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Prospects for the lithium deposits development in Ukraine

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Abstract. The article is devoted to establishing the current state of lithium deposits exploration in Ukraine and the prospects for providing strategic sectors of the economy with this critical raw material. The countries with the most favourable conditions for the lithium extraction from ore and sediment deposits, as well as the potential of Ukraine on the world market, were determined. Global trends in lithium consumption in various industries, as well as its impact on market value, have been established. The main directions of lithium use of in high-tech sectors of the economy and forecast indicators of the level of consumption until 2035 are given, which confirms the critical role of this material in the construction of electric vehicles, renewable energy and the defence industry. The mining and geological conditions for the occurrence of lithium deposits have been established, which indicates the possibility of mining this material by underground and surface method. The geological characteristics of the largest Ukrainian lithium deposits have been studied, which allows determining further directions for its development. Estimated reserves of lithium have been established in the most significant deposits of Ukraine, which include Polokhivske, Shevchenkivske, Dobra and Kruta Balka. The approximate content of lithium in the ore of the specified deposits has been determined, which makes it possible to forecast the country's resource availability with this critical raw material and the strengthening of global technological chains in the future.

1 Introduction

Lithium is a critical mineral raw material that, in combination with graphite, cobalt and nickel, ensures the development of the economy strategic branch in the manufacture of electric vehicles [1]. Today, one of these four critical elements, lithium is the most important and critical in the world electric vehicles production. The main direction of its use is the manufacturing technology of storage batteries [2]. Over the last ten years, the demand for this critical raw material has increased significantly in many times. Despite this, further crucial growth of its consumption is predicted. An analysis of the manufacturing processes of hybrids and electric vehicles shows that up to 12 kg of lithium is used in a standard hybrid, while 22 to 50 kg of this raw material must be involved in the production of Tesla model electric vehicles [3].

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Analysis of the world market of critical mineral raw materials consumption and forecast data shows that according to the US Geological Survey, as of 2021, world lithium reserves are estimated at 86 million tons [4]. Up to 58% of estimated world reserves are located at the intersection of three South American countries – Bolivia (21 million tons), Argentina (19 million tons) and Chile (up to 10 million tons) in the so-called "lithium triangle". Also, significant reserves of critical raw materials have been discovered in the USA (7.9 million tons), Australia (6.4 million tons), China (5.1 million tons), Germany (2.7 million tons), the Czech Republic and Serbia (1.3 and 1.2 million tons, respectively).

An analysis of the global experience of lithium mining shows that in 2019 the main countries with lithium mining are Australia (52.9%), Chile (21.5%), China (9.7%) and Argentina (8.3%) [5]. The lithium deposits in the Uyuni salt flats in Bolivia are mined by surface mining from salt lakes by processing lithium-containing brine.

Today, dozens of new mining enterprises aimed at lithium production are being prepared for commissioning in the world. However, the price of lithium on world markets undergoes significant fluctuations in accordance with the increase in demand and the appearance of information about the commissioning of new deposits. For example, the price of lithium in 2018 reached 17 000 $/t and in 2020 it decreased to 8 000 $/t, after which it reached its maximum mark of 75 000 $/t in 2022, while its production is constantly increasing [6] (Fig. 1).

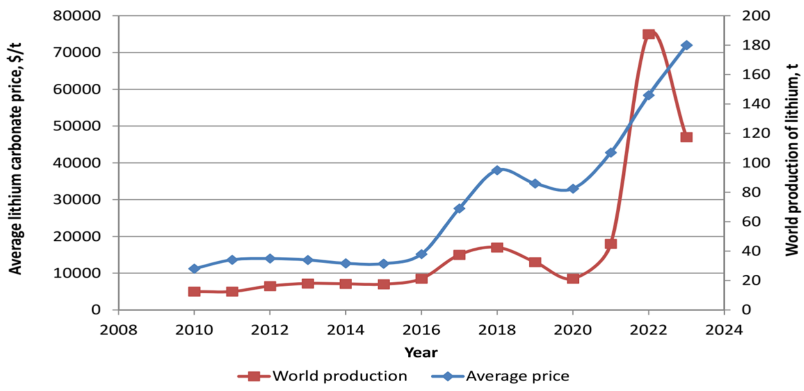

Fig. 1. World production and average price of lithium in the period 2010 – 2023.

According to the indicators presented in Fig. 1, there is a significant increase in global lithium production. From 2015 to 2023, its production increased 9 times from 20 to 180 thousand tons. However, this still does not allow to stabilize its cost, which in the period 2020 – 2022 increased 9 times to 75 000 $/t, however, in 2023 it sharply decreased to 47 000 $/t.

2 Analysis of mining and geological conditions of lithium deposits and its development

Pegmatite rocks and salt deposits should be singled out among the most common forms of lithium deposits. The first type of unique geological formations, which include spodumene, petalite and lepidolite minerals, are developed in a surface or underground mining, depending on the mining and geological conditions of the deposits. Today, in the world, about 40% sites for the extraction of lithium from pegmatite rocks, while mineral waters account for the greater part of 60%.

Lithium is distributed in pegmatite and non-pegmatite liquid metal ores, as well as in mineralized waters. It is also customary to consider its close association with beryllium when it comes to liquid metal ores, which in most cases are aluminosilicate or silicate raw materials. This is due to the fact that lithium and beryllium in ore bodies are almost always found together, for example, in liquid metal pegmatites, but there are also elements of other minerals, for example, chromium, tantalum, niobium, aluminum, etc. If we consider non-pegmatite ore bodies, beryllium minerals are also present together with lithium minerals – for example, lepidolite. In addition, the association of lithium and beryllium, in the form of isomorphic impurities, can form lithium beryllium minerals in the crystal lattices of other minerals. Due to the extraction of only these elements from ores, a rather large percentage of *Li* and *Be*, as well as *Cs*, *Rb*, *Al*, etc. is irreversibly lost with waste due to the lack of complex technology for processing such ores in Ukraine. There is also dumping of tailings into dumps after the enrichment of raw materials containing the above-mentioned valuable components without their appropriate disposal.

Ore and non-ore concentrates, which are obtained during the enrichment of liquid metal ores, have the following features. From ore concentrates, lithium, beryllium concentrates, their combinations, cesium concentrates, as well as heavy metal concentrates are most often isolated. From non-ore concentrates, lithium and quartz-feldspar, mica and fluorite concentrates are distinguished, which, depending on the type, are used in various industries, such as the production of insulating materials, ceramics and glass, as well as thermonuclear energy.

The existing world practice of lithium extraction from concentrated brines due to various technologies can also be partially considered in the complex of technologies for the development of unique deposits of Ukraine. Of course, this technology is largely due to its use in tropical countries, but with the use of selective inorganic sorbents, it can be adapted to other conditions as well. The first type of water that gained industrial importance as a source of lithium was intergranular sodium carbonate-chloride brine with lithium, and the most successful example is the dry Lake Searles in California, USA. Brine is extracted from two salt layers – upper and lower, the lithium content in the upper layer is up to 115 mg/l, and in the lower one – up to 40 mg/l. Lithium concentrate is obtained from brine-likonts, in fact it is a by-product in the production of boron, potassium, sodium, etc. salts. After processing the liquid with sulphuric acid, a mixture of solid lithium and sodium sulphates and diluted phosphoric acid is obtained, which is separated by a centrifuge. Also, a number of technological processes allow lithium sulphates to be precipitated [7]. Lithium was mined in a similar way in the Silver Peak deposit, in the state of Nevada, USA. But only lithium was extracted from natural mineralized waters here, with some changes in technology in accordance with the natural conditions of the deposit.

A deposit in the north of Chile, found within the boundaries of a salt pan, belongs to chloride-sodium type brines Salar de Atacama. Here, lithium is extracted from brines due to staged solar evaporation, which results in an increase in lithium concentration by more than an order of magnitude. The technology at this deposit did not ensure the extraction of other valuable components from the brine, which was a serious drawback. Therefore, in the future, a complex technology for the use of raw materials was developed, which made it possible to obtain commodity compounds of lithium and potassium for long-distance transportation [8]. But at the same time, the low quality of the received lithium was noted, due to which its import to a number of countries, such as Japan, was stopped.

Rare-metal granitoids of the Ukrainian shield play an important role in the mineral and raw material base of Ukraine, as far as critical lithium raw materials are concerned. Lithium ore occurrences were recorded in the Kryvorizka-Kremenchutsk suture zone and in the central part of the Ukrainian shield. Therefore, a detailed analysis of their origin and determination of the role played by the host rocks in their formation is necessary, which will allow a more correct approach to the search and discovery of promising areas of rare metals in them.

Today, metasomatic and magmatic [7] are considered the most substantiated mechanisms of formation of rare-metal granitoids, but there is still no unified point of view. In this researches general attention direct to the features that relate to the geochemical types of lithium-fluorite plumasite alaskites, rocks of increased alkalinity and some standard granites for comparison. The metasomatic origin of lithium-fluorite granites, which include granitoids of the Perzhan, Korosten, and Korsun-Novimyrhorod complexes, is beyond doubt. They are confined to fault zones and relatively containing rocks and have a significant age gap of about 10 million years [8, 9]. This is one of the signs, along with the geological-structural, petrological and geochemical differences from the granites of the brine formation. The granitoids of the stone-burial complex are also close to the geochemical type of lithium-fluorite granites, but a different mechanism of formation takes place here [9, 10]. The magmatic genesis of these rocks is indicated by the presence in them of fluid textures elements, in these direction scientists have conducted a large-scale set of studies [9, 11].

That is, based on the above, two geochemical types of plumasite are distinguished rare-metal granites of the Ukrainian shield – lithium-fluoride and standard granites, which are evidenced by the different degree of accumulation of rare elements. This gives an idea about the potential ore bearing of granitoid massifs. There are also data that the degree of greisenization decreases with depth, and below 80 m the phenomenon of metasomatic changes in granites is not recorded, that is, some types of lithium-fluorite granites turn into standard granites. For example, according to a complex of geological features, the rock-grave granites are considered to be quite limited in their ore-bearing capacity for rare metals. Remarkable, from the point of view of metallogeny, are the granites distributed on the territory of the Volyn megablock, namely, the Emelyanivsky and Ignatpilsky granites rock-shaped granites.

3 Use of lithium in high-tech production processes

One of the industries using lithium is metallurgy, in which this critical metal is need to remove impurities in the process of refining zinc, copper, iron, nickel, and other alloys of these metals. Use in the manufacture of pharmaceuticals and synthetic rubber should also be highlighted [12].

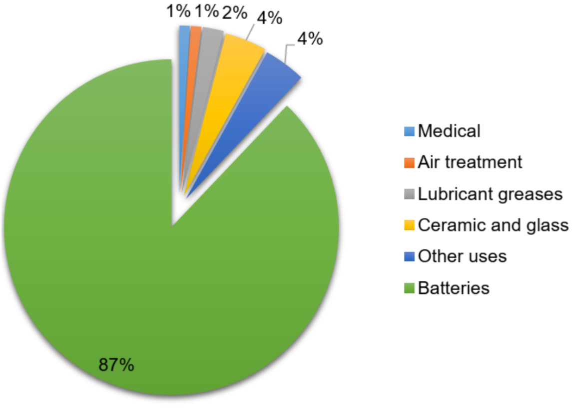

Fig. 2. Lithium end-usage in the global market share (2023).

But the main field of lithium use is mechanical engineering, namely the manufacture of lithium-ion batteries for electric vehicles (Fig. 2), which this material plays a key role in the transition to “green” technologies. Lithium, having high electrical conductivity, low density and low mass, is ideal for energy storage. Everyday gadgets where lithium contained are batteries in laptops, smart phones, video surveillance cameras, cardio-defibrillators, as well as in the development of space technologies [13].

In addition, it is used in electronics, nuclear power and porcelain industry. Lithium raw materials are used for the production of lubricants, glass, ceramics, synthetic plastics, and metal alloys. Grease containing lithium has high resistance to moisture, does not react with oxygen and does not solidify at high temperatures [14].

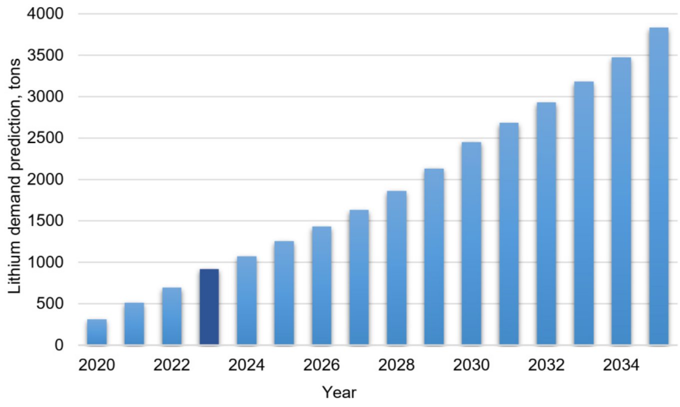

Fig. 3. Prediction of lithium consumption in the World economy to 2035.

Currently, the world does not produce enough lithium hydroxide to meet the demand caused by the dramatically growing of electric vehicles popularity [15]. As shown in Fig. 3 global demand for lithium carbonate equivalent is only projected to grow, surpassing the 2 400 t mark in 2030, which in turn is almost 2 times more than in 2025. This is due to the increase in the production of electric vehicles, which is the driver of lithium consumption in the next decade. It is expected that by 2035, the world consumption of lithium concentrate will be 3 800 t. However, this will still not be enough to cover the production capacity of lithium batteries. In this connection, there is a need for EU countries to increase the production of their own equivalent of lithium carbonate to cover the deficit in the production of electric cars.

4 Research results

4.1 Prospects of the lithium deposits development in Ukraine

Ukraine has significant deposits of lithium, which are estimated at 500.000 tons (up to 10% of world reserves) [16] Such volumes of this critical raw material, in the future, allow creating a profitable branch of industry with income to the budgets of all levels. However, the process of lithium beneficiation raw materials [17] into marketable products is quite expensive, so Ukrainian private enterprises aim only to sell ore [18]. In this regard, Ukraine should adopt the experience of EU countries, which are trying to process raw materials to obtain products with added value [19]. At the same time, tax revenues are increasing, new jobs are being created [20], and technological solutions are being improved in the country [21].

The most prominent lithium deposits in Ukraine [22] are the Polokhivske deposit and the Dobra site in the Kirovohrad region, Shevchenkivske in the Donetsk region, as well as the “Kruta Balka” of the Zaporizhzhia region (Fig. 4).

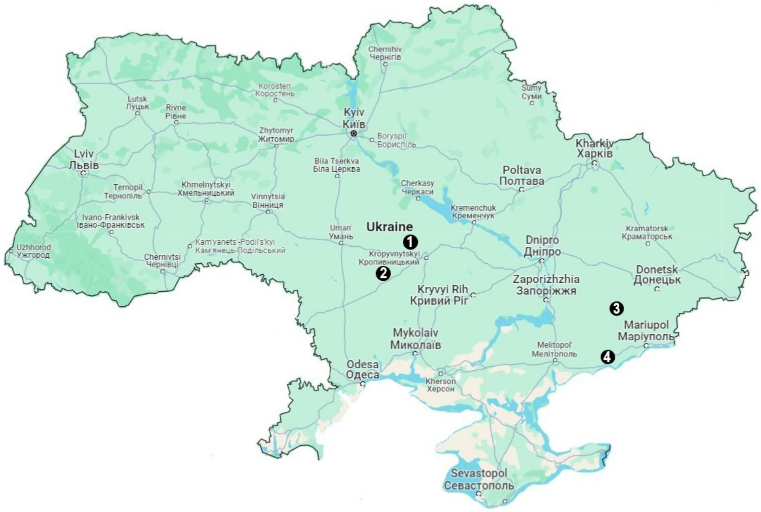

Fig. 4. Lithium deposits of Ukraine: 1 – Polokhivske; 2 – Dobra site; 3 – Shevchenkivske; 4 – Kruta Balka.

In 2017, the company “Ukrlitiivydobuvannia” received a special permit for the extraction of lithium from the Polokhivske deposit, the largest of the four mentioned, with a declared productivity of 1.5 million tons of ore per year. Currently, reserves are being assessed; a conclusion on production and the search for financing are being developed. The deposits are represented by three steep ore bodies that lie at an angle of 60º at depths of more than 400 m. The thickness of the overburden sedimentary rocks varies from 60 to 100 m, which indicates the feasibility of developing the deposit underground method [23].

The main mineral in the Shevchenkivske deposit is lithium, although it also contains accompany mineral: tantalum, niobium and beryl. The area of the entire field is 40.72 hectares, which are located in the Velykonovoselivskyi district of the Donetsk region, on the eastern outskirts of the village. Shevchenko. This deposit is represented by six pegmatite bodies that lie at angles of 55 – 88º. The main ore pegmatite component is lithium, the content of its oxide in the deposits varies from 0.3 to 4%, with an average value of 1.1 – 1.2%. As for the mining and geological conditions for the deposit development [24], the depth of the deposits is up to 500 m with a sediment thickness of up to 120 m, which also indicate an underground mining method. It should be noted that due to the small area of the ore-bearing field (length 1100 m, width 200 m), the development of the deposit can be carried out with one underground mine [25]. The deposit’s reserves are estimated at 12 – 14 million tons of lithium ore. At the same time, according to categories C_1 – 528 thousand tons, C_2 – 1574.7 thousand tons.

The Dobra site is located in the Novoukrainskyi district of the Kirovohrad region and covers an area of 88.14 hectares. It is represented by lithium spodumene and petalite lithium minerals, and the following minerals stand out among the associated minerals: beryllium, tantalum, rubidium, niobium, cesium, tin, gold and tungsten. The presence of two types of lithium ores allows for their selective development [26]. The subsoil area consists of two separate sites located close to each other: Stankuvatska and Nadiia. The first ore bodies are a series of 8 – 12 layers with a steep dip of 65 – 75º and a thickness of up to 20 – 30 m. The Nadiia site with a width of up to 390 m and a total length of 1600 m is represented by quite powerful bodies (30 – 32 m). The thickness of overburden is up to 80 m, which can be suitable for both underground [27] and surface mining [28]. The assessment of reserves made it possible to establish the volume of lithium ores with an average content of lithium oxide of 1.34% at the level of 1.2 million tons.

There are also unexplored lithium reserves at the "Kruta Balka" site, which is located within the Berdianskyi district of the Zaporizhzhia region, not far from the villages of Radivonivka and Osypenko, on the right bank of the Berda River. The area of this ore deposit is 146.69 hectares. The main minerals of this area are lithium, tantalum, rubidium, niobium, and cesium-bearing ores. Associated minerals [29] at this deposit include quartz, muscovite, spodumene, feldspar and others. The average value of lithium oxide in deposits is 1.1 – 1.4%.

4.2 Determination of lithium average content by deposits

The above deposits contain deposits of petalite ores with lithium content up to 3.0 – 4.5% (Fig. 5). Each of them is unique and complex with a number of valuable accompanying rare elements [30], which has no analogues in the world. Despite the presence of four explored deposits with balance reserves, lithium mining is not carried out in our country today.

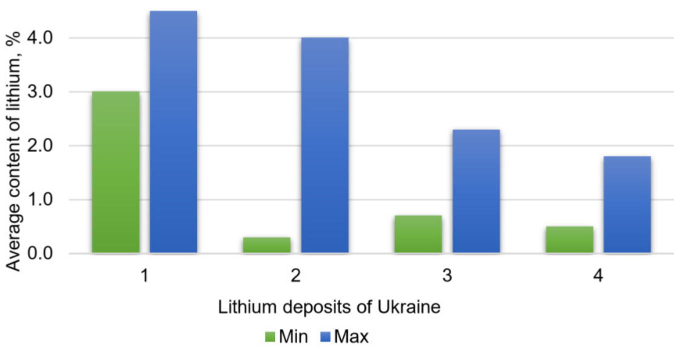

Fig. 5. Average content of lithium by deposits: 1 – Polokhivske; 2 – Shevchenkivske; 3 – Dobra site; 4 – Kruta Balka.

It is worth noting that the ores of Ukrainian lithium deposits are represented by petalite or spodumene-petalite varieties, which are difficult to enrich, so the development cost will be higher than that of competitors in South America, where lithium lies in hydromineral ores in salt lakes.

Determining the exact lithium reserves in Ukraine is currently limited, as this information is classified by the SBU [31]. However, the State Commission on Reserves of Ukraine in 2018 estimated the deposits of the Polokhivske deposit at 27.0 million tons of ore with a content of valuable components of more than 1%, which is approximately 270 thousand tons of lithium. As for the Shevchenkivske deposit, the State Geology and Subsoil Service estimated its reserves at 13.8 million tons of lithium ores with a content of lithium oxide Li_2O – 1.5%, which is 207 thousand tons.

5 Conclusions

It was established that the development of the electric vehicle market caused a significant increase in global lithium production. The high level of lithium involvement in the industry for the energy storage elements production is confirmed by the fact that almost 87% of the total volume of its consumption falls on rechargeable batteries. In addition to the electric vehicle industry, lithium batteries are used in laptops, smartphones, video surveillance cameras, cardio-defibrillators, space technology development, and the defence industry.

Lithium has been found to play a key role in the transition to "green" technologies.

It was determined that over the past 8 years, lithium production has increased 9 times from 20 to 180 thousand tons, which only partially made it possible to stabilize its cost, which in the period 2020 – 2022 increased 9 times up to $75.000/t, and decreased in 2023 up to $47.000/t. According to the forecasts of world rating agencies, the growth of lithium consumption in the next 10 years will occur with high intensity, and with the existing demand, the need of the world industry for this material will increase 4.5 times from 800 to 3.800 thousand tons by 2035.

The conducted researches allow indicating the high potential of the mineral and raw material base of Ukraine in supplying global technological chains with lithium raw materials. According to open data, the country has significant deposits of lithium, which, according to experts, can be estimated at 500.000 tons (up to 10% of world reserves).

It was determined that the main reserves of lithium raw materials in Ukraine are concentrated in rare-metal granitoids. Lithium ore occurrences were recorded in the Kryvorizka-Kremenchutsk suture zone and in the central part of the Ukrainian Shield. The most promising for development are the Polokhivske deposit and the Dobra site in the Kirovohrad region, Shevchenkivske in the Donetsk region, as well as Kruta Balka in the Zaporizhzhia region. These deposits contain petalite ores with a lithium content of 3 to 4.5%. According to the estimate of the State Commission on Reserves of Ukraine, in 2018 the deposits of the Polokhivske deposit amounted to 27 million tons of ore with a content of valuable components of more than 1%, and the Shevchenkiv deposit contained 13.8 million tons of lithium ore with a content of lithium oxide Li_2O – 1.5%.

A general assessment of Ukrainian lithium deposits allowed to establish that they are represented by petalite or spodumene-petalite varieties, which are difficult to enrich compared to the conditions of hydromineral ores in salt lakes. In this regard, in the future, a detailed analysis of their origin and determination of the host rocks role is necessary, which will allow a more correct approach to the identification of promising areas for mining.

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