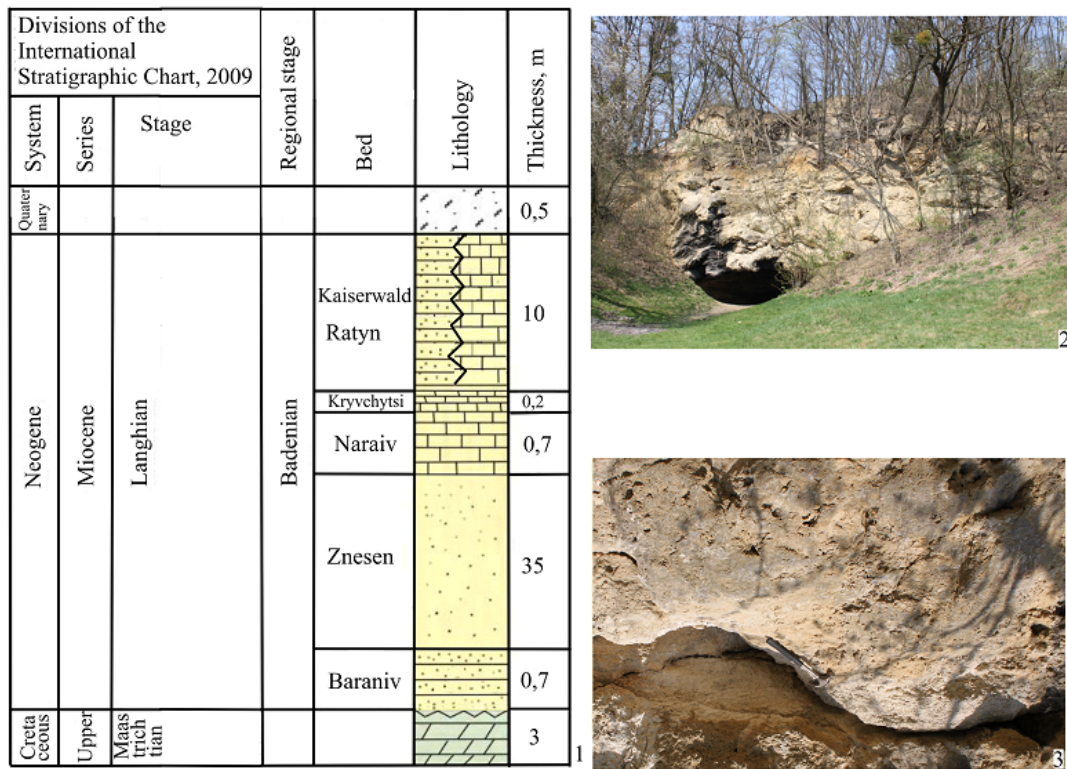


Fig. 3. Geological landmark Medova ('Honey') cave: 1 – schematic stratigraphic column; 2 – general view of the cave; 3 – Ratyn limestones. Symbols to the stratigraphic column in fig. 2.

Medova ('Honey') cave (Fig. 3) have legal status. They are local landmarks declared as geological sites, that require a regime of limited protection with a recommendation for mass tourism. They are scientific-educational and scientific-tourist sites with a high degree of attraction and important for the noesis of geological development history.

Gora Leva is a polytypic geological landmark because it belongs to the geomorphological and stratigraphic categories of geosites. The mountain is an erosion remnant, on the slopes of which the reference sections of the Kaiserwald and Ternopil layers of the Neogene are described (Bezvinnyj, et al., 2006; Ivanina, Hotsanyuk, Spilnyk, Pidlisna, 2018; Ivanina, Bornyak, 2018).

Mount Ratyn is a polytypic stratigraphic, geomorphological and speleological site. It is an erosional remnant and a supporting sequence (only in Western Ukraine) of the Ratyn layers of Neogene, composed of limestone. The mountain is known primarily for the horizontal cave (Honey Cave) of karst origin, which is located in limestones. The cave was entered in the State Register of Protected Areas in 1970 and partially described in the Geological Landmarks of Ukraine (Bezvinnyj et al., 2006).

Kortumova Gora is a geological landmark of Ukraine since 1970, a polytypic geo-tourist object since it is an erosion remnant (geomorphological category) and a reference sequence of the Neogene of Roztochchya (stratigraphic category); briefly described in Geological Landmarks of Ukraine (Bezvinnyj et al., 2006).

Gora Vysokiy Zamok is listed in the Register of Geological landmarks of Ukraine in 1970 (Bezvinnyj et al., 2006), is a monotypic object of the geomorphological category. It is an erosion remnant with the outcrop of the Kaiserwald layers of the Neogene and is a favourite vacation spot of Lviv residents and city visitors.

The other five geosites located in the territory of the Regional Landscape Park Znesinnia are monotypic stratigraphic (typical sequence of the Pasmovy (Gryadove) Pobuzhzhya; a typical section of the Cretaceous and Neogene boundary deposits – the only section within Lviv; a typical section of the Narayev layers and borders); reference sequence of the Kaiserwald beds of the Neogene) and paleontological (unique paleontological site without official status, described in detail in Ivanina et al., 2016, 2018) categories. All geosites are important geotouristic objects with a high degree of geotourist attraction, with considerable scientific, educational and cognitive aesthetic, cultural value, and are the object of geological ex-

cursions and practice sessions, described in scientific (Ivanina et al., 2016, 2018 and others) and popular science literature.

Hydrogeologically, the territory of Lviv is located within the Volyn-Podilskyi artesian basin, where the main aquifers are confined to Quaternary, Neogene, and Upper Cretaceous deposits. The most common is the aquifer in the sandy deposits of the Neogene Baraniv beds with Maastricht marls serving as the water resistance. The water associated with it is low pressure, fresh, mainly calcium carbonate, with satisfactory physical properties. It is unloaded in the form of numerous springs along the slopes of Roztochchya, Lviv Opillya and the Davidovsky horseback and forms the sources of streams and the River Poltva. Springs with different flow rates are located in the picturesque green corners and are a natural decoration of Lviv. Most of them are interesting geotourist sites of hydrogeological type. In particular, at the foot of the northeast slope of the Gora Vysokiy Zamok, the Neogene aquifer is unloaded in the form of a highly debit spring, which is mentioned in historical documents from 1510 and is known as the Royal Source or St. Mary's Source (Fig. 5).

History of the formation and functioning of Lviv, like most other cities, is related to the geomorphological features of the territory and its geological structure. After all, the erection of any historic city depends mainly on the availability and types of natural stone building materials (natural geological resources) and defence capability (defensive geomorphological conditions). Natural stone material has been widely used throughout the world due to its durability, and its facilities allow us to see the historical and economic evolution of cities, to trace the architectural style of each era, to evaluate the suitability of each type for various processing for construction use, sculpture, interior or exterior. The natural stone of the walls of the buildings is an interesting object of urban tourism and attracts the attention of both tourists and scientists (De WEVER, Baudin, Pereira et al., 2017; Górska-Zabielska, Zabielski, 2019).

The geotouristic objects of the anthropogenic supergroup in Lviv are numerous and diverse. Their discovery, research, systematization, cataloguing and mapping have only just begun. They are divided into two groups: natural-cultural (stone for building needs, urban fossils, museum exhibitions, historical and cultural sites related to geology or well-known geologists) and mining (former quarries) (Fig. 6).

The historical buildings in the construction of which natural stone material was used (for walls, decoration, facing), pavement, road stone determined

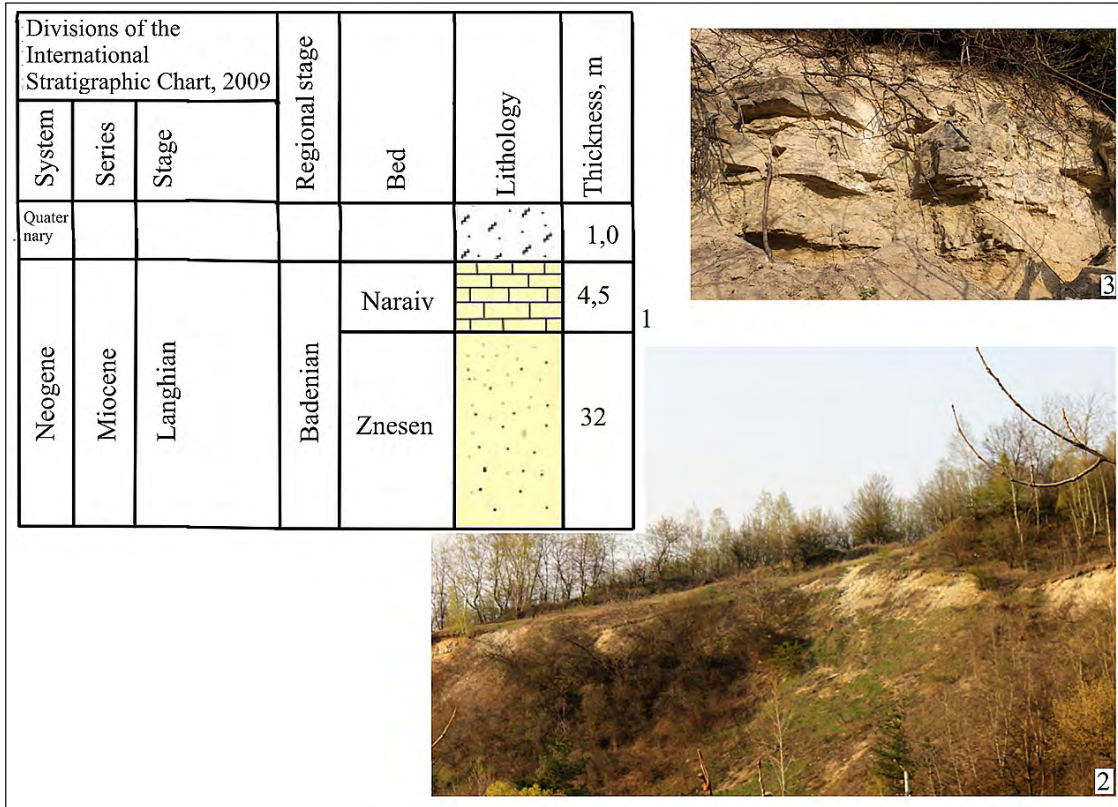


Fig. 4. Geological Landmark Kortumova Gora: 1 – schematic stratigraphic column; 2 – general view; 3 – Naraiv limestones. Symbols to the stratigraphic section in Fig. 2.

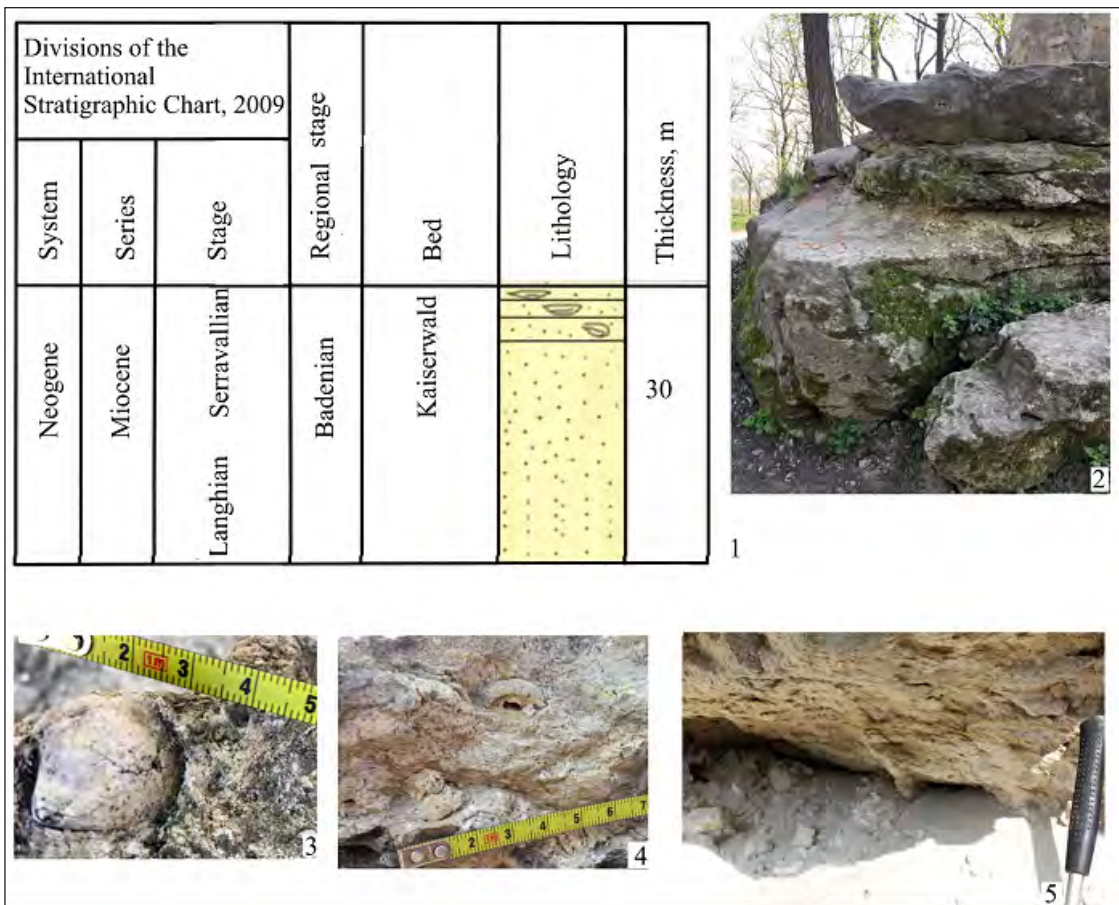


Fig. 5. Geological Landmark Gora Vysokiy Zamok: 1 – schematic stratigraphic column; 2 – an outcrop of the Kaiserwald sandstones; 3, 4 – mollusc fossils; 5 – sediments of the Kaiserwald layers sand and sandstone. Symbols to the stratigraphic column in Fig. 2.



Fig. 6. Types of geotourist objects of Lviv: 1 hydrogeological type of group of natural formations “Royal” spring at the foot of the northeast slope of the Gora VysokiyZamok; 26 anthropogenic geotourism sites: 2 mining group: a former quarry of limestone mining on Mount Ratyn; a group of natural-cultural objects: 3, 4 – wall stone (sandstone) of Lviv defensive structures (3 broken stone; 4 general view of the wall); 5 stone (limestone) sculptures of the Cathedral; 6 wall stone (limestone) of historical buildings (Boim’s chapel).

the architectural identity of Lviv. The buildings of the central part of Lviv, built at different times, show the trends of stone material usage during certain historical periods. First used was local stone, which did not cost much to extract and transport. Mostly it was limestone, which in the form of broken stone and hewn blocks we see in the remains of the defensive walls of Lviv (Fig. 6). The hewn blocks of various lithogenotypes of limestone are the main building material of the central part of the city. Here we see sacral and residential

buildings that are built solely from it or in combination with other material, including bricks. Sandstone was somewhat less used. During a walk through the city centre, we have the opportunity to see the main types of limestones and sandstones mined in Lviv and its surroundings, their structural and textural features, fossils, areas of destruction and characteristic forms of weathering, mineral growths on them. The objects are all structures of the historical part of Lviv, in which the stone is not closed to inspection (Fig. 6).

The interior decoration of these buildings is much richer, although dominantly there is the alabaster of different colours (Fig. 7), Devonian black limestone known as ‘dębnik’, red-coloured Devonian sandstones and marble. The use of igneous rocks has become a hallmark of modern alterations and decorations. Granite and labradorite are dominant among them. Other objects where you can see this material are modern monuments and memorial plaques.

The Lviv cobblestone pavement deserves particular attention (Fig. 7). The tradition of laying street cobblestone was introduced in Lviv at the same time as the start of stone construction (Pihurko, U. 2000). For this purpose, broken stone of various sizes,

paving stones, hewn blocks, face pavers, bar and mosaic from paving stones were used. Besides, natural stone paving was used on sidewalks and squares. The material which was used for the covering is very diverse. Certainly, the first one used was sandstone, which was mined in quarries near Lviv. If you look at the roads in the central part of Lviv today, it seems that they are mostly made of basalt. However, outside the central streets we see under our feet a diverse composition of shapes and colours.

A special place where a unique collection of different rocks is assembled in a small restricted area is the cemeteries (Del Lama, E.A., 2018). There are several historic cemeteries in Lviv, among which the

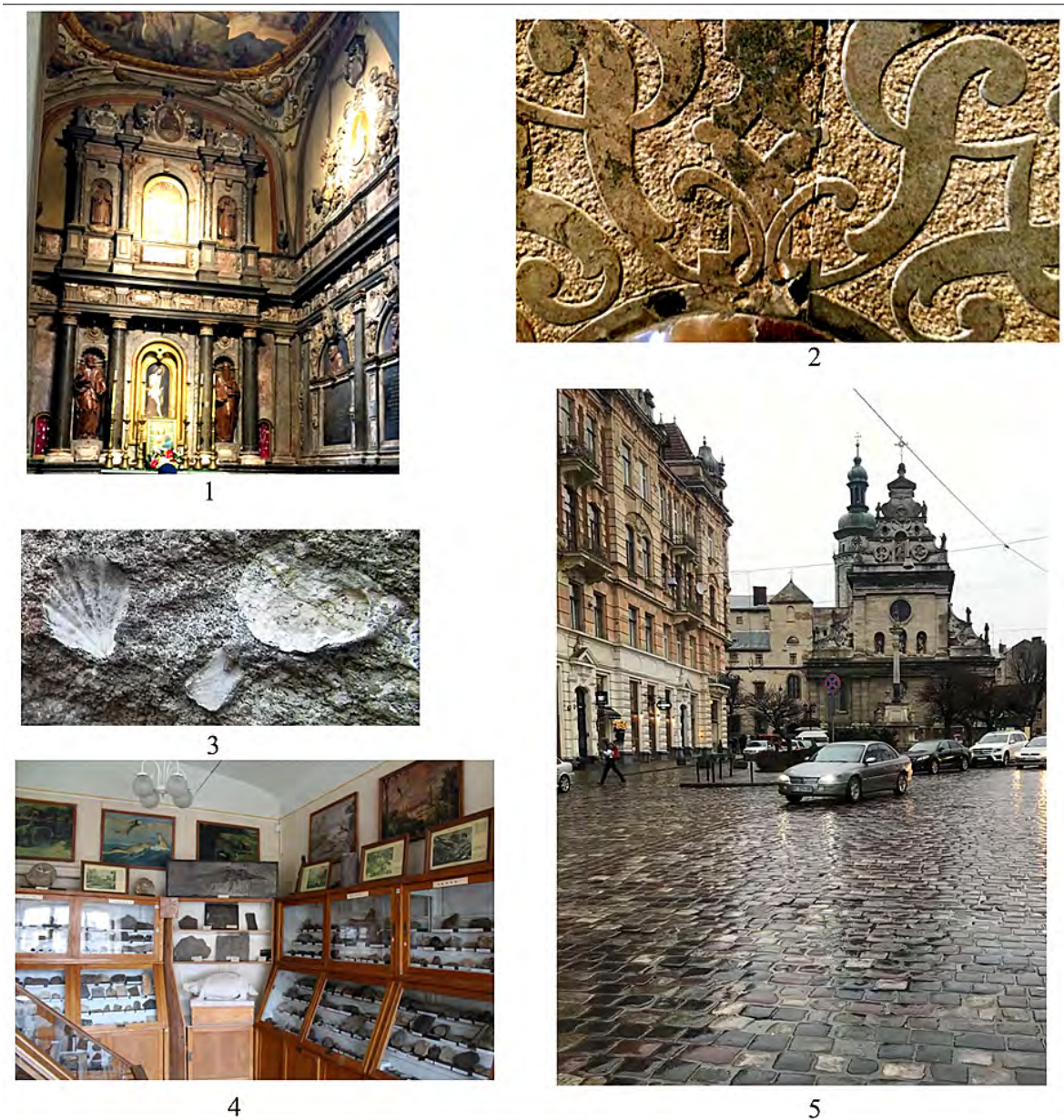


Fig. 7. Some anthropogenic natural-cultural geotourist sites of Lviv: 1, 2 – the natural decoration stone of the walls of the Chapel of the Campians of Latin Cathedral (1 – general view of the chapel, 2 – a fragment of the decoration of the wall with alabaster, or «Rusyn marble»); 3 – urban fossils (prints of the *Bivalvia* molluscs shell in the wall stone of the City Arsenal); 4 – exposition of the Paleontological Museum of the Geological Faculty of LNU I. Franko; 5 – pavement of Halytska Square

main attraction for tourists is the memorial cemetery “Lychakivsky Necropolis” one of the oldest existing communal cemeteries in Europe (Fig. 1). On the graves of the cemetery there are about 500 sculptures, mostly made of natural stone. Here you can trace the tendency to use one or another material depending on the preferences and capabilities of the customer, to assess the stability of natural stone in the conditions of ‘open-air’, to trace the main causes and directions of the destruction of various materials. This is a source of historical information, as well as a unique, very specific gallery of works of art, both of famous artists and unknown masters, which makes it an extremely attractive tourist destination.

In natural wall and road stone of sedimentary origin, fossil remains of animal and vegetable origin occur—urban fossils. It is an interesting and specific object of geotourism and paleontological research, the study of which requires a special technique, based mainly on visual observations in conditions of limited access to the fossils. The urban fossils of Lviv are numerous in the wall stone of ancient buildings, built in the XIV - beginning of the XX century. At this time the construction used the limestone of the Neogene, which contain fossils of algae, bivalves, gastropods, sea urchins (Fig. 7), etc.

For scientific-tourist purposes and educational activities, museum exhibits of specialized geological museums are important components of natural-cultural geotourist sites. There are four museums of geological profile in Lviv: Paleontological Museum (Fig. 7), Mineralogical Museum, Ore Formation Museum of the Geological Faculty of I. Franko Lviv National University. and paleontological exposition of the Natural History Museum of NAS of Ukraine. Their characteristics are in the public domain, including on their sites.

Different minerals have been mined around Lviv since ancient times. Anthropogenic influence on the territory of Lviv is traditionally manifested in the exploitation of rocks for construction purposes. These were quarries of sandstone, limestone, marls, gypsum and later (most intense in the second half of the XX century) the open-cast exploitation of sand deposits . Because of the intensive development of deposits

landscapes of Lviv were transformed, anthropogenic forms of relief were created, and on the site of former mining, there are bowls of inactive quarries that were not reclaimed at one time.

Steep upper and gentle contours, working walls, soles of quarries that characterize geometry, size of quarries and their depth have well preserved (fig. 2). They are classified as monotypic geo-industrial ge-

osites with valuable geological features.

Conclusion. Lviv is a city with high geotourism potential due to the large concentration of unique easily accessible geotourist sites in the area, well-developed tourist infrastructure and good information support. The geotourist sites of Lviv are carriers of historical and cultural information, an element of the urban ecosystem. They are a particularly valuable asset to be preserved in the first place. Most of Lviv’s urban geobjects have just started to be explored. They are divided into two supergroups (natural, anthropogenic), four groups (natural formations, natural processes, geotourism trails, natural-cultural, mining), two subgroups (polytypic, monotypic), 11 types and 19 categories. The main groups of geosites and promising directions of development of geotourism in Lviv are briefly characterized. That will allow geomorphological and geological features of the city to be shown , allow us to get acquainted with the history of geological development, help to draw attention to the stone material used in the organization of urban space. Lviv as an urban complex of geotouristic objects has scientific, cognitive, cultural and aesthetic value. All geosites are easily accessible, useful for the educational process, are an important link for reconstructing the Earth’s history, exposing the geological structure of Lviv territory. They demonstrate new approaches to geotourism that combine nature, history and culture. Combining stone memorials with a cultural and tourist aspect is a great approach for disseminating geological knowledge.

Future tasks related to urban geo-tourism in Lviv include cataloguing objects by geological attractiveness and informative nature, laying out routes that emphasize the relationship between the main stages of urban planning and geological features of the territory, and further exploration of anthropogenic geotourism objects.

References

- Andreeva-Grigorovich, A. S., Gruzman, A. D., Kulchytsky, Y. O, Ivanina, A. V. et al., 1997. Regional stratigraphic scheme of Neogene formations of the Central Paratethys in the Ukraine. *Geologica Carpathica*. 48 (2), 123-136.
- Babynek, A. E., Burov, V. S., Vyalov, O. S. i dr., 1958. *Putevoditel ekskursii s'ezda Karpato-Balkanskoj Asociacii* [The Guide to excursion of the Congress of the Carpathian-Balkan Association]. Lvov: Lvov Univ. (in Russian).
- Bezvinnyj, V. P., Biletskyj, S. V., Bobrov, O. B. ta in., 2006. *Geologichni pamyatky Ukrainy* [Geological land-

- marks of Ukraine: In 4 volumes]. Kyiv: Dia (in Ukrainian).
- Del Lama, E. A., Bacci, D. D. L. C., Martins, L, Garcia, M. G. M., Dehira, L. K., 2015. Urban geotourism and the old Centre of São Paulo, Brazil. *Geoheritage*. 7, 147–164. <https://doi.org/10.1007/S12371-014-0119-7>
- Del Lama, E. A., 2018. Potential for Urban Geotourism: Churches and Cemeteries. *Geoheritage*. 11 (3), 717728. <https://doi.org/10.1007/s12371-018-0325-9>
- Del Monte, M., Fredi, P., Pica, A., Vergari, F., 2013. Geosites within Rome City center (Italy): a mixture of cultural and geomorphological heritage. *Geografia Fisica e Dinamica Quaternaria*. 36, 241-257.
- Denysyk, G. I., Strashkevskaya, L. V., Korinnyj, V. I., 2014. *Geosayty Podillya [Geosites of Podillya]*. Vinnitsya: Vinnitsa Regional Printing House (in Ukrainian).
- Derzhavnageologichnakarta Ukrainy. 2004. Mashtab 1: 200 000, arkush M-34XVIII (Rava-Ryska), M-35-XIII (Chervonograd), M-35-XIX (Lviv). [State geological map of Ukraine, scale 1: 200 000, sheets M-34XVIII (Rava-Ryska), M-35-XIII (Chervonograd), M-35-XIX (Lviv)]. Kyiv: Ministry of Environment and Natural Resources of Ukraine (in Ukrainian).
- De Wever, P., Baudin, F., Pereira, D., Cornée, A., Egoroff, G., Page, K., 2017. The importance of geosites and heritage stones in cities—a review. *Geoheritage*. 9, 561–575. <https://doi.org/10.1007/s12371-016-0210-3>
- Geology of Lviv // Wikipedia, the free encyclopedia [Electronic resource]. – 20052015. – [Cited 20052015]. – Available from: <https://uk.wikipedia.org>
- Górska-Zabielska, M., Zabielski, Z., 2017. Potential values of urban geotourism development in a small Polish town (Pruszków, Central Mazovia, Poland). *Quaestiones geographicae*. 36(3), 75-86.
- Górska-Zabielska, M., Zabielski R., 2019. Stone in an urban space – its potential to promote geotourism. *GeoJournal of Tourism and Geosites*, 26(3), 1033–1045. <https://doi.org/10.30892/gtg.26327-415>
- Grytsenko, V.P., Ishchenko, A.A., Rusko, Yu.O., Shevchenko, V.I., 1995. *Geologichni pamiatky pryrody Ukrainy: problemy vyvchennya, zberezheniya ta racionalnogo vykorystannya*. [Geological natural monuments of Ukraine: study, preservation and natural use]. Kiev: NAN of Ukraine. /Preprint NAN of Ukraine. 95-1 (in Ukrainian).
- Grytsenko, V.P., Korniyets N. L., Rusko, Yu. O., Yarozhshuk E. O., 2001. Muzejny aspekt vyvchennya geologichnich pamiatok Ukraine Museum aspect of the study of geological monuments of Ukraine]. *Bulletin of the National Museum of Natural History*. Kiev. 1. 15-28. (in Ukrainian).
- Hozhyk, P. F., Semenenko, V. M., Polietaiiev, V. I. ta in., 2012. *Stratyhrafichni kodeks Ukrainy [Stratigraphic code of Ukraine]*. – Kyiv. – 66 (in Ukrainian).
- Ivanina, A., Bornyak, U., 2018. Potenciyni obekty miskogo turyzmu Lvova [Potential objects of Lviv city geotourism]. *Geotourism: practice and experience*. Lviv, Kamenyar, 4649 (in Ukrainian).
- Ivanina, A., Hotsanyuk, H., Spilnyk, H., Pidlisna O., 2018. Systematizacia I characteristic geoturystychnych obektiv regionalnogo landschaftnogo parku Znesinnya (m. Lviv) [Systematization and characteristics of geo-touristic objects of the Regional Landscape Park “Znesinnia” (Lviv)]. *Dniprop. Univer. bulletin. Geology, Geography*. 26(1), 50-63 (in Ukrainian). Doi: 10.15421/111806
- Ivanina, A., Hotsanyuk, H., Spilnyk, H., Pidlisna O., Salinska, H., 2016. *Characteristica unikalnoi paleontologichnoi pamyatky – misceznahodzhennya miocenovoi bioty v centri Lvova [Characteristic of unique paleontological Miocene biota location sights in the center of Lviv]*. *Visn. of the Lviv Univ. Geol. Ser.* 30, 149–158 (in Ukrainian).
- Ivanina, A., Pidlisna O., 2017. Standartyzovana characteristic pryrodnykh geologichnykh objektov regionalnogo landschaftnogo parku Znesinnya (Lviv) [Standardized characteristic of natural geological objects of the Regional Landscape Park “Znesinnia” (Lviv)]. *Visn. of the Lviv Univ. Geol. Ser.* 31, 118–129 (in Ukrainian).
- Khomenko, Yu. T., Isakov, L. V., Manyuk, V. V. 2018. On the development of geotouristic routes on the objects of the Precambrian Rock Association of the Western Priazovia. *Journal of Geology, Geography and Geoecology. Dnipro*, 27(2), 244260.
- Kudrin, L. N. 1966. *Stratigrafiya, facii ekologicheskij analiz fauny paleogenovyh i neogenovyh otlozhenij Predkarpattia*. [Stratigraphy, facies and ecological analysis of the Paleogene and Neogene deposits in the Precarpathians]. Lvov: Printing Center of Lvov University (in Russian).
- Lomnicki, M., 1884. *Slodkowodny utvortzecziorzedny na Podolu Galicyjskim*. *Kosmos*, 9, 712. Lviv City Council. 2020. Lviv City Council. Retrieved from: <https://lviv.travel/en>
- Malska, M. P., Zin'ko, Yu. V., Shevchuk, O. M., 2014. *Perspektyvy rozvytku geoturizmu v Ukraini [Prospects for development of geotourism in Ukraine]*. *Geotourism: practice and experience*. Lviv, NVF KartyiAtlasy, 152 (in Ukrainian).
- Manyuk, V. V., 2015. *Objects of Geological Heritage in the Kirovohrad Region as Basis for Geotourism Development*. *Visn. of National Nature museum*. 13, 1016.
- Matolych, B. M., Kovalchuk, I. P., Ivanov, E. A., 2009. *Pryrodni resursu Lvivshchyny*. [Natural Resources of Lviv Region]. Lviv: P P Lukashchuk V. S. (in Ukrainian).
- Migoń P., 2012. *Geoturystyka*. [Geotourism]. Warszawa: Wyd. Naukowe PWN (in Polish).
- Palacio-Prieto, J. L., 2015. *Geoheritage within Cities: Urban Geosites in Mexico City*. *Geoheritage*. 7, 365–373. doi: 10.1007 / s12371-014-0136-6

- Pihurko, U. 2000. Lvivsky bryki (za materialamy proektu schlyahovykh pokryt i moschennya pischokhidnykh terytoriy centralnoi chastyny Lvova [Lviv pavers (according to the materials of the project of road coverings and paving of pedestrian territories of the central part of Lviv)]. Visn. of the Institute "Ukrzakhidproektrestavrasiya". N 11.2330 (in Ukrainian).
- Rodrigues, M. L., Machado, C. R., Freire, E., 2011. Geotourism routes in urban areas: a preliminary approach to the Lisbon geoheritage survey. *GeoJournal Tour Geosites*. 8, 281–294.
- Ross, K., Dowling and David Newsome, 2006. *Geotourism*. Oxford; Burlington, MA: Elsevier Butterworth-Heinemann. 260.
- Słomka, T., Kicińska-Świederska, A., 2004. Geoturystyka podstawowe pojęcia. [GeoTurystyka]. T. 1(1), 5–7.
- Unesco. 2020. Retrieved from: <https://unesco.org/>
- Venglinskyi, I. V., Goretskyi, V. A., 1979. Stratotypy mio-cenovykh otlozheniy Volyno-Podolskojplyty, Pred-carpatskogo i Zakarpatskogo progibov [Stratotypes of Miocene deposits of Volyn-Podol plate, Precarpathian and Transcarpathian foredeeps]. Kyiv: Nauk. dumka (in Russian).
- Voloshyn, P., Slyvko, E., Knysh, I., Kremin, N., Bubniak, I., 2017. Geoturystychny ipotencial okolye Lvova. [The geo-tourism potential of Lviv outskirts]. *Zeleni Karpaty*. 14, 8285 (in Ukrainian)..
- Vyalov, O. S., Goretskyj, V. A., Kudrin, L. N., Pasternak, S. I., 1954. *Kratkij geologicheskij putevoditel po Lvovu*. [A brief geological guide to Lviv]. Lvov: Printing Center of Lvov University (in Russian).
- Wimbledon, W. A. P., Gerasimenko, N. P., Ishchenko, A. A., 1999. Problemy ohorony geologichnoi spadshchyny Ukrainy. [Problems of protecting the geological heritage of Ukraine]. Kyiv: DNCRN-SNANUkrainy. (in Ukrainian).
- Wimbledon, W. A. P., SmithMeyer, S., Erikstad, L., Brilha, J., van den Ancker, H., 2013. *Geoheritage in Europe and its Conservation*. ProGEO.