

УДК 504.064.2:552.53.04(477.8)

Overall geological industrial assessment of salt resources in the Carpathian region of Ukraine

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There are significant salt resources within Carpathian region of Ukraine. They are represented with rock salt deposits, potassium-magnesium salts and natural brines ones: Solotvyno rock salt deposit within Transcarpathian internal depression, Kalush-Golyn, Stebnyk, a few small potash (potassium-magnesium) salt deposits comprising industrial rock salt layers as well as a few nature brine deposits within Carpathian foredeep. Earlier some salt mining enterprises operated on the base of these deposits. Recently, all great salt mining enterprises of the region have stopped their activities due to various reasons, namely, because of economic and environmental causes. Territories of salt mining enterprises often suffer from dangerous geological phenomena manifestations (salt karst etc.) taking a scope of geoeological catastrophes sometimes. Therefore one of the main reasons for the general stop activities of all salt mining enterprises are serious environmental problems that have arisen in the activity territories as potash enterprises and the only enterprise producing rock salt (SE “Solotvyno salt mine”). This paper is expert analytical comprehensive assessment of salt resources current state as the base for designating treatment strategy with ecologically disturbed territories and accidents, and development of the main concept of further salt recourses uses for salt industrial revival in this region. The basis for performed analytical assessment is thorough analysis of official and actual quantitative salt reserves, their changes because of salt massifs technogenic degradation processes resulting in erroneous strategy of reserves recovering, accompanying industrial and environmental problems, as well as the state of the salt market that determines the issues of the salt industry development. Rock salt deposits are of significant interest for rock salt extraction by shaft mining method and leaching one for obtaining of rock salt and vacuum-evaporated salt in stock (food, technical, fodder rock salt of different milling, evaporated salt “extra”, officinal-cleanness salt et al.) as well as a creation of tourism and medical facilities within the salt massifs (speleosanatoriums). Potash (potassium-magnesium) deposits in Carpathians have the unique sulfate composition and no analogues in Europe. They are a powerful source of raw materials for producing of a wide range of chemical products (potassium hydroxide, potassium carbonate, potassium chlorate, potassium permanganate, potassium magnesia, etc.). Fulfilled expert analysis substantiates possibility and advisability of revival and development of Carpathian salt industry, shows all possible options for it, which are rather workable being provided enough raw materials base for works foundation. The further use of deposits demands adoption of conceptual solutions in the framework of the proposed options.

Keywords: mining industry, rock salt, potassium salts, magnesium salts, ecological safety.

Загальна геолого-промислова оцінка соляних ресурсів Карпатського регіону України

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У межах Карпатського регіону України наявні значні соляні ресурси, представлені кам'яною сіллю, калійно-магнієвими солями та природними розсолами. Розглянуто можливості відновлення калійної промисловості Передкарпаття і перспективи розвитку експлуатації родовищ кам'яної солі. Території гірничодобувних підприємств соляної промисловості характеризуються проявами небезпечних геологічних явищ (соляного карсту тощо), що набувають часом масштабу геоекологічних катастроф. Висвітлено проблеми реабілітації деградованих територій та охорони соляних ресурсів.

Ключові слова: гірничодобувна промисловість, кам'яна сіль, калійні солі, магнієві солі, екологічна безпека

Introduction. Salt industry in the Ukraine Carpathian region is one of the most economically important areas of mining activity. Recently, however, salt industry of the region is in distress due to manifestation of the economic

and environmental signs of a crisis. So, the most of salt mining enterprises have stopped their activities so far.

Urgency of this problem statement is the need for scientific substantiation of the raw material base for

revival of the salt industry in the region, the treatment strategy with salt resources in the frame of overcoming the aforementioned signs of a crisis in salt resources operation.

Under conditions of properly functioning economy, rock salt and natural brines are widely used in the food industry for the salt production (food, technical, fodder salt), in the chemical industry for the production of soda, hydrochloric acid, chlorine, sodium, ammonia, detergents and etc., and in the textile, paint, pharmaceutical and other industries. In addition, under the presence of favourable geological conditions the rock salt deposits can be used for multipurpose underground storage facilities construction (for instance, natural gas, crude oil, oil products, toxic waste, etc.).

Potassium salts are predominantly raw materials for mineral fertilizers production as well as for obtaining potassium hydroxide, potassium carbonate, potassium chlorate, potassium permanganate, potassium magnesia, etc. Magnesium salts are raw materials for building material production and metallurgical, chemical, aerospace and pharmaceutical manufacturing.

Thus, both rock salt and potassium and magnesium salts are high demand raw materials under market economy conditions. Until recently, two large mining-and-processing integrated works – Kalush (Ivano-Frankivsk region) and Stebnyk (Lviv region) – worked on the base of Kalush-Golyn and Stebnyk potash salt deposits and represented the entire potash mining of the Ukraine. State Enterprise “Solotvyno salt mine” executed rock-salt-making process on the base of Solotvyno rock salt deposit (Transcarpathian region). All of these enterprises have completely terminated their activities by now. Moreover, dangerous geological phenomena development up to environmental catastrophe level has occurred within these mining enterprises’ activity territories.

The purpose of this scientific work is expert evaluation of the current salt resources, industrial and ecological problems connected with their exploitation; identification of strategic priorities and main directions of their effective use as well as treatment strategy in relation to ecologically disturbed territories of salt industry’s enterprises.

The submitted work has been fulfilled by means of analytical integration of official data from the State balance of mineral resources of Ukraine, available geological information and published scientific materials, archival ones about salt enterprises mining activities as well as current ecological state of their ac-

tivity territories. In addition, data of authors’ research in these directions including territories detail survey have been used.

Current state of salt mineral resources. Salt mineral resources are unequally spread around the Carpathian region being confined to two geological regions: Carpathian foredeep and Transcarpathian internal depression one.

Within Transcarpathian basin the salt deposits are confined to Badenian salt-bearing formation (Tereblyanska suite) located in the lower part of the Neogene molasses. They form sheet-like accumulations ranging from 50 to 500 m thickness at depths exceeding 1.500 m and also salt dome structures (there are several dozen ones here), composed of rock salt with beds of clay, anhydrite, gypsum and sandstones [Bosevska, 2013; Bosevska, Kyrpach, 2013; Khrushchov, Kompanets, 1988]. Salt dome structures being near the Earth’s surface are available for exploitation: at depths from 100 to 500 m – by underground mining, at depths up to 1000 m and more – by leaching (using geotechnological method).

Within Carpathian foredeep basin, the salt deposits are confined to Vorotyschenska series (Upper- and Lower-Vorotyschenska as well Zagorska suites), Balychska and Tyrasska suites. Sediments of the whole Vorotyschenska and Balychska suites are essentially potassium-bearing. Salt-bearing breccia with beds of contaminated rock salt and saline terrigenous rocks present in this stratum. There is local distribution of potassium-bearing rocks within it. There are lenses of rock salt within Tyrasska suite sediments; they might be of some interest to operate. Thickness of the Lower-Vorotyschenska suite is up to 700 m; Upper-Vorotyschenska is up to 800 m; Balychska is up to 500 m; Tyrasska is up to 360 m.

Three material types of deposits represent salt mineral resources of the Carpathian region of Ukraine: rock salt, natural brines and potash-magnesium salts.

Deposits of rock salt and natural brines. The State balance of mineral resources of Ukraine presents salt reserves of four rock salt deposits (table 1) and three natural brines ones.

According to scientific conclusions the Solotvyno rock salt deposit is the best one within Ukraine in terms of qualitative characteristics of salt raw (it includes thick layers of rock salt with sodium chloride content up to 99.9%) as well as underground microclimate parameters defining its high medicinal properties (at the depth about 300 m).

Two mines (#8 and #9) have functioned until quite recently. However, both mines were being self-flood-

Table 1

State balance reserves of rock salt deposits of Ukrainian Carpathian region (January 1, 2015)

Region (geological, administrative)		Deposit's name	Reserves categories, mln. tons		
			A+B+C ₁	C ₂	Outbalance reserves
Carpathian foredeep	Lviv region	Stebnyk	248.7	198.9	74.6
		Hubytske	53.7	–	–
	Ivano-Frankivsk region	Verchnystrutynske	34.9	–	–
Transcarpathian internal depression		Solotvyno, total among them:	346.7	108.6	397.7
		- reserves residue approved for extraction by mining	197.5	59.4	354.3
Transcarpathian region		- reserves of the North site approved for extraction by leaching method	149.2	49.2	43.4

ed during last 6 years due to huge technogenic karst development within overlying rocks. By the result of abandonment of the salt mines, more than 50% of balance reserves approved for extraction by underground mining have not been extracted from the depths (it's mainly reserves, which are approved for the mine #9, dispersed within the northern and northwestern parts of the deposit).

There is a site with approved reserves for rock salt extraction by underground leaching within the north-eastern flank of the deposit at depths exceeding 700 m at the same time. Detailed exploration of this site (so-called the North site of the Solotvyno rock salt deposit) was executed in the late 1970's – early 1980's. Its purpose was to study of rock salt as raw material for evaporated edible salt obtaining. That is why rock salt reserves were approved as on specially developed raw material conditions for underground leaching (the USSR State Reserves Committee (GKZ), Protocol #10040 of September 24, 1986). It was planned a brine extraction site creation and vacuum-evaporation plant construction on the base of the Northern site with commissioning of an enterprise for 1995.

Because of various reasons (political, economic), the salt reserves of the Northern site have not been used so far. Designing of site development facilities have not been carried out.

Natural brine deposits' reserves of the Precarpathians are the following (m³/day): Drohobych – 172 (cat. B) and 30 (cat. C₁); Bolekhiv – 280 (cat. B), 125 (cat. C₁) and 910 (cat. C₂); Dolyna – 203 (cat. B), 66 (cat. C₁) and 125 (cat. C₂). Dolyna and Bolekhiv deposits were in operation until quite recently. Currently, Drohobych deposit is only in operation.

Potassium and magnesium salts deposits. There are three potassium-bearing basins in Ukraine: Dnieper-Donetsk, Donetsk and Carpathian foredeep (the Precarpathians). However, commercial deposits with the balance reserves are only fixed in the Carpathian foredeep basin. Total balance reserves of potassium salts in Ukraine are 2.349.989 ths. tons (cat. A+B+C₁) and 1.252.280 ths. tons (cat. C₂); out balance reserves are 255.132 ths. tons (table 2). We can see on this table the Stebnyk deposit is the most major potash deposit within this region, and more it is a single source of raw materials for sulphate fertilizers in Ukraine.

Table 2

Balance reserves of potassium salt deposits of the Ukrainian Carpathian region (January 1, 2015)

Deposit's name	Reserves categories, mln. tons		
	A+B+C ₁	C ₂	Outbalance reserves
Stebnyk	698.9	579.2	241.1
Boryslav	454.9	59.2	–
Kalush-Golyn	442.6	–	5.6
Pomyarky	187.6	100.3	–
Nynev & Smolyany	167.5	232.8	–
Dobrogostiv	107.6	28.1	–
Trostanets	92.3	252.6	–
Ulichno	76.9	–	–
Dolgoluka	46.0	–	–
Girne	32.3	–	–
Tura Velyka	25.3	–	–
Morshyn	18.2	–	–
Kadobna	–	–	8.4

Calculated MgO reserves at Stebnyk and Kalush-Golyn deposits are 80.531 ths. tons (cat. A+B+C₁), 48.988 ths. tons (cat. C₂) and 20.194 ths. tons (outbalance reserves).

There are serves of Rozsilna-Markova group of potassium salts deposits are 457.141 ths. tons (cat. C₁+C₂) by the results of preliminary reserve estimates. Gorokholina-Nadvirna territory, which is extension of Rozsil'na-Markova area, was also reconnoitered; here forecast salt resources were estimated as 178.300 ths. tons of raw rock (cat. P₁+P₂).

Thus, Ukrainian Carpathian region has huge potassium and magnesium salt mineral resources.

However, in recent years it has become clear that potassium salt reserves estimation submitted in the State balance of mineral resources of Ukraine is deficiency correct as of now. Firstly, reserves of all deposits (saving Stebnyk) were studied and approved in 1948 – 1960 years and earlier based on exploration materials of those years. Secondly, during more than 40 years some territories with the estimated reserves were being built-over or got into protected zones of different facilities and settlements. Finally, by now serious environmental problems associated with flooding of Dombrovsky open pit, disturbance of geological environment (karst) and huge accumulation of waste products (solid and liquid) on the Earth's surface have occurred within the territories of the extractive enterprises (Stebnyk and Kalush). Because of the mentioned reasons a significant part of the estimated reserves of potassium salts (particularly, Kalush-Golyn) have lost their commercial value and cannot be used in the nearest future.

According to the existing view, actual balance reserves of all these deposits (saving Stebnyk and any part of Kalush-Golyn) are in fact forecast resources (cat. P₁ and C₂), including Pyilo site of Kalush-Golyn deposit intended for industrial development. Initially this site reserves estimated at 45.3 mln. tons of K₂O, however the current estimates indicate its real active reserves are no more than 10 – 14 mln. tons of K₂O [Khrushchov, Geychenko, Kyrpach, 2011].

Thus, strategic reassessment of potassium and magnesium salts reserves of the Precarpathians is needed; nevertheless, this region is one of some worldwide leaders on sulfate potassium salts reserves de facto. In particular, the Stebnyk deposit has unique mineral and chemical composition of salt (including sulfate one) and has no world analogous ones, so, there are deposits like it in Sicily and Spain only [Poberezhskyy, Stupka, 2009].

Industrial and environmental problems related to salt resources operation. Operation problems of two matter-industrial group of deposits are examined: potassium and magnesium salts as well as rock salt. Crisis developments of production and ecological types are inherent to both groups in a number of features.

Potassium and magnesium salts deposits. Status of industrial production. Two mining and chemical plants – Kalush and Stebnyk – presented Ukrainian potash industry earlier; now they don't work. These plants produced potash and potash-magnesium fertilizer and magnesium and other products (Kalush). Their production met the requirements of agro-industrial complexes of Ukraine and other former Soviet republics, as well as exports to non-CIS countries. Construction of a third plant was planned. However, it should be noted that the negative aspect of their production activities was deferment the decision of growing ecological problems.

So, the tailings dam breach in Stebnyk in 1983 became the first serious ecological problem that led to a catastrophic chemical pollution of the Dniester River since about 5 mln. m³ poisonous brines penetrated in the river water. This accident became an international problem and triggered a gradual production cutback. Before that time Stebnyk enterprise extracted more than 3 mln. tons per year of potash ore by two mines [Bosevska, Mishchenko, 2009].

In the first years of the XXI century Stebnyk State Mining and Chemical Enterprise "Polimineral" provided only about 20% of the minimum potash fertilizer needs of Ukraine producing only low-grade fertilizer – natural raw ground kainite comprising 9% of potassium oxide (K₂O). Currently Stebnyk mine #2 is in abandonment; mine #1 ("Kyubek") was partially flooded by brines but it can be restored for functioning under certain conditions.

Joint stock company "Oriana" in Kalush produced potassium magnesia (30% K₂O), potassium sulfate (48 – 50% K₂O), and magnesium chloride solution to produce magnesium metal. In 2000 production volume decreased by 10 times with 1989. Currently, production activity is completely stopped. Mines "Kalush", "Golyn", "New Golyn" have been filled with concentrated brines; Dombrovsky open pit is being filled with atmospheric waters.

Environmental problems within potash deposits territories. Environmental problems within potash mining territories are considerably more complicated than problems within rock salt mining territories. It depends on more complex process for rock mass

management due to higher solubility of potash salt, as well as its compound technological processing. The main technological feature of potash fertilizer is potash ore enrichment predominantly using flotation. Therefore consequent effect of potash-magnesium extraction and processing always is accumulation of significant amounts of industrial waste (liquid and solid stages) up to 70% extractable ore. Solid wastes form saline dumps, liquid wastes (toxic for the environment) are accumulated in special sludge storage tanks. The potash-magnesium processing wastes pose severally huge ecological problem within potash mining territories seeing large areas become unusable.

One of the most serious problems of potash mining is to maintain a producing rock mass in a stable condition. Because of the difficult financial and economic situation at the enterprises, reducing their production volumes, this task has become rather difficult and undecidable. As a result, the caprock over potash mines have become to collapse due to intensive salt karst development resulted in a flooding of mines.

The main reason for the Kalush-Golyn deposit mines flooding was non-optimal parameters of mining method structural elements that did not provide long-term stability of the load-bearing pillars. Surface subsidence over minefields ranged between 5 – 100 mm per year, and caves on the Earth's surface were formed within sites of sharply reduced load-bearing capacity.

Currently because of the mentioned factors, influence complex of environmentally hazardous technogenic-geological phenomena is manifested within the full activity areas of both potash plants. Such a phenomenon development is rather representative for technogenic intervention into salt geological environment overall (Fig. 1).

At Kalush mining region these dangerous phenomena are the following:

- Dombrovsky open pit flooding which threatens the brines to break through Sivka Kalush River to Limnytsa River and finally to Dniester River; in addition, distribution area advance of groundwater salinization and loss of significant part of potash salt reserves become possible;
- karst progressing development over mining fields followed by the Earth's surface deformations, including large collapse holes that threaten urban and rural development areas, as well as the expansion of groundwater salinization areas;

- waste accumulation by the results of potash raw processing in saline dumps and tailing dumps; it also provides spreading saline components with winds and atmospheric waters being of high risk for the nearby settlements;

- existence of poorly placed and unsanctioned toxic waste disposal applications within Dombrovsky open pit and other areas (established facts).

In the Stebnyk mining region territory the geological environmental disturbances have manifested themselves in flooding of mine lower horizons and significant Earth's surface deformations development. During the enterprise operation, karst cavities were being formed at different levels at the depths from 90 to 380 m. The total volume of karst cavities is estimated above 30 mln. m³, and individual karst cavities are up to above 500 m³. There are Stebnyk's residential buildings and highways over these cavities. It is being the cause of ecological hazards development in the region.

Activization of the environmental problems was associated with water breakout in the mine #2 in 1987 in spite of 20-years struggle with the water inflow. The water breakout resulted in progressive underground karst development and finally mine flooding.

Currently ongoing processes are regarded as moderate or controlled in comparison with the state of the Kalush region, but it should remember that influent aggressive water continues to leach pillars and gradually reduces their load bearing capacity that can lead to a grand disaster.

As for Stebnyk mine #1, then it is in a satisfactory condition.

Rock salt deposits. *Environmental problems within exploitation territories of rock salt deposits and nature brines ones.* The most serious geological environment disturbances associated with the operation of the rock salt were occurred within the Solotvyno rock salt deposit.

By 2010 a geoecological catastrophe¹ had started up within State Enterprise "Solotvyno salt mine" activity territory. This situation was classified as an emergency situation of the state level [Bosevska, Khrushchov, 2011]. The catastrophe has manifested itself in scaling deep karst which resulted in a rapid flooding of operating mines #8 and #9 with above-salt waters, as well as significant Earth's surface subsidences, degradation of the landscape including the development of the huge collapse holes that pose a

¹ Geoecological catastrophe is set of serious, predominantly irreversible violations of geological environment resulting in significant ecological, industrial and social damage.



Fig. 1. The salt karst development in Dombrovsky open pit, Kalush, 2007

threat to the population and infrastructure. Finally, this situation has resulted in a loss of functioning salt mines and unique underground speleosanatoriums of Ukrainian allergological hospital which were related to the mine workings of salt mines both spatially and technically [Bosevska, Khrushchov, 2011; Bosevska, 2013].

During nature brines deposits exploitation the technogenic disturbance of geological environment are usually moderate. According to data of Ukrainian Salt Research Institute they are insignificant subsidences of the Earth's surface nearby production wells with the velocity from 2 – 3 mm per year (along the periphery of the subsidence troughs) to 6 – 8 mm per year (nearby operational wells and mines) under permanent scheduled pumping brines. Insignificant technological disturbances of the natural brine extraction sites are generally related to not-big production quantity of the salt-evaporated plants.

In case of regulation violations of the brine pumping the significant deformation of the Earth's surface might happen. These deformations can be manifested in the formation of a pronounced local subsidence trough, as well as sometimes dislocation with a

break of continuity accompanied forming of sinkholes [Bosevska, Mishchenko, 2009]. One of the main reasons for Carpathian nature brine plants' activity reducing is high net cost of evaporate-salt producing using salt-evaporating pan (pan method). Thus, nature brines extraction development is only possible if there will be a complete change of salt-evaporation technology (for example, more modern vacuum-evaporation).

Treatment strategy with ecologically disturbed territories and accidents within salt mining objects.

The methodological base for treatment with salt geological environment disturbance territories based upon the main trend biosphere violence and management of dangerous phenomena has been developed so far [Bosevska, 2013; Khrushchov, Bosevska, Kyrpach, 2010; Khrushchov, Bosevska, 2014]. A principal scheme of the management for processes of salt environment disturbances includes the following phases:

- monitoring,
- violence detection and identification;
- environmental audit, risk assessment;
- project preparing, risk efficient technologies choose;

- project implementation;
- degraded landscapes remediation, recultivation (for territories of accomplished exploitation).

Common reasons of geological violence within all salt mining territories are identified:

- incorrect choice of mining activity areas, and accordingly a mistaken strategy of mining operations;
- incorrect choice of mining and processing methods and technologies;
- infringement of the technological rules of mining operations;
- ignoring the generally accepted rules of liquidation (conservation) of used spaces including the remediation of open cast mining, as well as a packing (gobbing) for unstable system of mine workings;
- pendency of issue on remove and processing of exploitation waste (saline dumps and tailing dumps);
- lack of timely prevention and elimination of violations.

Based on the target analysis of above mentioned objects we (with the participation of scientific, design and production organizations) have developed:

- draft program of environmental, social and industrial solutions in Solotvyno;

- conception of environmental and industrial problems solutions for Kalush mining area.

Strategic priorities and basic trends in salt resources effective use and protection. Making use of Transcarpathia salt massifs. Our proposed strategy for dealing with industrial problems (and related social and environmental) that have arisen as a result of geo-environmental disaster in Solotvyno, includes two main objectives: to restore of salt mining (by shaft mining and leaching) and to renew speleotherapy by means of new underground speleosatorium creation.

Two the most opportune geological objects for these purposes are Solotvyno and Tereblya salt structures. Based on the carried out target investigations including author's structural lithological modelling [Bosevska, 2013; Bosevska, Kyrpach, 2013], the potentially favorable sites for underground construction have been allocated to each of the two objects (Fig. 2, 3). Essentially geological groundings for project documentation and feasibility studies have been prepared.

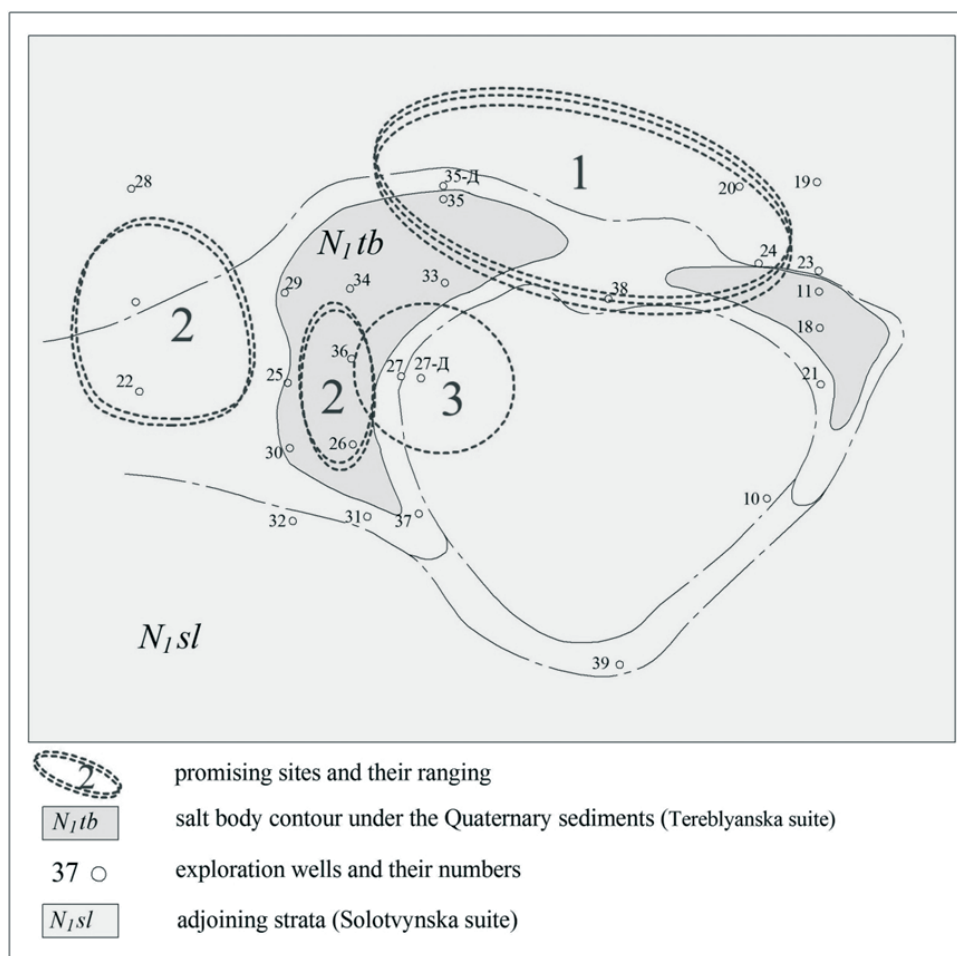


Fig. 2. Promising sites of the Tereblya salt structure
1 – the most prospective site which may be considered for different technological methods using;
2 – second degree prospects – the sites may be using for rock salt extraction by geotechnological method;
3 – third degree prospects – the site includes rock salt of high industrial quality but needs confirmation because of some exploration data inconsistency

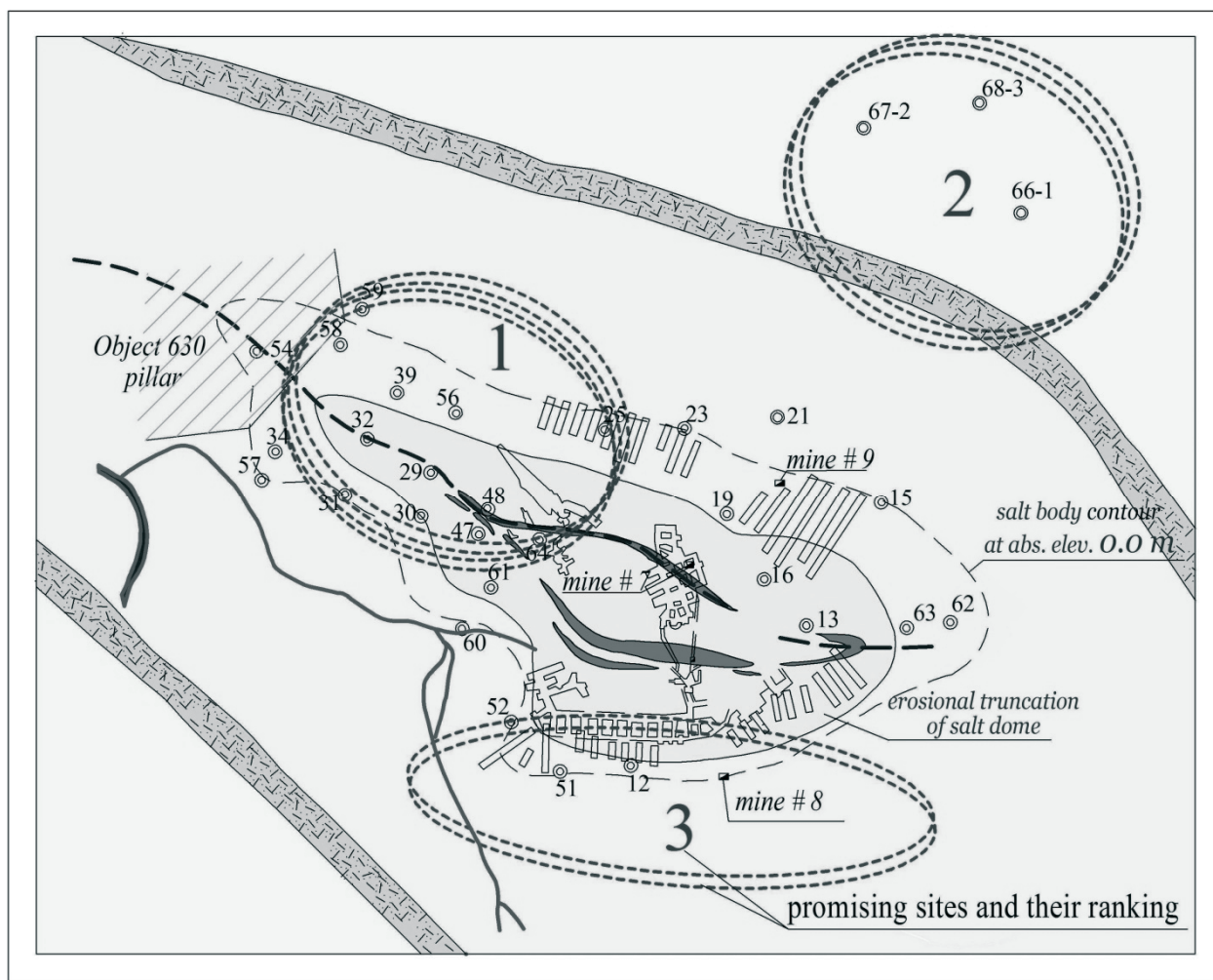


Fig. 3. Promising sites of the Solotvyno salt structure:

- 1 – promising site, which may be considered for underground shaft mining under adequate protection barrier establishing; this site has the approved reserves;
- 2 – promising site of second degree: this site may be used for rock salt extraction by leaching (geotechnological) method; this site has the approved reserves;
- 3 – third prospect degree site: this site is applicable for salt mining and salt extraction by leaching under flooded mine workings below the abs. elevation – 200 m on condition of lateral approach to the salt body; this site has no approved reserves.

Other notation conventions are on fig. 2.

Ranging assessment of these objects on different criteria (geological study, natural protectability, technogenic violence of salt massifs, and infrastructural availability in consideration of common risk assessment) has been made. There are favorable sites for the man-made object creation on both structures, however Solotvyno structure is regarded as a priority subject for further evaluation works due to the presence of intact slabs with the approved reserves of the highest quality edible salt in the region (I, II and higher grade) and high studying deposits [Bosevska, 2013; Bosevska, 2013; Bosevska L., 2014]. At the same time the Tereblya structure has the advantage on the criterion of natural protectability level which was not impaired practically. Overall, salt massif of the Tere-

blya diapir is marked by more high content of non-salt impurities and widely developing breccia's zones. Pragmatic definition of prospects of the salt structures also implies the existence of approved reserves. There are no approved reserves within Tereblya salt structure.

Concerning the Solotvyno rock salt deposit, there are two sites with proved reserves here (promising site #1 and #2 on the fig. 3). There are the promising site for underground shaft mining (#1) and the Northern site for rock salt extraction by leaching at the depth above 700 m (#2). However, taking into account ongoing disturbance processes within the upper part of salt massive and Earth's surface, further use of its reserves might be possible after completion of

active destructive stage and taking technical measures for protectability salt body rising.

Taking into consideration the characteristics of man-made disturbance of Soltvyno deposit, non-big amount of approved rock salt reserves for underground shaft mining as well as the developed medical infrastructure, the priority for the reserves using is the development of speleotherapy, namely, construction of a new underground speleosatorium with concomitant salt extraction in output 100 – 200 thou tons per year [Bosevska, Khrushchov, 2011; Bosevska, 2013; Bosevska L., 2014]. Nevertheless, it is the longer-term use of Soltvyno deposit reserves.

The expediency of reserves development of the Soltvyno Northern site having the approved reserves for salt extraction by leaching is beyond doubt. This site located away from damage zones is the most promising for development in the nearest future. Quantitative, qualitative and technological characteristics of rock salt of the Northern site were well studied during the detailed exploration and implementation of core testing complex (1980s years). Ukrainian salt research institute carried out the basic cycle of technological tests in accordance with known technological chain: dissolution of rock salt, the evaluation of the crude brine, brine purification development options, the assessment of salt derived from purified brine by vacuum-evaporation.

Balance reserves of upper block of the Northern site approving according to leaching conditions in 1986 are 149.2 mln ton (cat. B+C₁). Approved reserves have a good quality (NaCl content is 93.0 – 99.2%) for extraction by leaching.

Taking the recovery factor of rock salt no more 15% (the world experience for that depth) as well as taking the fact that we can only get approximately 91% of salt into commercial output (analogy with modern Slavyansk salt-works), industrial approved reserves of upper block will be enough for 65 years if salt production volume is not more 300 thou tons per year. It should be noted that there is unlimited possibility of adding reserves for the Northern site. Therefore, the recovery ratio increasing is not recommended in order to avoid accidents such as those that have been at the different salt-brine-works all over the world.

Possible revival of speleotherapy and salt mining in Soltvyno will surely solve the social, economic and environmental problems of the region, strengthen the tourist attractiveness of the region that can serve as the basis of state support for the project.

In particular, salt extraction by leaching allows receiving chloride-sodium brine, which can become a

source of hydrochloric products in stock (evaporated salt “extra”, officinal-cleanness salt et al.), as well as it can also be the raw material for chemical production to obtain a spectrum of popular chemical products. Namely, there are soda, soda ash, sodium hypochlorite (electrolytic), sodium hydrogencarbonate (NaHCO₃), sodium hydroxide (NaOH) and gaseous chlorine (Cl₂), strong oxidizer (NaClO₄). Sodium hypochlorite (NaClO) is of our main interest in the above mentioned products list. High demand for sodium hypochlorite is anticipated on the European market since it is widely used as an environmentally friendly disinfectant, an effective tool for cleaning and disinfection of drinking, technical and waste water, bactericidal and sterilizing agent (with an additive effect of long-acting) alternatively direct water chlorination (instead of liquid chlorine or other chlorine-containing reagents). Sodium hypochlorite is very popular for sterilization of water in swimming pools. In addition, the brines obtaining at leaching site can be used for balneological and recreational purposes.

Any works for the further reserves development of the Soltvyno deposit might be begin after comprehensive predictive evaluation of the deformed-stressed state of the upper part of salt massive resulting in geometrization of dangerous and promising sites circuits. Eco-mining-geological monitoring implementation within the entire territory Soltvyno deposit for 2 years at least is necessary for such evaluation. It is also necessary to fulfill a revaluation of structural element condition of the deposit development system in connection with the recent changes. Unfortunately, some scientists who have not dealt with peculiar salt geomechanics ignore this need and greatly complicate the ecological risk assessment process. It should be reminded that the situation emerged within the Soltvyno territory is typical for salt mining under complicated (hydro) geological conditions in the case of operating errors.

Prospects for potash branch revival in Precarpathians. The reasons of potash branch decline and finally its self-destruction in Ukraine are nomenclatural and conjunctural; particularly, there were non-high quality of potash raw and serious mistakes in planning of minefields not taking into account the possibility of suspending the activities of enterprises. So, work system of mining enterprises provided for a continuous production process.

Accordingly, geomechanical mining unstable system was created with no reserve of long durability to increase the recovery factor. It was envisaged that the mine workings will be stone gobbing using salt dumps material soon after working off.

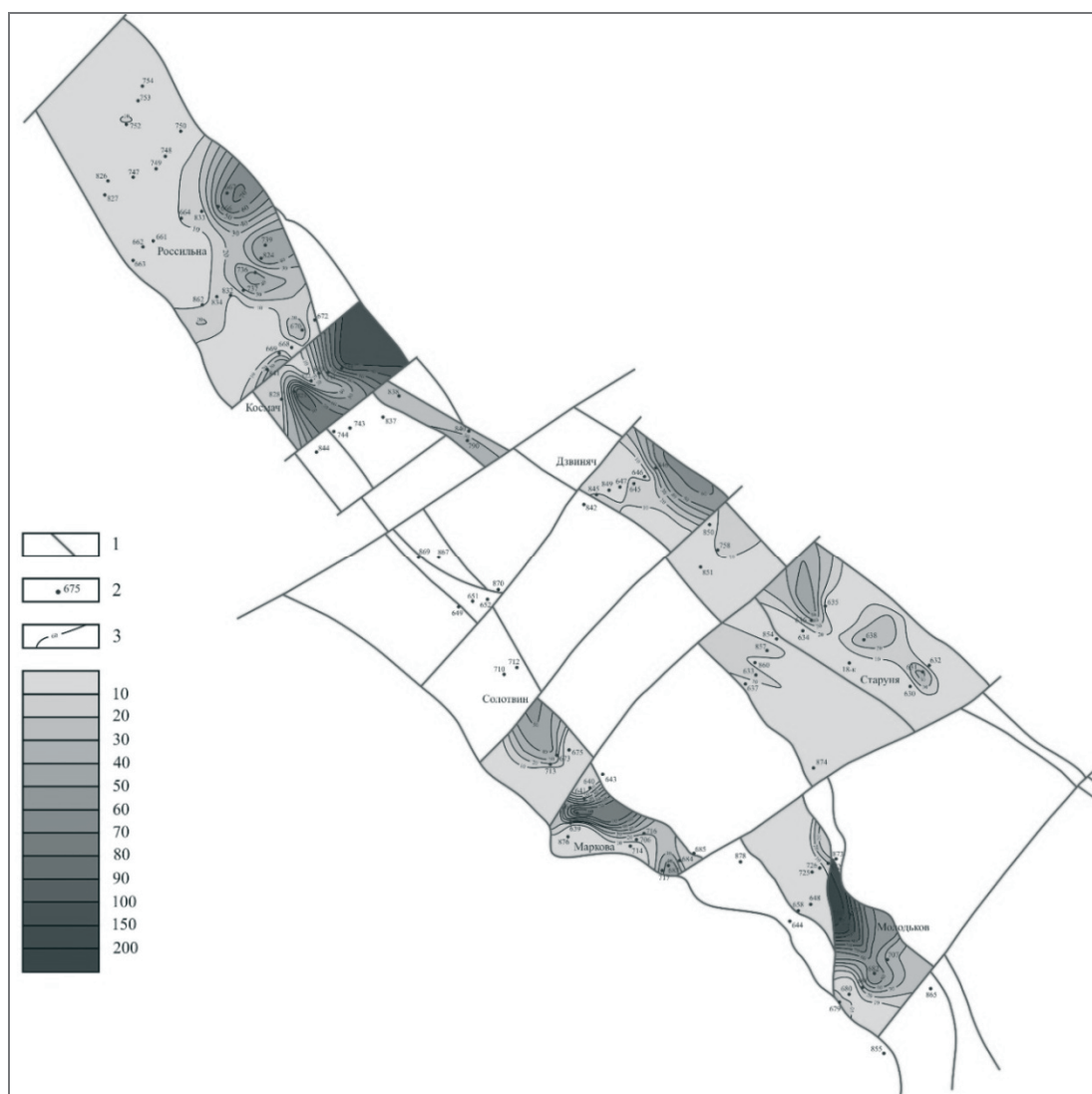


Fig. 4. The digital structural-lithological model visualization of the Rozsilna-Markova group of potassium salts deposits. The map of potassium salts thickness:

1 – thrusts and faults; 2 – wells and its numbers; 3 – lines of potassium salts thickness

But gradual production decline and increasing of environmental problem, high production price and its non-high quality in the absence of modern marketing schemes and the absence of financial investments did not allowed to stop the production decline, and therefore the problems of potash companies territories acquired a catastrophic level [Bosevska, Mishchenko, 2009].

At the same time, there are two factors defining the possibility and practicability of revival and further development of the potash industry at least for the production of fertilizers: unique material composition of potash-bearing sediments (predominantly sulfate salts) and rather significant ore reserves. Presently there are no major analogous deposits in Europe. Similar deposits in Sicily were worked out long ago.

However, we should underline unfavorable features of potash ore within the Carpathian foredeep: relatively low content of potassium, high content of insoluble residue as well as very complicated geological structure of the whole region and, consequently, potash deposits (Fig. 4) [Khrushchov, Kompanets, 1988; Khrushchov, Geychenko, Kyrpach, 2011; Kyrpach, 2009]. These features require, on the one hand perfection of processing technology, and the other hand changes the technological development principles of some deposits, which will be discussed further.

Taking into account the unpredictability of economic and socio-political situation, as well as environmental requirements when revival strategies potash industry developing, it is essential to envisage the invariance of the proposed strategic priorities.

Two ways for the production restoration are possible. They are revival of the existing plants activities (Kalush and Stebnyk) or the creation of new enterprises (we remind that the third potash plant construction was being planned in 1980s). In the current financial and economic state, the first way is more acceptable due to about preserved infrastructure. New enterprises construction has advantage of new modern processing line creation; it might be possible in major financial investments.

The implementation of any option includes two groups of tasks: provision of raw reserves and complete innovative technological upgrading.

There are two objects with different operating and technological solutions at Kalush plant: Pyilo site and Dombrovsky open pit. Now to use Dombrovsky open pit's brines and residual reserves is technologically possible, but economically disadvantageous. Pyilo site development might be implemented abiding by above-mentioned restrictions; meanwhile it is well to bear in mind that the real active potash ore reserves are no more than 10 – 14 mln. t.

In addition, there are other deposits around Kalush enterprise; primarily it is the above-mentioned Rozsilna-Markova group of potassium salts deposits (see fig. 4). It is necessary to assess technically implementing options for transporting ore solid or brine in order to determine the feasibility of these reserves development using existing infrastructure.

To restore Stebnyk enterprise activity it could be used the remaining part of deposits balance reserves at the first stage. Reserves of the nearby prospected deposits (Boryslav, Dobrogostiv, Pomyarky, Ulichno, Dolgoluka, and Girne) can be subsequently used (see table 2).

Alternatively, the development of small and medium deposits identified exploration in various parts of the Carpathian foredeep (Belyna Velyka, Yasyntsya Solna, Blazhev, Lanchyn and Nezhukhov et al.) may be considered. They are expected to be developed using geotechnological method (by leaching). The geotechnological method provides significant advantages including ecological risks mitigation, namely, the extraction activity does not violate salt sediments natural protectability, it does not conduct to tailing dumps creation, reduces industrial area, and finally, useful mineral is extracted as brines, but not solid ore, that is, a reduction of one of the process operations occurs [Bosevska, Mishchenko, 2009; Khrushchov, Geychenko, Kyrypach, 2011; Khrushchov, Bosevska, 2014]. The obtained brine can be transported to existing enterprises, or to be processed at small stand-alone technological complexes.

Conclusions. Thus, all represented possible options for revival and development of Carpathian salt industry are rather workable. They are provided with enough raw materials base for works foundation.

As for potash industry, defining marketing requirement for its development is competitiveness of products (potash fertilizers). It means technological process have to be capable of their high quality. Exactly low quality of producible fertilizers was one of the reasons to stop potash industry in 1990s. Therefore, upgrading production lines of enterprises for the production of high quality non-chlorine potash (and complex) fertilizers, which could be competitive on the world market, is needed.

Currently the Northern site of the Solotvyno rock salt deposit is only completely prepared to salt mining using leaching method. Its approved balance reserves could provide salt extraction for a few decades if rational extraction ratio. Furthermore, additions to reserves for rock salt mining by leaching are possible and unlimited.

The extracted leaching brines can be a raw for obtaining rather wide range of products. In addition, these brines could be the subject of a direct sale for balneological and recreation needs, since this direction is in high demand in the region with well-developed medical infrastructure aimed at treatment of allergological diseases.

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Надійшла до редколегії: 27 жовтня 2016