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Preliminary study of the salt deposits of the Pripyat salt-bearing basin for fuel storage construction

Wstępne badania pokładów solnych w zagłębiu solnym rzeki Prypeć pod kątem budowy podziemnych magazynów paliw

Aliaksei V. KIRYKOVICH[1], Natalia S. PETROVA[2], Natalia Y. DENISOVA[3]

[1] The State Enterprise "SPC Geology", Kuprevich str., 7, Minsk, 220141, Belarus, e-mail: lexkirik@mail.ru
[2] Belarusian State University, Nezavisimosti av., 4, Minsk, 220030, Belarus, e-mail: belnigri@list.ru
[3] The State Enterprise "SPC Geology", Kuprevich str., 7, Minsk, 220141, Belarus, e-mail: denisov.nat@yandex.by

Abstract

The paper is devoted to considering salt deposits of the Pripyat salt-bearing basin as potential underground fuel storage. Geological risks of gas storage construction in salt deposits are described. Zoning of the halite subformation within the Pripyat trough was carried out for identification of prospects for underground fuel storages. Prospect with potential salt domes and further detailed risk assessment plan are described.

Key words: geological risks, fuel storage, Pripyat basin, salt deposits.

Streszczenie

W artykule rozważono możliwości podziemnego składowania surowców energetycznych w złożach soli należących do basenu Prypeci. Opisano ryzyko geologiczne związane z budową podziemnych magazynów. W celu identyfikacji możliwości poziemnego magazynowanie paliw przeprowadzono analizę subformację soli kamiennej w rowie tektonicznym Prypeci.

Słowa kluczowe: ryzyko geologiczne, magazynowanie podziemne paliw, basen Prypeci, złoża soli

Introduction

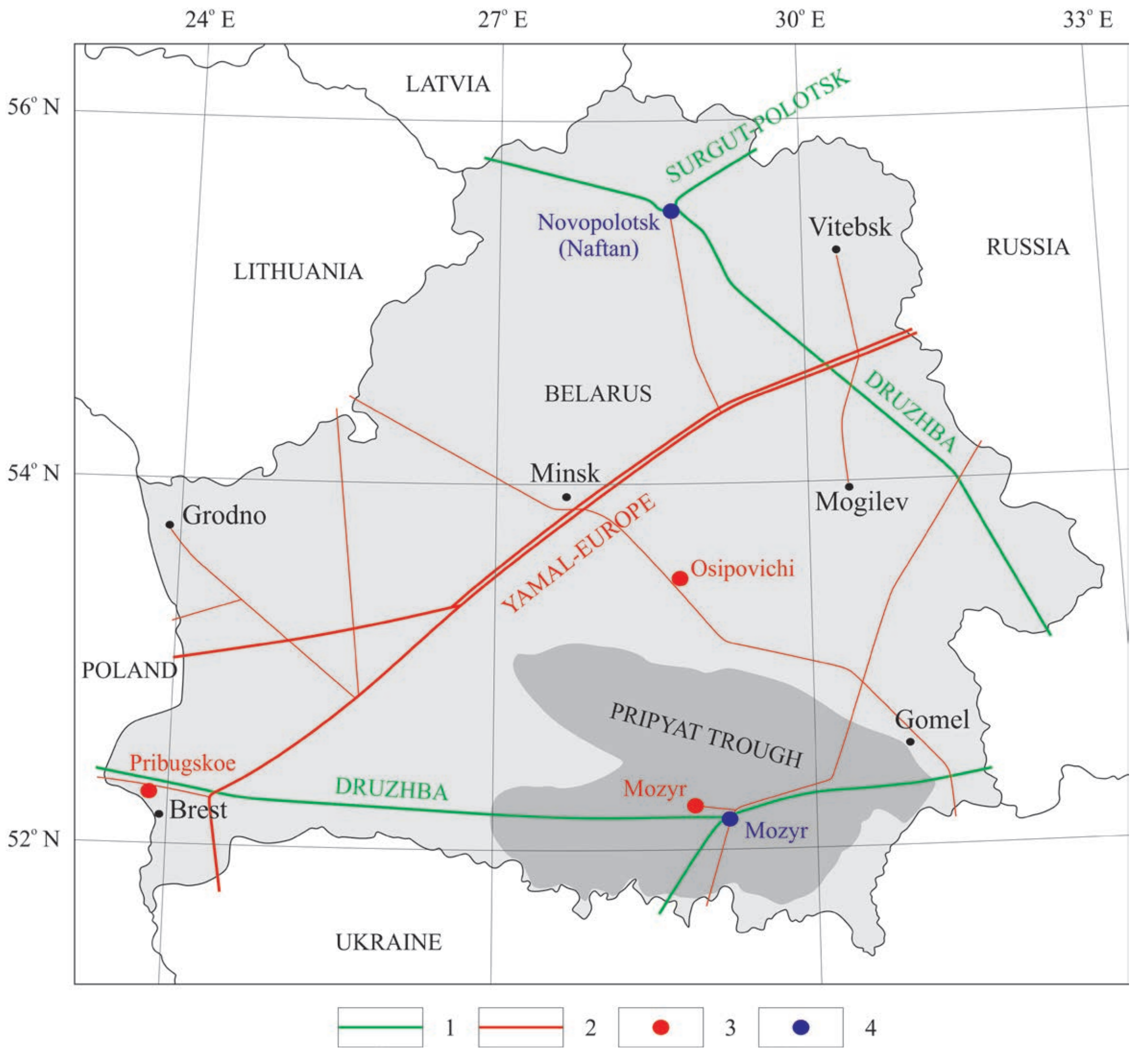
Important factor for support the energetic safety of the country is presence of enough reserves of gas in underground storages. Gas storages help to regulate seasonal irregularity in gas supply, provide reserve consumption during cold winters, compensate gas supply in case of accidents of gas pipelines, guarantee reliability of gas export. As practice shows the reserves of storages in Belarus have to be about a billion cubic meters of gas to cover peak irregularity in gas consumption during autumn and winter exploitation.

JSC "Gazprom Transgaz Belarus" has three underground gas storages on the territory of Belarus (Fig. 1): Osipovichi and Pribugskoe storages are created in aquifers and Mozyr one is located in salt dome. The Mozyr salt dome contains 14 salt caverns that store about 300 millions cubic meters of gas.

Underground salt deposit is an excellent container for gas, oil, and petroleum products because of the properties of underground salt. Salt is inert to hydrocarbons. As a rock formation, salt can be extremely strong, hard, and dense, with a compressive strength similar to concrete in formations used for storage. When relatively pure and not interbedded with other rocks, salt can have permeability and porosity so low that it is impermeable to hydrocarbons. When rock salt is subjected to the pressure and temperature caused by the weight of the overburden it becomes "plastic" and flows or moves. As a consequence of this inherent characteristic, a cavern created in salt deposit has the tendency to close up slowly over time, a phenomenon called "salt creep." Additionally, any fractures or fissures in salt have a tendency to close and "heal" over time. This results in a self-sealing quality that makes underground salt a good choice for safe and secure storage of hydrocarbons.

Materials and methods

The sedimentary cover of the Pripyat basin is a complex-built natural system displaying a set of various parameters. Four stages of chloride salt accumulation were distinguished in



Ryc. 1. System transport ropy i gazu w Białorusi: 1 – rurociąg ropy naftowej, 2 – rurociąg gazu, – podziemne magazynowanie gazu, 4 – rafineria

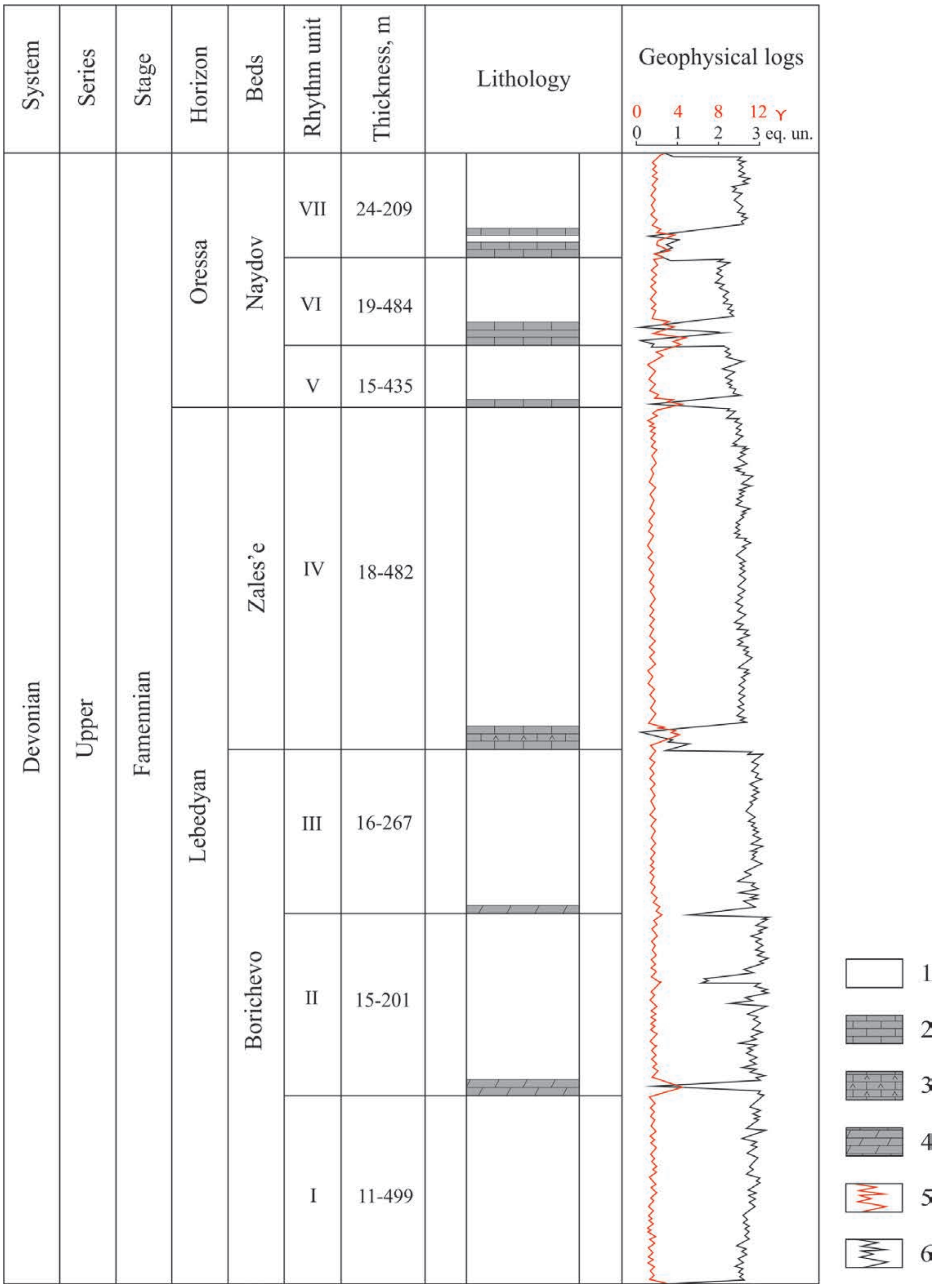
Fig. 1. *Oil and gas transportation system in Belarus: 1 – oil pipeline; 2 – gas pipeline; 3 – underground gas storage; 4 – oil refinery*

the history of the trough development: Eifelian, Late Frasnian, Early Famennian, and Late Famennian stages. There are two sub-formations in the Middle-Upper Famennian chloride saliferous formation, distinguished by their characteristics: halite (lower) and potash-bearing (upper) ones (Garetsky et al., 1984).

The Middle-Upper Famennian halite subformation is widespread within the Pripyat trough. 41.4 % of all salt reserves of the trough belongs to the halite subformation. The thickness of the subformation varies from 32-100 to 2000-3250 meters. Such significant changes in the thickness are due to both a change of geological structure and halokinesis. Seven rhythmic units are identified in the geological structure of the halite subformation (Fig. 2). Layer of non-saliferous rocks underlies rock salt strata at the bottom of each rhythmic unit. Most thick non-salt layers (30 m or more) are located at the bottom of rhytmic unit V, VI and VII. It is difficult to recognize inner structure of the halite subformation in salt domes. Non-salt layers are broken and shifted, non-saliferous rocks are turned into breccia because of intensive salt flow (Garetsky et al., 1982).

Salt domes used for natural gas storage are generally developed between 1900 m and 460 m beneath the surface. Salt creep increases rapidly below 900 m (Favret, 2003), and burial depths less than this are preferable. For domal and highly deformed salts, a geologic assessment becomes more focused on resolving structural complexity, precisely identifying the edge of salt and resolving potentially problematic internal features such as anomalous zones, shear zones and faulting. It is important to remember that domal and deformed salt are potentially active geologic features whose current configuration and internal material properties are determined by initial stratigraphy, deformational history, dissolution, etc. Therefore, salt movement and dissolution can pose risk factors for drilling, well integrity and cavern integrity.

Salt beds are shallower, thinner formations, with salt generally being interbedded with mudstones and anhydrite beds.



Ryc. 2. Zgeneralizowana kolumna litostratygraficzna odformacji halite: 1 – sól kamienna, 2 – wapień, 3 – facja węglanowo-siarczanowa, 4 – magiel, 5 – profilowanie gamma, 6 – profilowanie neutron

Fig. 2. *Generalized lithostratigraphic column of the halite subfomation: 1 – rock salt; 2 – limestone; 3 – carbonate-sulphate rocks; 4 – marlstone; 5 – gamma ray log; 6 – neutron log*

One of the most important factors is a requirement for a bedded salt over 300 m thick. In the case of bedded salts, the focus, geologically, is more on internal stratigraphy as the distribution of dirty (impure) salt or non-salt interbeds laterally and vertically could potentially limit the space for cavern development in pure salt (Baker et al., 2017). Once a salt cavern is introduced they are more prone to deterioration and tend to be more expensive to develop than salt domes. Horizontal caverns obviously "fit" bedded salt formations better than vertical ones readily constructed in salt domes, and bedded salt may be available where domes are not.

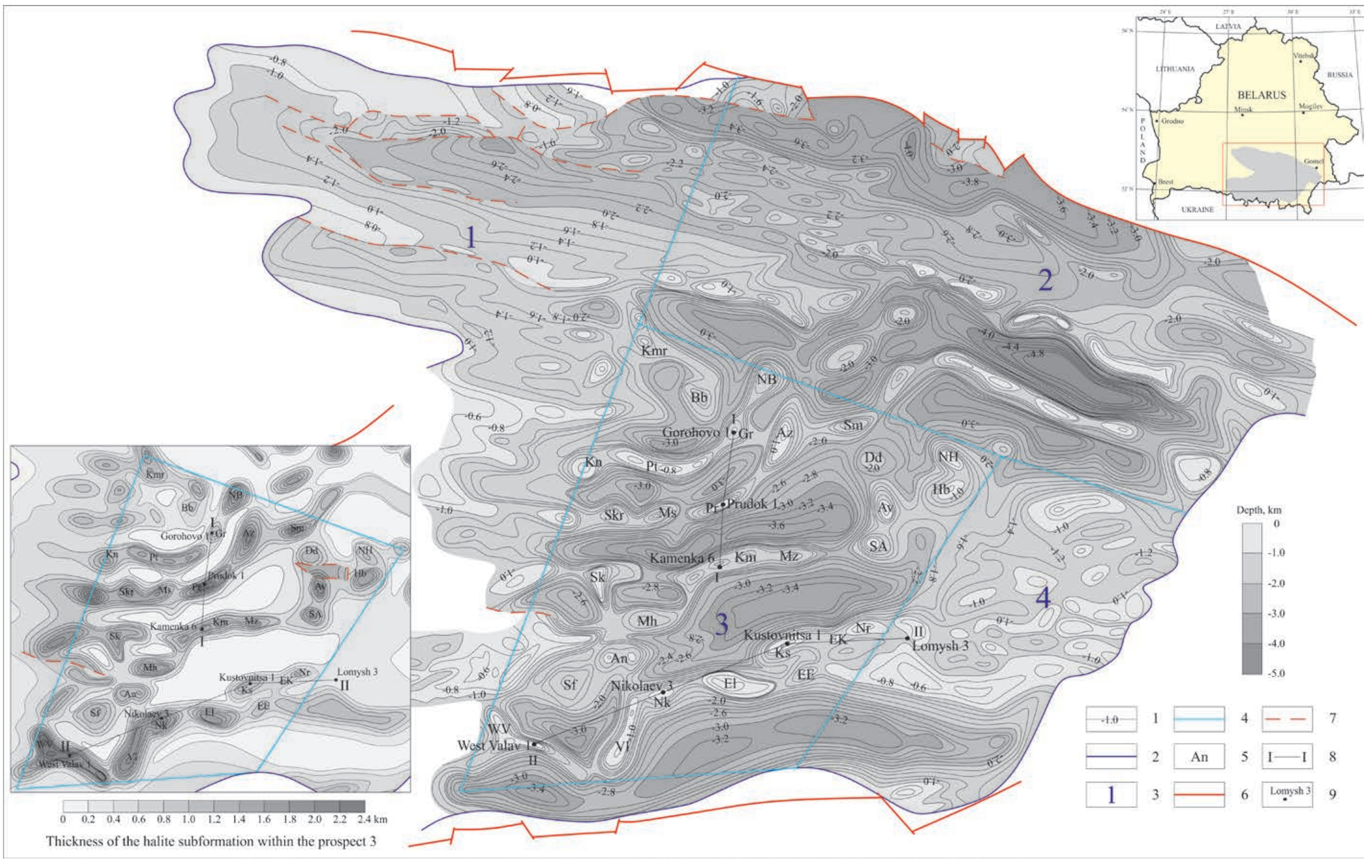
Results

Considering the features of geological structure of the halite subformation and all sedimentary cover of the Pripyat trough primary zoning of the trough for underground storage prospects (Fig. 3) was made according to

a) depth of burial,
b) thickness of halite subformation,
c) type of salt deposits (salt domes or bedded salt),
d) presence of existing wells and active exploitation of mineral deposits.

The first prospect area is situated in the western part of the Pripyat salt-bearing basin. This area is characterised by shallow depth of halite subformation surface. The depths varies from 0.8 km close to western limit of the subformation to 3.0 km in the north of the trough (Konishchev, 1975). The thickness of the halite subformation is less than 400 meters. Salt deposits are represented by bedded salt predominantly. Salt domes occur in the central and southern parts. Active halokinesis is absent in the first area but there are faults in the north. In the geological structure of the subformation carbonate and sulphate rocks replace lower rhythmic units. The potash bearing subformation that lies above the halite subformation contains productive potash horizons of the Starobin, Petrikov and Oktyabr potash salt deposits.

The second prospect area occupies the north-eastern part of the trough. Depth of burial (from 0.6 to 5.0 km) and the thickness most vary here. Some salt domes are great in the thickness (about 3.0 km). This territory is area of active development of oil fields in the Pripyat trough. All oil-be-



Ryc. 3. Strefowość bruzdy Prypeci z perspektywicznymi obszarami do budowy podziemnych magazynów paliw: 1 – subformacja soli kamiennej – izohipsy powierzchni (km); 2 – granice subformacji soli kamiennej, 3 – obszary perspektywiczne dla podziemnego magazynowania; 4 – granice obszarów perspektywicznych, 5 – wyniesienia soli (An – Anisimovo; Av – Avtjuki; Az – Azertso; Bb – Bobrovichi; Dd – Dudichi; EE – East El'sk; EK – East Kustovnitsa; El – El'sk; Gr – Gorohovo; Hb – Hobnino; Km – Kamenka; Kmr – Komarovichi; Kn – Konkovichi; Ks – Kustovnitsa; Mh – Mahnovichi; Ms – Myshanka; Mz – Mozyr; NB – North Bobrovichi; NH – North Hobnino; Nk – Nikolaev; Nr – Narovlya; Pt – Ptich; Pr – Prudok; SA – South Avtjuki; Sf – Sofievo; Sk – Skolodino; Skr – Skrygalovo; Sm –Smaglov; Vl – Valav; WV – West Valav); 6 – uskoki formujące bruzdę; 7 – uskoki w subformacji soli kamiennej; 8 – linie korelacji geologicznej, 9 – otwory wiertnicze

Fig. 3. *Zoning of the Pripyat Trough for the prospect areas of underground fuel storage construction: 1 – halite subformation surface isohypses (km); 2 – limits of the halite subformation; 3 – prospects for underground fuel storage; 4 – boundaries of the prospect areas; 5 – salt uplifts (An – Anisimovo; Av – Avtjuki; Az – Azertso; Bb – Bobrovichi; Dd – Dudichi; EE – East El'sk; EK – East Kustovnitsa; El – El'sk; Gr – Gorohovo; Hb – Hobnino; Km – Kamenka; Kmr – Komarovichi; Kn – Konkovichi; Ks – Kustovnitsa; Mh – Mahnovichi; Ms – Myshanka; Mz – Mozyr; NB – North Bobrovichi; NH – North Hobnino; Nk – Nikolaev; Nr – Narovlya; Pt – Ptich; Pr – Prudok; SA – South Avtjuki; Sf – Sofievo; Sk – Skolodino; Skr – Skrygalovo; Sm –Smaglov; Vl – Valav; WV – West Valav); 6 – trough-forming faults; 7 – faults within the halite subformation; 8 – lines of geological correlation; 9 – borehole of geological cross-section*

aring complexes (the intersalt and subsalt) lay below the halite subformation. Therefore the second area is characterized by a high density of existing deep wells. Potash salt prospects are located in synclinal zones.

The third prospect area is represented by alternation of salt uplifts and synclinal zones in the central part of the Pripyat trough. There are about 30 salt domes here that are characterized by great thickness (1.0–2.5 km) and shallow depth of burial. The upper rhythmic units V, VI and VII are the thickest within the third area (Fig. 3, 4). According to the gamma ray logs rock salt is also pure in these rhythmic units. Mozyr salt dome that is exploited as a gas storage is located in this Prospect. This area is a potential for prospecting of oil fields.

The fourth prospect area occupies the south-eastern part of the Pripyat trough. This area is characterised by shallow depth and small thickness (32–479 m) of halite subformation. In the geological structure of the subformation carbonate and sulphate rocks replace lower rhythmic units. Faults are identified in the inner structure of the halite subformation. There is a geological uncertainty in this area because of small amounts of wells that examine the subformation.

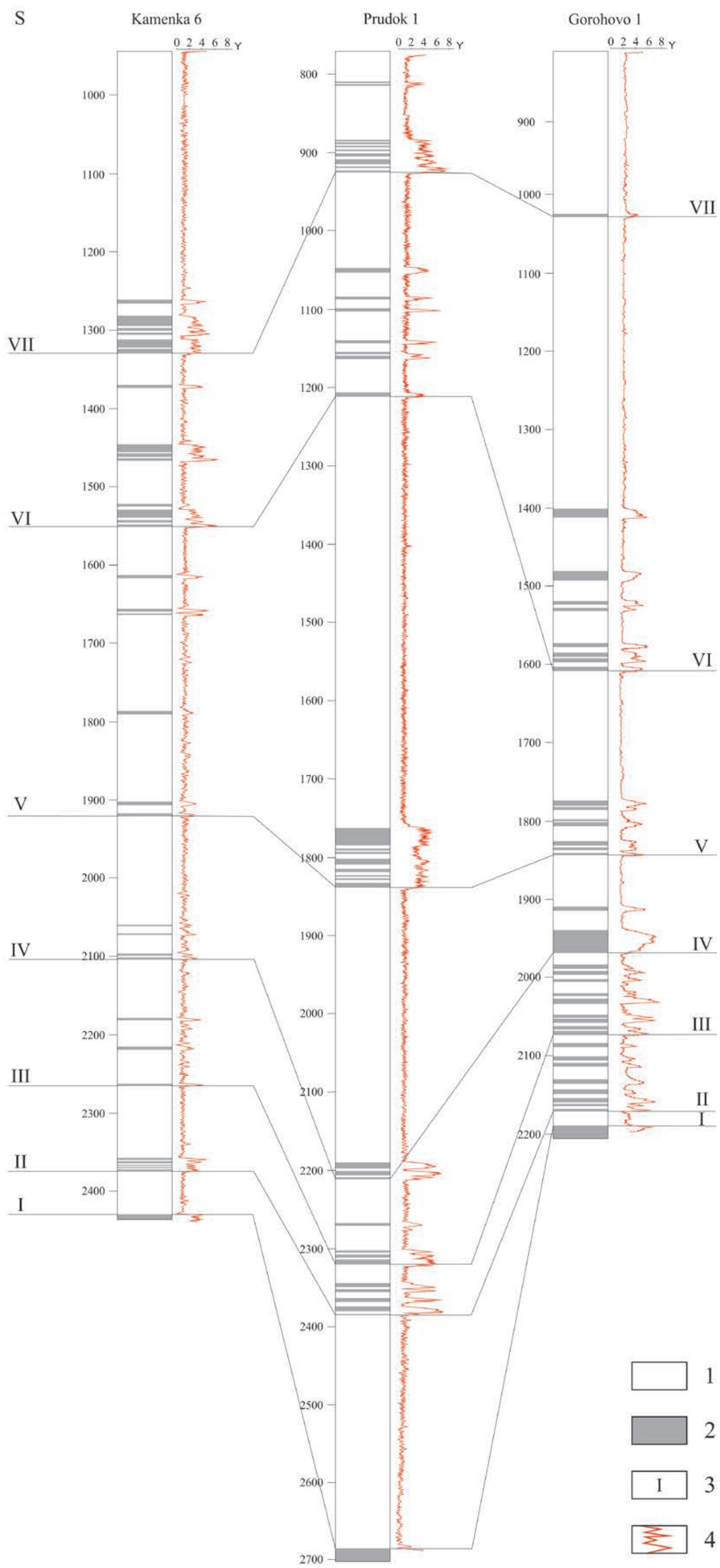
According to the zoning the most suitable for underground gas storage is the third prospect area. The further geologic risk evaluation of salt domes in the third area should include an analysis of the following parameters (Baker et al., 2017):

1. Salt body geometry – areal extent and edge of salt, thickness, structural configuration;
2. Salt quality – salt quality, thickness, geomechanical properties, impurity content (lithology, amount less than 35 %, distribution), non-salt interbeds (beds greater than 2 m of thickness should be avoided), anisotropy and heterogeneity, weak zones, highly soluble zones, creep prone zones, porous salt, and others;
3. Caprock thickness and lithology;
4. Protected groundwater – isolation distance and permeability/porosity of intervening rock;
5. Zones of active water flow or salt dissolution;
6. Potential geologic risk elements, which may include but are not limited to:

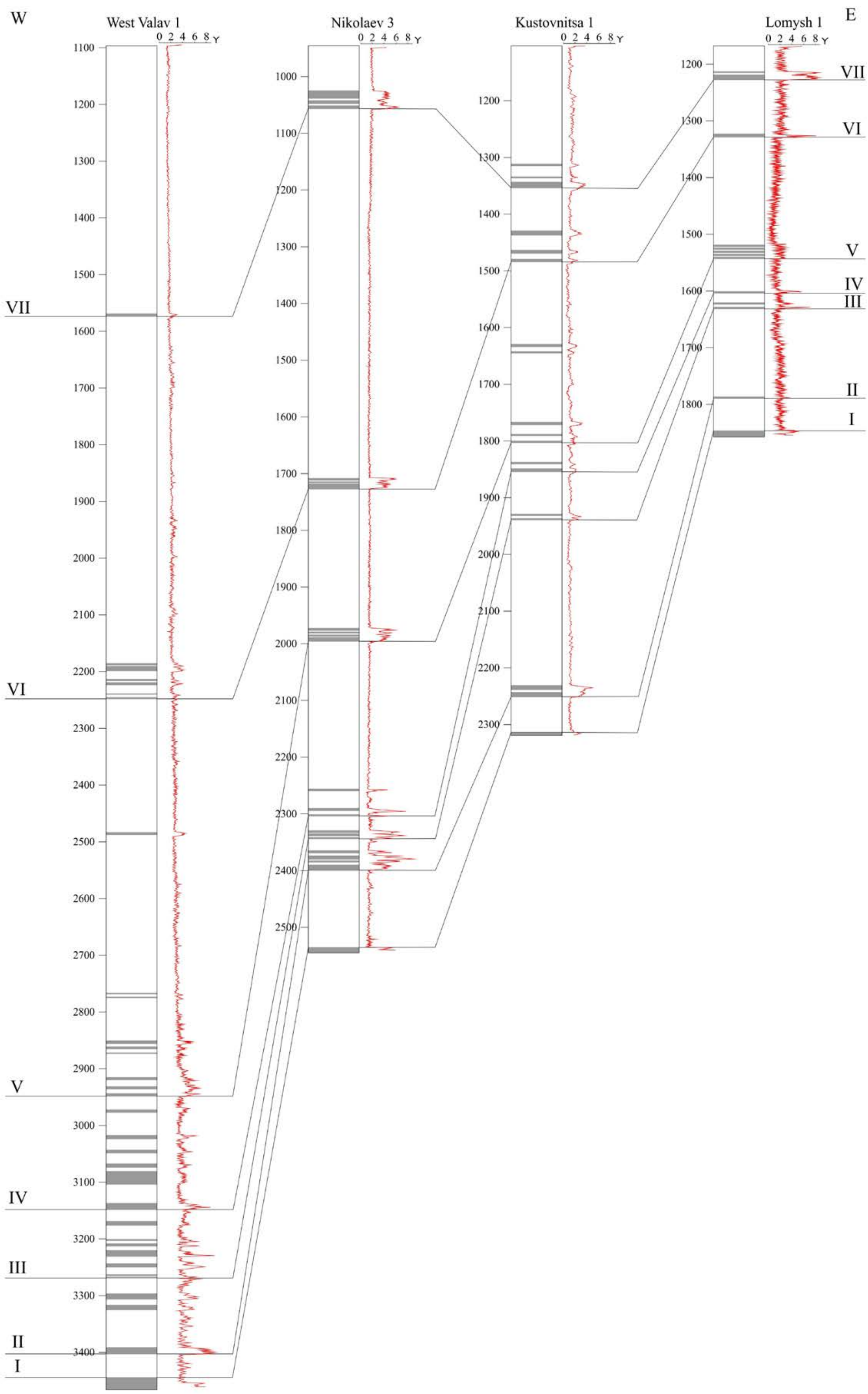
a) Too close to edge of salt, edge of dome, stratigraphic pinchout, bounding faults, dissolution fronts, non-deposition;

b) Different salt movement, shear zones and faults within the salt (boundary shear zones and edge zones);

c) Migration pathways to edge of salt via faults, boundary shear zones, weak salt, permeable salt;



Ryc. 4. Korelacja geologiczna wzdłuż linii 1-1: 1 – sól kamienna, 2 – utwory płonne, 3 – cyklotem, 4 – profilowanie gamma
Fig. 4. *Geological correlation along the line I-I: 1 – rock salt; 2 – non-saliferous rocks; 3 – rhythmic unit; 4 – gamma ray log*



Ryc. 5. Korelacja geologiczna wzdłuż linii II-II: 1 – sól kamienna, 2 – utwory płonne, 3 – cyklotem, 4 – profilowanie gamma
Fig. 5. *Geological correlation along the line II-II: 1 – rock salt; 2 – non-saliferous rocks; 3 – rhythmic unit; 4 – gamma ray log*

d) Proximity to existing salt caverns (thin salt pillar), mines or wells drilled into salt;

e) Caprock faulting and lost circulation zones – pose drilling risk and can compromise integrity of well casing and cementation.

Conclusion

Potential for underground fuel storage construction within the halite subformation is not homogenous in geological structure within the Pripyat trough. Carried out primary zoning of the trough one prospect area was identified with suitable geological features to the storage construction. Further detailed investigations of salt domes should pay more attention to the lithology of non-saliferous rocks and structure and texture features of rock salt. Salt deposits of the Pripyat salt-bearing basin are suitable for storage both fuel and radioactive wastes. Further researches of potential storages in salt domes depend on economy needs of the country.

Podsumowanie

Możliwości budowy podziemnego magazynu paliw w zasobach halitu nie są jednoznaczne ze względu na budowę geologiczną doliny rzeki Prypeć. Przeprowadzone wstępne strefowanie niecki pozwoliło ustalić jeden perspektywiczny rejon, wykazujący odpowiednie cechy geologiczne, umożliwiające budowę magazynu. Kolejne, dokładniejsze badania wysadów solnych powinny się skupić na litologii skał płonnych oraz budowie i cechach konsystencji zasobu soli kamiennej. Zasobdy soli w zagłębiu solnym rzeki Prypeć nadają się do składowania zarówno paliw, jak i odpadów radioaktywnych. Dalsze badania możliwości budowy magazynów i składowisk w wysadach solnych będą uzależnione od potrzeb gospodarczych kraju.

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