

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

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

Journ.Geol.Geograph.
Geoecology,
27(3), 510-519
doi:10.15421/111875

M. Syvyj, B. Gavrychok

Journ.Geol.Geograph.Geoecology, 27(3), 510-519

Construction sands of Podillya: patterns of distribution, resources and use

M. Syvyj¹, B. Gavrychok¹

¹Ternopil National Pedagogical V. Hnatyuk University, Ternopil, Ukraine, syvyjm@ukr.net

Received 11.09.2018;

Received in revised form 20.09.2018;

Accepted 20.10.2018

observed with the simultaneous increase in the thickness of the overlapping strata of the rocks. There is no apparent correlation between the thickness of sandy interlayers and the quality of sands. The interdependence of the chemical composition of Neogene sands and the sand size module is established. The genetic predisposition for the distribution of building sands in different parts of the Podillya territory has been established. Four groups of sand deposits of different age have been identified within the Podillya regions, which contrast sharply with single deposits in the neighbouring territories. There is a very uneven distribution of explored reserves of sandy raw materials across the region and accordingly in the provision of construction sands in the different oblasts /regions of Podillya. The areas best provided with sandy raw materials are the central districts of Ternopil region and Slavutsky district of Khmelnytsky region. Sands of the Baltic stage distributed in Vinnytsia region are mostly poor in quality, clogged with clay material and require enrichment. The further development of the mineral raw material base and the prospects for increasing the production of construction sand in the Podillya regions is associated with the increase in production at the prepared deposits, the commissioning of reserve deposits, the conducting of prospecting and exploration work in the proposed potentially exploitable areas and additional exploration of individual deposits that are exploited. The research allows us to evaluate objectively the existing base of sand raw materials for various purposes in the Podillya region and to develop on this basis measures to increase it. The importance of the study is determined by the acute shortage of the raw material in most administrative districts of Khmelnytsky and Vinnytsia regions, by the growth in the volume of construction work (and accordingly the requirements for sandy raw materials) both in Podillya and in the country.

Keywords: sand raw materials, construction sands, book volume, inferred resources, provision of sand raw materials

Будівельні піски Поділля: закономірності поширення, ресурси, використання

М. Сивий¹, Б. Гавришок¹

¹Тернопільський національний педагогічний університет імені Володимира Гнатюка, м. Тернопіль, Україна, syvyjm@ukr.net

Анотація. Подано характеристику ресурсної бази будівельних пісків у межах трьох подільських областей, закономірності поширення пісків, пропозиції щодо нарощування видобутку сировини. Встановлено, що будівельні піски Поділля приурочені до відкладів верхньої крейди, неогену та антропогену. Простежено зменшення потужності піщаних верств опільської світи неогену у східному напрямку з одночасним зростанням потужностей перекриваючих товщ порід. Видимого взаємозв'язку між потужністю піщаних проверстків та якістю пісків не виявлено. Установлюється взаємозалежність хімічного складу неогенових пісків і їхнього модуля крупності. Установлено генетичну зумовленість поширення на теренах Поділля будівельних пісків різного призначення – в межах подільських областей виявлено чотири угруповання родовищ пісків різного віку, які різко контрастують з поодинокими покладами на сусідніх територіях. Встановлено дуже нерівномірний розподіл розвіданих запасів піску будівельного по території регіону й, відповідно, різну забезпеченість ними окремих адміністративних одиниць подільських областей. Найкраще забезпечені піщаною сировиною центральні райони Тернопільської та Славуцький район Хмельницької областей. Піски балтського ярусу, поширені на Вінниччині, в основному дрібні, засмічені глинистим матеріалом та потребують збагачення. Подальший розвиток мінерально-сировинної бази та перспективи зростання видобутку будівельного піску в подільських областях пов'язуються з нарощуванням обсягів видобутку на підготовлених родовищах, введенням у експлуатацію резервних родовищ, проведенням пошукових та розвідувальних робіт на запропонованих перспективних площах, дорозвідкою окремих родовищ, які експлуатуються. Здійснене дослідження дозволяє об'єктивно оцінити наявну базу будівельного піску різного призначення в подільських областях, розробляти на цій

основі заходи для її нарощування. Важливість дослідження визначається гострим дефіцитом охарактеризованої сировини у більшості адміністративних районів Хмельницької та Вінницької областей, зростанням обсягів будівельних робіт (і, відповідно, потреб у будівельному піску) як на Поділлі, так в країні загалом.

Ключові слова: піщана сировина, будівельні піски, балансові запаси, прогнозні ресурси, забезпеченість піщаною сировиною

Introduction. The Podillya region (Ternopil, Khmelnytsky and Vinnytsia regions) is relatively poor in explored reserves of construction sands (5.9% of the explored reserves in Ukraine). In addition, the distribution of deposits across the territory is rather uneven, which requires the transportation of raw materials across considerable distances both within the region and from the neighboring territories as well. The latter has a significant effect on the cost of sand. The extraction from the local explored deposits has increased somewhat in recent years (1,114 thousand m³ in 2017 compared with 701 thousand m³ in 2010), but this is not enough to meet the growth in the volume of construction work both in the region and in the country in general. Therefore, we consider that conducting research aimed at generalizing the available information on the present state of the raw material base of construction sand for various purposes in the region is of current and urgent interest.

Purpose of the article. The tasks performed by the conducted research were as follows: a) to establish the patterns of distribution of sandy deposits of different ages, their functions and genesis on the territory of Podillya regions; b) to analyze the degree of exploration of Podillya sandy deposits; c) to establish the provision of buildings and for different purposes to administrative units of the region; d) to propose some possible ways to increase the raw material base and to increase the production of building sands in the region.

Materials and methods of the investigation. It should be noted that there are very few published materials on the stated problem and almost all of them were published before the 1990s, when some exploration work on construction raw materials was widely conducted in the above mentioned areas. We can distinguish a number of recent papers where some aspects of the problem were considered (Syvyj M. Ya., 2004; Syvyj M. Ya., Paranko I. S., Ivanov Ye. B., 2013; Syvyj M. Ya., Havryshok B. B., 2016; Kitura V. M., Syvyj M. Ya., 2016; Syvyj M. Ya. et al., 2017). The questions of scientific-methodological and methodological support for research on mineral resources in general and of construction raw materials in particular have been discussed in the following publications (Hryhorovych M. B., Nemyrovskaya M. H., 1987; Korghnev M. M., 2003; Mychailov V. A. et al., 2011; Michshenko V. S., 2011; Paranko I., Burman L., Jarkov S., 2011; Rudenco L. H. et al., 2004;

Rudco H. I., Kurylo M. M., Radovanov S. V., 2011; Syvyj M. Ja., 2009 et al.).

The basis for conducting the research and writing the research paper was the stock materials of the SRDE Geoinform of Ukraine and its local departments. The research was conducted in the context of the budget topic of the Geography Department of Ternopil National Pedagogical University named after V. Hnatiuk "Complex geographic studies of natural and economic geosystems in Podillya region". Traditional methods were used: collection of actual materials for the formation of the data on the construction sands deposits in the region, analytical work related to systematization and generalization of the collected stock materials, designing of cartographic models, etc.

Research results. In the territory of Podillya, construction sands are confined to deposits of the Cretaceous, Neogene and Quaternary series.

The sands of the Cenomanian stage of the Upper Cretaceous are distributed in the extreme southwestern part of Ternopil region and in the northwestern part of Khmelnytskyi region, in the valley near the Horyn River. The sands are earthy-grey and greenish-grey, quartz-glaucinite, often argillaceous, sometimes with inclusions of flint pebbles, mostly fine-grained; in the valley near the Horyn River they are with thin interlayers of sandstone. As a rule, they are of small thickness. Adamivske-2 deposit of glauconite-quartz sands in Yarmolyntsi district of Khmelnytskyi region has been explored, the stocks are approved by the State Commission of Ukraine in 2017, and the deposit is prepared for industrial exploitation.

The sands of the Badenian stage of the Neogene series are distributed in the southwestern, western and central parts of Ternopil region and are represented by deposits of two formations: Opillia and Kosiv, according to the nomenclature adopted by geologists-industrialists.

The Opillia formation of the Middle Miocene is composed of the sediments of several genetic types: argillaceous-calcareous-sand, algal, organogenic-fragmental, sand and calcareous-sand. Sandy sediments were formed in the tidal sea area. The sands of Opillia formation are quartz, fine-grained and very fine-grained, argillaceous, some sections are ferruginized, light grey, yellowish-brown and dark grey. Their thickness varies widely - from 2-2.5 to 12-18 meters. According to the physical-mechanical analysis, the content of particles larger than 0.63 mm in the sands is usually less than 1%,

although in some areas it reaches 3-11 %, and the content of particles smaller than 0.11 mm in most cases does not exceed 10-12%. The size module of sand varies from 0.4 to 3 the content of clay particles is from 0.5 to 12%. The thickness of the overburden is 2-16 m in the explored and examined deposits (Syvyi, 2004).

There is a clear interdependence between the content of different size particles and the chemical composition of sands: with an increase in the content of particles smaller than 0.16 mm, the content of silica is drastically reduced and the content of alumina is increased. This revealed feature can be used to predict the qualitative characteristics of sands in the new and less explored areas. There is no visible interconnection between the thickness of the sand layers and the quality of sands. However, we can clearly see a decrease in the thickness of the

sandy layers in the eastern direction with the simultaneous increase in the thickness of the covering earth formations (Syvyi, 2004).

Within Ternopil region, 20 deposits with reserves of more than 34 million m³ by A+B+C₁ categories and 20 occurrences of sands, which were examined with tests for physical and mechanical analysis, with inferred resources of more than 11 million m³ are connected with the deposits of Opillia formation (Table 1). As has been already mentioned, they are located mainly in the southern, western and central districts of the region.

Several deposits are also found in Husiatyn, Pidvolochysk and Kremenets districts of the region, and they are referred to Kosiv formation of the Middle Miocene (Yablunivske, Maloberezhtsivske).

Table 1. Stratigraphic confinement of deposits and occurrences of construction sands in Podillya*

Region Stratigraphic taxa	The quantity of deposits and occurrences		Distribution in the region (districts)
	Explored reserves, thousand m ³	Inferred resources, thousand m ³	
Ternopil region Upper Anthropogenic (Q _{III})	4/8190	1/150	Buchach, Shumck
Lower and Middle Anthropogenic (Q _{I-II})	–	2/65	Zboriv, Borshchiv
Sarmatian stage Miocene (N _{1s})	16/23350	10/835	Lanivtsi, Terebovlia, Ternopil, Chortkiv, Shumsk
Kosiv formation (N _{1ks}) Badenian stage Miocene	2/3382	1/75	Husiatyn, Kremenets, Pidvolochysk
Opillia formation (N _{1op}) Badenian stage Miocene	20/34170	20/11280	Berezhany, Borshchiv, Buchach, Zalishchyky, Zbarazh, Kozova, Zboriv
Cenomanian stage Cretaceous series (K ₂)	1/130	–	Monastyrskyi
Khmelnitskyi region Recent beds (Q _{IV})	3/9800	–	Slavuta
Middle and Upper Anthropogenic (Q _{II-QIII})	26/59500	6/2700	Bilohiria, Iziaslav, Kamianets-Podilskyi, Po- lonne, Slavuta, Shepetivka
Sarmatian stage Miocene (N _{1s})	9/18000	16/6300	Vinkivtsi, Horodok, Kamianets-Podilskyi, Polonne, Stara Syniava, Chemivtsi
Vynnytsia region Upper Anthropogenic (Q _{III})	19/9150	9	Haisyn, Bershad, Illintsi, Pohrebyshche, Tro- stianets, Chechelnyk
Middle Anthropogenic (Q _{II})	6/13500	2	Lypovets, Haisyn
Baltian formation Miocene-Pliocene (N _{1-2bl})	10/15700	6	Vynnytsia, Nemyriv, Zhmerynka, Teplyk, Tyvriv, Chechelnyk
Sarmatian stage Miocene (N _{1s})	6/5940	19	Mohyliv-Podilskyi, Murovani-Kurylivtsi, Pishchanka, Tomashpil, Tulchyn, Chernivtsi

*Data from Geoinform of Ukraine

The sands are quartz, light grey, greenish-grey, very fine-grained and fine-grained with interlayers of sandstones and clay. Their thickness varies from 5 to 16 m, and the explored reserves exceed 3 million m³.

The sands of Sarmatian stage are widespread in the territory of all three regions of Podillya.

In Ternopil region they have been explored and are being exploited in Ternopil, Terebovlia,

Chortkiv, Lanivtsi, and Shumsk districts. The sands are mostly quartz, consertalwith a predominance of fine fraction (the size module is often 0.4-2.0), light grey, greenish grey, sometimes with a brown or yellowish tint, with the interlayers of clay and sandstones. Often the explored reserves of sands (for example, in Ternopil region: Ternopil, Chystyliv, Shliakhtyntsi deposits) in their natural state (without enrichment) do not meet the requirements of the

existing state standards for sands as fillers for concrete, construction mortars, and materials for road construction due to the low size module, large content of grains less than 0.16 mm, and large content of argillaceous, muddy and dusty particles. In the region, 16 deposits of Sarmatian sands with total reserves of more than 23 million m³ have been explored, and another 10 deposits have been inspected and their inferred resources are not great (Table 1).

In Khmelnytskyi region, 9 sand deposits explored in detail and 2 previously explored ones are connected with Sarmatian formations. They are located in Iziaslav district (Novosilkivske and Pivneva Hora with reserves of more than 14 million m³ by C₁+C₂ categories) and 16 occurrences (the inferred resources are more than 6 million m³) are found in Vinkivtsi, Horodok, Kamianets-Podilskyi, Polonne, Slavuta and Shepetivka districts. The sands are mostly white, light grey, dark grey, yellowish-grey, consertal with the predominance of fine-grained. In the sand series, the interlayers of thick dark brown coal clay and cobbles can be seen. Sometimes the sands are with a large amount of clay material. Their thickness varies widely - from several meters to 15-20 m, sometimes even more. The deposits of Sarmatian sands in the northern parts of the region can be of great interest, where they often lie directly under the sands of Anthropogenic age, which contributes to their joint development.

In Vinnytsia region, the reserves of 6 explored deposits in Mohyliv-Podilskyi, Tomashpil and Yampil districts with sand reserves of more than 5,940 thousand m³ and 19 surveyed occurrences in Murovani Kurylivtsi, Pishchanka, Tulchyn and Chernivtsi districts are connected with the Sarmatian deposits. The sands are quartz yellowish-grey, white, greenish-grey from fine-grained to coarse-grained, but mostly their size module is 1.0-2.1. They often meet the requirements of State Standard of Ukraine B V. 2.7-32-95 (Instrukcia ..., 2007). In some cases they are suitable for the production of silicate bricks (Israilivske deposit). Sometimes, due to the large content of clay particles and the low size module, they need to be enriched for usage in construction mortars (Komarhorodske, Rakivske deposits).

The sands of the Baltian Miocene-Pliocene formation are distributed exclusively in Vinnytsia region, in its central and southeastern parts: Zhmerynska, Nemyriv, Tyvriv, and Chechelnyk districts. 10 sand deposits of Baltian stage with total raw materials reserves of about 16 million m³ have been explored. 6 investigated occurrences, the reserves of which have not been evaluated, have been found as well. The sands are grey and greenish-grey, fine-grained and medium, with the large content of clay

fraction, and their average thickness up to 2.0-3.0 m. The size module is preferably 1.0-2.0. In their natural state they mostly do not meet the requirements of State Standard of Ukraine B V. 2.7-32-95 (Instrukcia ..., 2007) due to the large content of clay particles and can only be used after enrichment (Syvyi, Paranko & Ivanov, 2013).

Sand deposits of the Quaternary age can be found mostly in Khmelnytskyi and Vinnytsia regions. In Ternopil region there is only one explored deposit with small reserves in Buchach district. Another 3 surveyed deposits with small inferred resources have been found in Shumsk, Zboriv and Borshchiv districts as well.

The main sand reserves of the Quaternary age are located in Slavuta district of Khmelnytskyi region, and partially in other northern parts of this region such as Bilohiria, Iziaslav, Shepetivka, and Polonne districts. The total explored sand reserves of the Middle and Upper Anthropogenic are estimated at over 59 million m³ of raw materials, and another 2.7 million m³ belong to the inferred resources in 6 surveyed deposits (Table 1). The sands of the Middle-Upper Anthropogenic of two genetic types are alluvial and fluvioglacial. The first are formed mainly in the valleys near such rivers as the Dniester, the Horyn, the Khomory. They are composed mainly of fine-grained and medium quartz, light grey, yellowish-grey sands, often with the gravel interlayers, sometimes with impurities of calcareous particles, and clay material. The sands are mostly conditioned, high-quality, suitable for various types of construction works, as concrete fillers, silicate bricks, etc. (Instrukcia..., 2007). Fluvioglacial sands occupy large areas in Slavuta district. These are quartz very fine-grained and medium sorts, sometimes very argillaceous. The size module is mostly 0.3-2.0. The sands are conditioned. Their thickness varies from several meters to 10-15 m, the depth of occurrence is small (Syvyi, Paranko & Ivanov, 2013).

In Vinnytsia region, the sands of the Upper Anthropogenic are also represented by two genetic types: alluvial and fluvioglacial. Alluvial sands are confined to the deposits of I-III terraces above the floodplain and are distributed along the valleys near such rivers as the Dniester, the Pivdennyi Buh. Also, they can be found in the valleys near small rivers like the Sob, the Savranka, and others. The sands are quartz, fine-grained and medium, mostly yellowish-grey, brownish-yellow, grey with gravel and pebble inclusions, with a thickness up to 6 m. The size module varies from 0.8 to 3.4. Their quality often meets the requirements of the State Standard 8736-85. Some deposits (Lukashivske, Skybynetske, Berizko-Chechelnytske, etc.) need to be enriched. 19 sand deposits of such type have been explored

mainly in Bershada, Haisyn, Trostianets, and Chechelnyk districts. (Syvyj, Paranko & Ivanov, 2013).

The fluvioglacial sands are found mainly in the northeastern part of the region and are represented by consertal, often fine-grained and medium varieties, and quartz. Sometimes they are argillaceous with a low size module. As a rule, these sands need to be enriched. There are noexplored deposits.

Three deposits (Polonske, Repyshchenske and Slavutske-1) related to recent sediments (Q_{1v}) have been explored in the valley near the Horyn River in Slavuta district of Khmelnytskyi region. Their total reserves are estimated at 9.8 million m³. The sands are quartz, fine-grained and medium, light grey, grayish-white, sometimes with a pink tint. The size module is 1.0-2.1. The sands are intended for filling concrete and construction mortars.

Nowadays, in the territory of Podillya, 120 construction sand deposits have been explored and included in the asset list. The total amount of reserves by the categories A + B + C₁ exceeds 191 million m³ (Korpan N.W. et al., 2018). As of 01.01.2018, 55 deposits of these types were being exploited, and 65 were in reserve. In the region, 11 deposits have been explored before (reserves are over 79 million m³ by the categories C₁+C₂) and 9 deposits have been searched (reserves are more than 17 million m³ by C₁ category).

113 surveyed deposits are also found, the inferred resources of which were estimated in Ternopil and Khmelnytskyi regions and exceed 26 million m³. The inspected deposits are periodically exploited by private individuals for local necessities and there is practically no information about the movement of reserves.

The sand deposits are usually small, with reserves of less than 10 million m³. There are only 7 deposits with the average reserves (approximately 10-15 million m³), 4 of them are included in the asset list, 3 deposits have been previously explored and one large deposit with reserves of more than 15 million m³ is in Khmelnytskyi region (Solo-viivske).

As we can see in Figure 1, which identifies the explored and surveyed sand deposits of Podillya, their distribution within the above-mentioned territory is rather uneven. Visually, some separated clusters of deposits are shown up in the central, western and southeastern parts of Ternopil region, in the northern parts of Khmelnytskyi and, partially, Ternopil regions, in the central and southern parts of Vinnytsia region. The location of sand deposits on the territory of Podillya is genetically predetermined. Thus, we can consider a zone of mainly alluvial sands of the Quaternary age as a whole, which extends along the Dniester through the

southern districts of Podillya (Monastyryskyi, Buchach, Zalizhchyky, Borshchiv, Kamianets-Podilskyi, Murovani Kurylivtsi, Mohyliv-Podilskyi, Yampil, Pishchanky, Chechelnyk). Another group of deposits clearly stands out in the central and western parts of Ternopil region. These are the Badenian sands of Berezhany, Zboriv, Kozova, Ternopil and Zbarazh districts. A very compact group of explored and surveyed deposits of alluvial and fluvioglacial sands of the Pleistocene is located in the north of Khmelnytskyi region. These are the deposits of Slavuta, Bilohiria and Iziaslav districts. And, finally, the fourth group of deposits associated with those of Miocene-Pliocene Baltic formation and Middle and Upper Anthropogenic occupies the central and eastern parts of Vinnytsia, in particular Vinnytsia, Tyvriv, Teplyk, Lypovets and Pogrebyshe districts. These four groups of deposits are quite clearly distinguished in the picture and contrast with the single occurrences or the complete absence of sandy raw materials in the neighbouring territories.

We provide some more information which is demonstrated by Picture 1 - a relatively small number of deposits which are exploited together with the explored reserves and a significant number of searched deposits, where the undiscovered reserves are exploited periodically. Of course, it is an alarming situation that has occurred in recent years and needs immediate resolution.

In Ternopil region, among 43 sand deposits included in the asset list, 26 were exploited with the reserves of 30.3 million m³ by A+B+C₁ categories in 2017 (Korpan N.W. et al., 2018).

Thus, 17 deposits with the supplies of 38.9 million m³ form a reserve in the region. Besides, 3 deposits with total reserves of 9 million m³ have been previously explored. These deposits can be considered as priority sites for conducting detailed exploration work and further commissioning. Another 4 deposits of the region are being searched and 39 have been already surveyed. The majority of sand deposits are located in two southern districts - Zalizhchyky and Borshchiv, but they have been surveyed only and are classified as small ones.

The deposits of industrial interest are located mainly in three districts: Zbarazh, Ternopil, and Terebovlia. Here the main amount of balance reserves of the region's sands is concentrated. First of all, these are such deposits as Chernykhovetske and Zarudechkiivske in Zbarazh, Chystylivske in Ternopil, and Volyske in Berezhany, and other districts. The last two deposits are not currently being exploited.

There is also a group of sand quarries directly close to the consumers which are construction or-

ganizations. For instance, we can see this in such towns as Berezhany, Chortkiv, Ternopil, Zbarzsh, Terebovlia and Shumsk. Such location of deposits creates certain conveniences in their exploitation and contributes to the cost reduction of sand.

Figure 2 shows the density of distribution of the explored reserves of construction sands in Podillya and their provision to separate administrative districts. In Ternopil region, the largest concentrations of construction sands per unit of the territory are observed in Zalischyky and Berezhany dis-

tricts. A high saturation of the territory with raw materials is also found in Ternopil and Zbarzsh districts. In all other regions, the figures of saturation vary in the range of 0.7-33.2 m³/ha. Monastyrskyi, Pidhaitsi, Zboriv and Pidvolochysk regions are completely devoid of explored sand reserves. Zalischyky, Berezhany and Zbarzsh districts are also famous for the provision of sand (the share of explored reserves per person of the district). All other areas are very poorly provided with this kind of raw material – 0.8-46 m³/person.

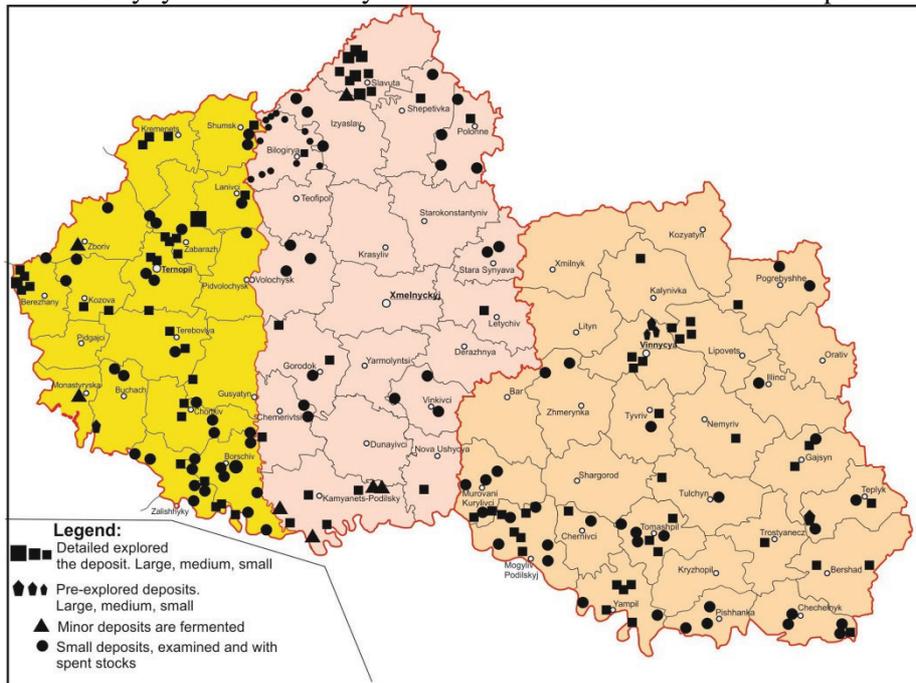


Fig. 1. Distribution and exploration of construction sand deposits in Podillya

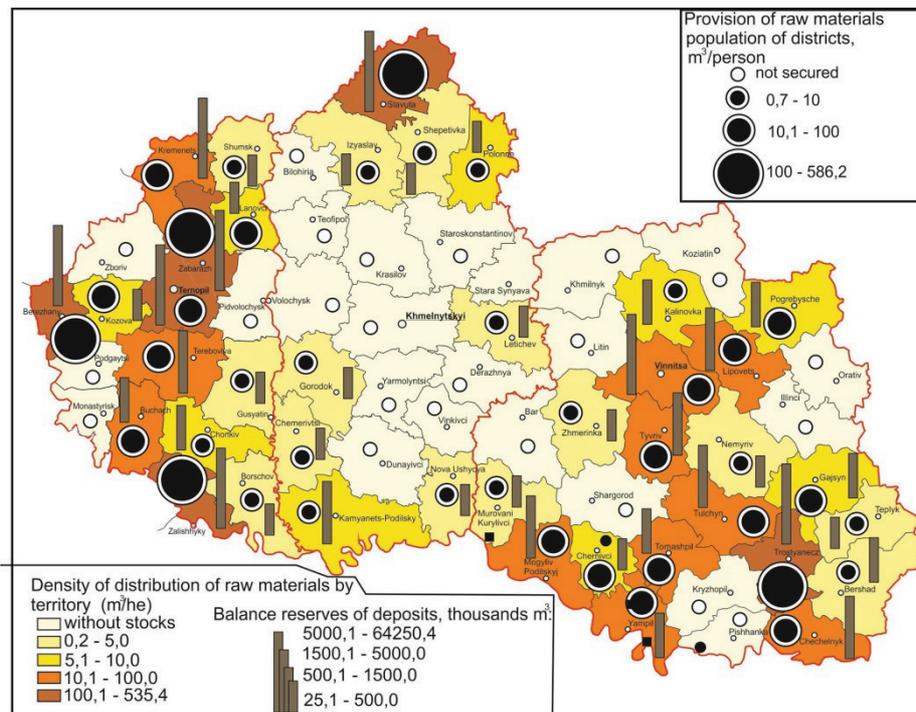


Fig.2. Distribution of reserves and provision with construction sand of the administrative districts of Podillya

The majority of explored sand reserves in the region are suitable only for production of construction mortars (more than 31 million m³). Their main part is located in Berezhany, Ternopil and Zalishchyky districts, some small reserves can be found in Husiatyn, Kozova, Terebovlia, Shumsk districts.

The sand reserves that are suitable for production of silicate bricks amount to a little more than 24 million cubic meters in the region and their main deposits are connected with Chernykhovetske deposit in Zbarazh, Chystylivske - in Ternopil and Novosilkivske - in Zalishchyky districts. Malobezhtsivske deposit in Kremenets district has some less reserves.

Sand for concrete, silicate blocks and bricks is found only in Zarudechkivske deposit (Zbarazh district).

In addition, in the region there are certain sand reserves for concrete, construction of roads and building mortars of 3.6 million m³ (small deposits in Zbarazh, Ternopil and Terebovlia districts).

On valuable arable lands in the region there are over 32 million m³ of sand reserves that cover an area of more than 281 hectares, and make some difficulties while conducting extraction operations. More than 40 million cubic meters of raw materials are located on non-arable lands and in the forests, with a total area of 275 hectares. The deposits on unoccupied territories are considered as a priority for future developments.

The exploitation of deposits is mainly carried out by commercial structures. The largest volume of production (66.8 thousand m³) was recorded at Zarudechkivske deposit in 2017, where the private enterprise "Grafit" extracts sand for silicate blocks, silicate bricks and construction mortars.

In total, in 2017, 356.6 thousand m³ of sand raw material was extracted in the region (Korpan N.W. et al., 2018).

In Khmelnytskyi region, as of January 1, 2018, 14 sand deposits with the approved reserves (20.2 million m³) were exploited, 22 more deposits with the potential of more than 57 million m³ were in reserve (Korpan N.W. et al., 2018). In addition, two pre-explored deposits with medium-sized reserves are found in Iziaslav district of the region: Novosilkivske deposit with the reserves of 13,200,000 m³ by C₁ category, which is located in a wetland, and the deposit Pivneva Hora with reserves of 13,032,000 m³ by C₁ category, which is located in a forested area. Both deposits are promising for detailed exploration work. In the region, there are 5 well-known searched deposits located mainly in Kamianets-Podilskyi district (alluvial sands), fine sands with reserves in of 8,256 thousand m³ by C₁+C₂ categories. One deposit (Bilotynske) is undergoing research work in

Iziaslav district (C₁+C₂ - 5,821 thousand m³). The investigated deposits are not being exploited. Moreover, in Khmelnytskyi region 35 deposits (occurrences) of construction sands were examined. They are usually fine with total inferred reserves of over 14 million m³. Some of them are periodically developed by private individuals for local needs (unauthorized extraction).

The distribution of construction sand deposits on the territory of the region is extremely uneven (Picture 1). Almost all explored reserves are located in Slavuta (95%) and, partially, in Kamianets-Podilskyi districts. Many small surveyed deposits with few reserves are also found in Bilohiria district. In most districts of the region, 2-3 small deposits are usually surveyed, and such districts as Krasyliv, Khmelnytskyi, Starokostiantyniv, Syniavtsi, Derazhnia, Yarmolyntsi (central) are completely devoid of construction sands.

Slavuta district is clearly distinguished due to the number of balance reserves. There are 18 deposits explored in detail with total reserves of over 64.2 million m³ by A+B+C₁ categories, 7 of which are being exploited (total reserves are over 43 million m³). According to the dimensions of reserves, such deposits as Horyn-Krupetske, Repshchenske, Slavutske, Soloviivske are distinguished. The last two are not being exploited. Some smaller reserves are found in two previously explored deposits of the neighboring Iziaslav district.

Only one district Slavuta (586.2 m³/person) is rich in explored reserves of construction sand. In Kamianets-Podilskyi and Polonne districts, this kind of raw material can be partially found as well (8.5 and 8.6 m³/person). In such districts as Horodok, Letychiv, Iziaslav, Chemerivtsi, Shepetivka, Nova Ushytsia, the supplies are 0.7-7.4 m³/person. Other districts of the region have no reserves of construction sand. A similar situation is observed when considering the territory's saturation of sand reserves (picture 2).

The largest reserves of raw materials suitable only for usage in construction mortars are concentrated in two deposits of Slavuta district - Repshchenske (over 8 million m³) and Slavutske (8 million m³). In the same area, the main sand reserves for silicate brick have been found (Krupetske deposit with reserves of about 15 million m³ of sand; it is not being exploited). In Slavuta district, the large sand deposit suitable for silicate blocks and bricks is Soloviivske with reserves of more than 15 million m³. It has been explored. It is the only one in the region and it is not being exploited now. Some more deposits are also found in the region: a sand deposit for the road construction and construction mortars (Horyn-Krupetske, more than 3.8 million m³), two sand deposits for concrete and construc-

tion mortars (Polianske and Starytsia-2 with total reserves of

38 million m³) and small deposits of sand, which can be used only for concrete, or for concrete, silicate blocks and bricks. Thus, in the region there is a shortage of quality sands for concrete, road surfacing but sands for construction mortars are widely distributed.

The deposits with balance reserves in the region occupy 267.6 hectares of arable land, in addition, another 32 hectares of productive land is under the deposits which are only being searched. At the same time, about 200 hectares of land are occupied by reserves of deposits that are currently under development. More than 16 million cubic meters of balance reserves, that is about 166 hectares of land, are located on non-arable land. Additionally, 116 hectares of non-agricultural land are occupied by pre-explored deposits (more than 13 million cubic meters of sand). Another 17 million cubic meters of balance reserves are located in forested areas (157 hectares); and 13 million cubic meters of the explored deposits in Iziaslav district (72 hectares) are in the forest area. So, the distribution of sand reserves on the territory of Khmelnytskyi gives hope that in the near future they will be exploited without significant losses to the agricultural lands in the region.

In 2017, the extraction from the explored reserves amounted to 683.6 thousand m³ of raw materials, which significantly exceeds the production in the neighbouring Ternopil and Vinnytsia regions during the same period. However, in fact, it is very small (for comparison, in 1992, 1,146 thousand m³ was extracted from the explored balance reserves). The largest extraction volumes were recorded in two deposits of Slavuta district - Horyn-Kropetske and Polianske, where sand is extracted for concrete and building mortars. All sand mining in the region is concentrated in Slavuta district.

The deposits of Slavuta district are exploited by private enterprises and, partially for construction of the Khmelnytskyi Nuclear Power Plant. The sand is used for the production of silicate bricks and blocks, for making concrete, construction and plaster mortars. Only Horyn-Krupetske and Repyshchenske deposits are provided with explored reserves for the long term; other fields need additional research or searching for new promising areas.

In Vinnytsia region, among 41 deposits explored in detail and included in the asset list, only 15 of them with reserves of more than 12.2 million m³ were developed, as of 01.01.2018 (Korpan N.W. et al., 2018).

In the region, 26 balance deposits with capacity of more than 32.3 million m³ are included in the reserves. Moreover, 5 pre-explored deposits

with the reserves of over 34 million m³ by C₁ + C₁ categories have been found. One of them (Pobirske) is large, located in Teplyk district. There are four other deposits, one of them (Sosonske-3) is also large, located in Vinnytsia district. 39 sand deposits in the region are considered to be preliminarily surveyed and they are periodically used to work out the unapproved reserves. Data on production volumes in these fields are absent.

As can be seen in Picture 1, the majority of the explored and searched deposits are located along the Dniester in the southern parts of the region: first of all, in Mohyliv-Podilskyi, as well as Murovani-Kurylivtsi, Tomashpil, Yampil, Pishchanka, Teplyk, Chechelnyk districts. All deposits are small, as a rule, their supply volume does not exceed 2 million m³, except Lukashivske deposit in Trostianets district, which has average reserves. One more group of deposits is stretched like a narrow band through the central districts of the region: Tyvriv, Vinnytsia, Lypovets, Pohrebyshche districts. These are mainly the sands of the Neogene-Baltian formation, rarely - alluvial and fluvioglacial sands. The deposits have a small supply volume. Vinnytsia district (6.0 million m³), Trostianets district (12.0 million m³), Tyvriv district (4.6 million m³) and Mohyliv-Podilskyi district (3.9 million m³) stand out for their balance reserves among the administrative districts.

In many districts (Haisyn, Chechelnyk, Yampil, Tomashpil, Chernivtsi, Tulchyn, Pohrebyshche, Kalynivka and Murovani Kurylivtsi) the total sand supplies range is 0.3-2.5 million m³. In some areas, mostly northern ones, there are no sand reserves at all. (Picture 2).

Trostianets (184.4 m³/person) and Tyvriv (87.5 m³/person) areas are best provided with sand. Other areas are poorly provided with this type of raw material (1.3-48.5 m³/person) (picture 2).

In the region, 12 deposits of sand for construction mortars have been explored, their total reserves exceed 12 million m³. Two small deposits are being exploited.

One sand deposit with average reserves (9.5 million m³) for silicate blocks and bricks has been found. It is Lukashivske. In general, 7 deposits of sands for the production of silicate bricks and blocks were explored. All of them are small. The sands of other deposits are suitable mainly for construction mortars, concrete and road construction.

The explored balance reserves of the deposits occupy 199 ha of arable land, 103 ha of which are on exploited fields. Another 72 hectares of arable land are occupied by previously explored deposits. On non-arable land there are only 9 million m³ of balance reserves (90 hectares) and about 16 million cubic meters of the reserves of previously explored

deposits (51 hectares). Besides, a certain amount of the balance reserves (about 3 million m³) is found in the forested areas and occupies more than 72 hectares; previously explored deposits in the forest area cover 21 hectares of land.

In 2017 extraction was actually carried out in four deposits: Hunchanske, Zherybylvske, Zhuravske, and Tyvrivske. The total production amounted to 116 thousand m³.

Conclusions and recommendations. 1. It has been established that the majority of construction sand deposits of Podillya for different purposes are confined to Quaternary (Anthropogenic) sediments, Badenian, Sarmatian and Baltian formations of Neogene and, partially the Cenomanian deposits of the Cretaceous series. Nowadays the latter are explored only within Adamivske glauconite-quartz sand deposit.

2. It was found that the location of the sand deposits in Podillya is genetically predetermined. Thus, a strip of mainly alluvial sands of the Quaternary age is distinguished as a single whole, which extends along the Dniester through the southern parts of Podillya. Another group of deposits clearly stands out in the central and western parts of Ternopil region. These are the Badenian sands of Berezhany, Zboriv, Kozova, Ternopil and Zbarazh districts. A very compact group of alluvial and fluvioglacial sands of the Pleistocene is located in the northern regions of Khmelnytskyi—the deposits of Slavuta, Bilohiria and Iziaslav districts. One more group of deposits, mainly associated with the deposits of Miocene-Pliocene and Anthropogenic Baltian formation, stretches like a narrow strip through the central districts of Vinnytsia region - Tyvriv, Vinnytsia, Lypovets, Pohrebyshche. These four groups of deposits are in contrast to the isolated occurrences or the complete lack of the explored reserves of construction sands in the neighbouring territories.

3. There is a clear interdependence between the content of different size particles and the chemical sand composition of Miocene Opillia formation on the territory of the explored region: with an increase in the content of particles smaller than 0.16 mm, the content of silica is drastically reduced and the content of alumina is increased. This revealed feature of sand formation can be used to predict the qualitative characteristics of sands in the unexplored parts of West Podillya.

4. There is no visible interconnection between the thickness of the sand layers and the quality of sands of Opillia formation. We can clearly see a decrease in the thickness of the sandy layers formation in the eastern direction with the simultaneous increase in the thickness of the covering earth formations (Syvyj, 2004).

5. The central and southern districts of Ternopil regions such as Zbarazh, Ternopil, Berezhany, Zalyshchyky, Slavuta district of Khmelnytskyi region, as well as the central and southern districts of Vinnytsia region such as Vinnytsia, Tyvriv, Lypovets, Trostianets and others are provided with the explored reserves of construction sands for different purposes best of all. A significant shortage of sandy raw materials is recorded in most parts of Khmelnytskyi. The sand deposits of Vinnytsia region have usually small reserves, and, in addition, because of the high content of clay fractions they often need to be enriched (Baltian formation, Sarmatian stage).

6. The explored (and exploited) sand deposits used mostly for production of construction mortars, road construction and provision of public services and utilities, recultivation and territorial usage predominate in all three regions. There is less sand for silicate products, and bricks. In Khmelnytskyi region there is a lack of high-quality sand for concrete and road construction. In Vinnytsia there is a lack of sand for silicate products, and road construction.

7. In our opinion, the further development of the raw mineral base of construction sands in Ternopil region can be done by: a) increasing the volume of sand extraction, primarily on the prepared deposits, in particular, Chystylvske, Shliakhtynetske, Berezhanske and others; b) the commissioning of reserve deposits such as Maloberezhztsivske, Novosilkivske, Volytske, etc., c) carrying out exploration works on some occurrences of sands with unapproved reserves (Lysovetsky, Yosyfivsky, etc.), d) conducting searches within promising areas (Kolodno-Selyshchanska of Zbarazh district, Kuty-Vaskivetska, Letovyshchenska and Tsetsenivska of Shumsk district).

The prospects for construction sand production in Khmelnytskyi region are connected, first of all, with the commissioning of balance reserves of such deposits of Slavuta district as Krupetske, Solovivske and others. The increase in industrial supplies should be expected after the detailed work on previously explored deposits of Iziaslav district (Novosilkivske, Pivneva Hora).

In Vinnytsia region, the extraction can be increased by commissioning the thoroughly explored deposits, as well as the additional research on unexplored ones with their subsequent exploitation. First of all, this concerns such large deposits as Sosonske-3 in Vinnytsia and Poborske in Teplyk districts, which are located on non-arable lands and forested areas. The growth of sand reserves can be achieved by carrying out exploration works on the promising areas and additional research on the ex-

pled deposits: a) in regions of Baltian deposits development (Vinnitsia, Zhmerynka, Tyvriv, Teplyk, Chechelnyk districts); b) in the areas of the alluvial deposits formation (mainly in the central and northern parts of the region), d) in the areas rich in Sarmatian deposits (the southern and southwestern parts).

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