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Resource Potential of Construction Sands of Podillya (Ukraine)

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ABSTRACT

The article analyzes the potential of the sand resource base for the construction of the Podillya region (Ukraine). The stratigraphic confinement of raw materials is determined. General regularities of distribution of productive horizons over the territory are characterized. The interdependence of Neogene sands on their size modulus was established. Four groups of deposits of different ages have been identified and their qualitative characteristics have been analyzed. The degree of provision with explored (balance) reserves and resources of individual administrative units of the three Podillya regions was calculated. The available raw material base of sandy raw materials for various purposes was objectively assessed. Conclusions are made about the prospects for increasing the production of sandy raw materials in the region through the study of promising areas and exploration of already known deposits.

Keywords: Sands for construction needs; explored reserves; promising areas; additional exploration; raw material base.

1. INTRODUCTION

Podillya region (Ternopil, Khmelnytsky and Vinnytsia regions) is relatively not rich 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 at considerable distances as within the regions 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 a little bit in recent years (1114 thousand m^3 in 2017 compared with 701 thousand m^3 in 2010) [1], but it is not enough due to the growth in the volume of construction work both in the region and in the country in general. Therefore, we consider that conducting of the researches aimed at generalizing of 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.

2. PURPOSE OF THE ARTICLE

The tasks solved by the conducted research were as follows: a) to establish the expansion 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 with building sand 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.

3. 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 nineties of the last century, when some exploration works on construction raw materials were widely conducted in the above mentioned areas. We can distinguish

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such recent papers where some aspects of the problem were considered [2,3], (Syvyi M.Ya., Havryshok B.B., 2016); [4,5]. The questions of scientific-methodological and methodical support for the researches of mineral resources in general and of construction raw materials in particular are studied in such publications [6,7,8,9,10,11,12,13].

The basis for conducting the researches and writing the research paper was the stock materials of the SRDE Geoinform of Ukraine and its local departments.

4. RESEARCH RESULTS

In the areas of Podillya, the construction sands are confined to the deposits of 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-gray and greenish-gray, quartz-glauconite, 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.

Opillia formation of 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 gray, yellowish-brown and dark gray. 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 overburden grounds is 2-16 m in the explored and examined deposits [2].

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 [2].

Within the Ternopil region, 20 deposits with the reserves of more than 34 million m^3 by $A+B+C_1$ categories and 20 occurrences of sands, which were examined with the tests for physical and mechanical analysis, with inferred resources of more than 11 million m^3 are connected with the deposits of Opillia formation (Table 1). As it 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	4/8190	1/150	Buchach, Shumck
Upper Anthropogenic (Q_{III})			
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	–	Monastyryskyi
Khmelnytskyi region	3/9800	–	Slavuta
Recent beds (Q_{IV})			
Middle and Upper Anthropogenic (Q_{II}-Q_{III})	26/59500	6/2700	Bilohiria, Iziaslav, Kamianets-Podilskyi, Polonne, Slavuta, Shepetivka
Sarmatian stage Miocene (N_1s)	9/18000	16/6300	Vinkivtsi, Horodok, Kamianets-Podilskyi, Polonne, Stara Syniava, Chemivtsi
Vinnytsia region	19/9150	9	Haisyn, Bershad, Illintsi, Pohrebyshche, Trostianets, Chechelnyk
Upper Anthropogenic (Q_{III})			
Middle Anthropogenic (Q_{II})	6/13500	2	Lypovets, Haisyn
Baltian formation Miocene-Pliocene ($N_{1-2}bl$)	10/15700	6	Vinnytsia, Nemyriv, Zhmerynka, Teplyk, Tyvriv, Chechelnyk
Sarmatian stage Miocene (N_1s)	6/5940	19	Mohyliv-Podilskyi, Murovani-Kurylivtsi, Pishchanka, Tomashpil, Tulchyn, Chernivtsi

**Due to Geoinform of Ukraine*

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

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 developed in Ternopil, Terebovlia, Chortkiv, Lanivtsi, and Shumsk districts. The sands are mostly quartz, consertal with a predominance of fine fraction (the size module is often 0,4-2,0), light gray, greenish gray, sometimes with a brawn 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, 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 m^3 have been

explored, and another 10 deposits have been inspected and their inferred resources are not big (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 the reserves of more than 14 million m^3 by C_1+C_2 categories) and 16 occurrences (the inferred resources are more than 6 million m^3) are found in Vinkivtsi, Horodok, Kamianets-Podilskyi, Polonne, Slavuta and Shepetivka districts. The sands are mostly white, light gray, dark gray, yellowish-gray, 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, that 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 m^3 and 19 surveyed occurrences in Murovani Kurylivtsi, Pishchanka, Tulchyn and Chernivtsi districts are connected with the Sarmatian deposits. The sands are quartz yellowish-gray, white, greenish-gray 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 [14]. 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 the usage in construction mortars (Komarhorodske, Rakivske deposits).

The sands of 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 m^3 have been explored. 6 investigated occurrences, the reserves of which have not been evaluated, have been found as well. The sands are gray and greenish-gray, fine-grained and medium, with the large content of clay fraction, and their average thickness is 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 [14] due to the large content of clay particles and can only be used after the enrichment [3].

Concerning the sand deposits of the Quaternary age they 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 placed in Slavuta district of Khmelnytskyi region, and partially in other northern parts of this region such as Bilohiria, Iziaslav, Shepetivka, Polonne districts. The total explored sand reserves of the Middle and Upper Anthropogenic are estimated at over 59 million m^3 of raw materials, and another 2,7 million m^3 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 ones 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 gray, yellowish-gray sands, often with the gravel interlayers, sometimes with the 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. [14]. 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 [3].

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 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-gray, brownish-yellow, gray 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 Bershad, Haisyn, Trostianets, and Chechelnyk districts [3].

The fluvioglacial sands are found mainly in the northeastern part of the region and are represented by consertal, often fine-grained and medium varieties, quartz. Sometimes they are argillaceous with the low size module. As a rule, these sands need to be enriched. There are no explored 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 m^3. The sands are quartz, fine-grained and medium, light gray, 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, 126 construction sands deposits have been explored and included in the asset list. The total amount of reserves by the categories A + B + C_1 exceeds 187 million m^3 [1]. As of 01.01.2020, 54 deposits of these ones were exploited, and 65 were in reserve. In the region, 11 deposits have been explored before (reserves are over 79 million m^3 by the categories C_1+C_2) and 9 deposits have been searched (reserves are more than 17 million m^3 by C_1 category).

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

As we can see at Picture 1, which indentifies 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 showed 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, Zalishchyky, 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 the 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 the ones of Miocene-Pliocene Baltian formation and Middle and Upper Anthropogenic occupies the central and eastern parts of Vinnytsia, in particular Vinnytsia, Tyvriv, Teplyk, Lypovets, Pogrebyshche 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 neighboring territories.

We provide some more information that 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 the immediate resolution.

In Ternopil region, among 47 sand deposits included in the asset list, 27 ones were exploited with the reserves of 26,9 million m^3 by A+B+C_1 categories in 2020 [1].

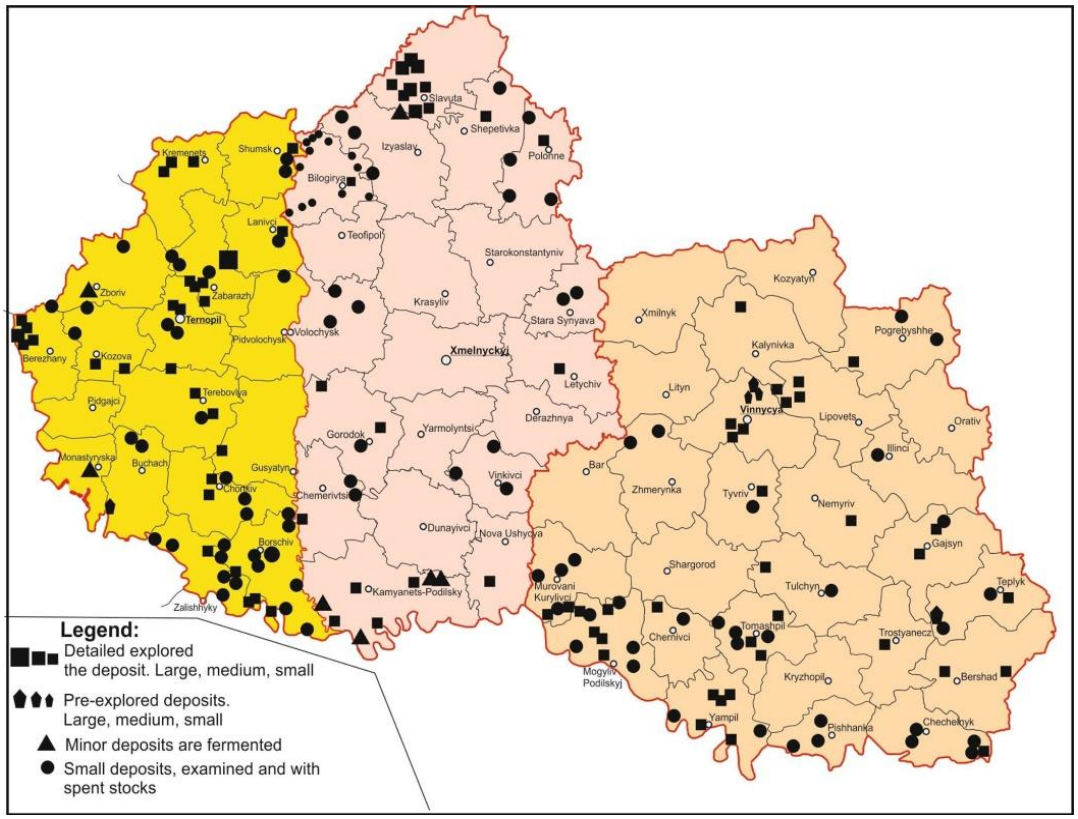
Thus, 17 deposits with the supplies of 38,9 million m^3 form a reserve in the region. Besides, 3 deposits with the total reserves of 9 million m^3 have been previously explored. These deposits can be

considered as urgent for conducting the detailed exploration work and further commissioning. Another 4 deposits of the region are being searched and 39 ones have been already surveyed.

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 focused. First of all, these are such deposits as Chernykhovetske and Zarudechkivske in Zbarazh, Chystylivske in Ternopil, and Volytske in Berezhany, and other districts. The last two deposits are not currently being exploited.

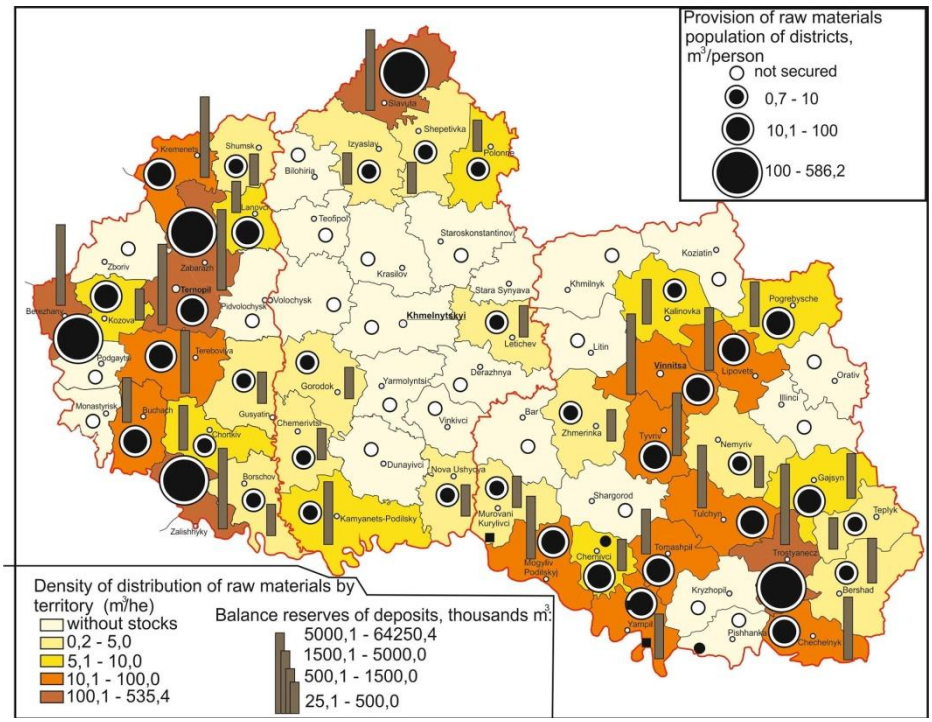
There is also a group of sand quarries directly close to the consumers, that are construction organizations. For instance, we can see this in such towns as Berezhany, Chortkiv, Ternopil, Zbarazh, Terebovlia, Shumsk. Such location of deposits creates certain conveniences in their exploitation and contributes to the cost reduction of sand.

Picture 2 shows the expansion 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 Zalishchyky and Berezhany districts. The large saturation with raw materials of the territory is also found in Ternopil and Zbarazh districts. In all other regions, the figures of saturation vary in the range of 0,7-33,2 m^3/ha. Monastyryskyi, Pidhaitsi, Zboriv and Pidvolochysk regions are completely deprived of the explored sand reserves. Zalischyky, Berezhany and Zbarazh 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 materials - 0,8-46 m^3/person.



Picture 1. Distribution and exploration of construction sand deposits in Podillya area

The majority of explored sand reserves in the region are suitable only for production of the construction mortars (more than 31 million m^3). Their main part is located in Berezhany, Ternopil and Zalishchyky districts, some small reserves can be found in Husiatyn, Kozova, Terebovlia, Shumsk districts.



Picture 2. Distribution of reserves and providence with construction sand of the administrative districts of Podillya

The sand reserves, that are suitable for production of silicate bricks, are a bit more than 24 million cubic meters in the region and their main pools are connected with Chernykhovetske deposit in Zbarazh, Chystylivske - in Ternopil and Novosilkivske - in Zalishchyky districts. Maloberezhtsivske 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 m^3 (small deposits in Zbarazh, Ternopil and Terebovlia districts).

On valuable arable lands in the region there are over 32 million m^3 of sand reserves that cover an area of more than 281 hectares, and make some difficulties while conducting mining operations. More than 40 million cubic meters of raw materials are located on noncroplands and in the forests, with a total area of 275 hectares. The deposits on unoccupied territories are considered as urgent for the future developments.

The exploitation of deposits is mainly carried out by commercial structures. The largest volume of production (66,8 thousand m^3) 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 2019, 410,8 thousand m^3 of sandstone was extracted in the region [1].

In Khmelnytskyi region, as of January 1, 2020, 14 sand deposits with the approved reserves (18,1 million m^3) were exploited, 22 more deposits with the potential of more than 57 million m^3 were in reserve [1]. 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 m^3 by C_1 category, that is located in the wetland, and the deposit Pivneva Hora with the reserves of 13032,000 m^3 by C_1 category, which is located on 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 8256 thousand m^3 by C_1+C_2 categories. One deposit (Bilotynske) is covered by research works in Iziaslav district (C_1+C_2 - 5821 thousand m^3). The investigated deposits are not being exploited. Moreover, in Khmelnitskyi region 35 deposits (occurrences) of construction sands were examined. They are usually fine with total inferred reserves of over 14 million m^3. Some of them are periodically developed by private individuals for the 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 deprived of construction sands.

Slavuta district is clearly pointed out due to the number of balance reserves. There are 18 deposits explored in detail with total reserves of over 64,2 million m^3 by $A+B+C_1$ categories, 7 of which are being exploited (total reserves are over 43 million m^3). According to the dimensions of reserves, such deposits as Horyn-Krupetske, Repyshchenske, Slavutske, Soloviivske are pointed out. The last two ones 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 m^3/person) is rich in the explored reserves of construction sand. In Kamianets-Podilskyi and Polonne districts, this kind of raw materials can be partially found as well (8,5 and 8,6 m^3/person). In such districts as Horodok, Letychiv, Iziaslav, Chemerivtsi, Shepetivka, Nova Ushytsia the supplies are 0,7-7,4 m^3/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 for only the usage in construction mortars are concentrated in two deposits of Slavuta district - Repshchenske (over 8 million m^3) and Slavutske (8,0 million m^3). In the same area, the main sand reserves for silicate brick have been found (Krupetske deposit with reserves of about 15 million m^3 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 m^3. It has been explored. It is the only one in the region and it’s 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 m^3), two sand deposits for concrete and construction mortars (Polianske and Starytsia-2 with total reserves of 38 million m^3) 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 construction, but the 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. Herewith about 200 hectares of land occupy the 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 noncroplands. 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 on the forested areas (157 hectares); and 13 million cubic meters of the explored deposits in Iziaslav district (72 hectares) are in the forest area.

In 2019, the extraction from the explored reserves amounted to 584,3 thousand m^3 of raw materials, which significantly exceeds the production in the neighboring Ternopil and Vinnytsia regions during the same period, however, in fact, it is very small (for comparison, in 1992, 1146 thousand m^3 were 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 the only Slavuta district.

The deposits of Slavuta district are exploited by private enterprises and, partially for Khmelnytskyi Nuclear Power Plant construction. 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 the explored reserves for some time; other fields need additional research or searching for new promising areas.

In Vinnytsia region, among 41 explored in detail and included in the asset list deposits only 13 of them with reserves of more than 10,8 million m^3 were developed, as of 01.01.2020 [1].

In the region, 26 balance deposits with the reserves of more than 32,3 million m^3 are in funds. Moreover, 5 pre-explored deposits with the reserves of over 34 million m^3 by $C_1 + C_1$ 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 preliminary surveyed and they are periodically used to work out the unapproved reserves. The data on production volumes in these fields are absent.

As can be seen on 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 m^3, except Lukashivske deposit in Trostianets district, which has the 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 small supply volume. Vinnytsia district (6,0 million m^3), Trostianets district (12,0 million m^3), Tyvriv district (4,6 million m^3) and Mohyliv-Podilskyi district (3,9 million m^3) 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 m^3. In some areas, mostly northern ones, there are no sand reserves at all. (picture 2).

Trostianets (184,4 m^3/person) and Tyvriv (87,5 m^3/person) areas are provided with sand best of all. Other areas are poorly provided with this type of raw material (1,3-48,5 m^3/person) (Picture 2).

In the region, 12 deposits of sand for construction mortars have been explored, their total reserves exceed 12 million m^3. Two small deposits are being exploited.

One sand deposit with the average reserves (9,5 million m^3) 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 the exploited fields. Another 72 hectares of arable land are occupied by previously explored deposits. On noncroplands there are only 9 million m^3 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 m^3) is found on the forested areas and occupies more than 72 hectares; previously explored deposits in the forest area cover 21 hectares of land.

In 2019 the extraction was actually carried out in four 13 deposits. The total production amounted to 134,6 thousand m^3.

5. CONCLUSION 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 2 glauconite-quartz sand deposit.

2. It was studied that the location of the sand deposits in Podillya is genetically predetermined. Thus, a strip of mainly alluvial sands of the Quaternary age is pointed out 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 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 Beltian 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 neighboring 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 (Syvyi, 2004).
5. The central and southern districts of Ternopil region such as Zbarazh, Ternopil, Berezhany, Zalishchyky, 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 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 providing of public services and utilities, recultivation and territories usage predominate in all three regions. There are less sands for silicate products, and bricks. In Khmelnytskyi region there is a lack of high-quality sands for concrete, road construction. In Vinnytsia there is a lack of sands for silicate products, and road construction.
7. In our opinion, the further development of 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, Chystylivske, Shliakhtynetske, Berezhanske and others; b) the commissioning of the reserve deposits such as Maloberezhtsivske, Novosilkivske, Volytske, etc., c) carrying out the exploration works on some occurrences of sands with unapproved reserves (Lysovetsky, Yosyfivsky, etc.), d) conducting searches within the 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, Soloviivske and others. The growth of 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 of pre-explored ones with their further exploitation. First of all, we can talk about such large deposits as Sosonske-3 in Vinnytsia and Poborske in Teplyk districts, which are located on noncroplands and forested areas. The growth of sand reserves can be done by carrying out the exploration works on the promising areas and additional research of the explored deposits: a) in regions of Beltian deposits development (Vinnytsia, 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).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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