

CONTENTS

Geology of Combustible Minerals

PAVLYUK Myroslav, SHLAPINSKY Volodymyr, SAVCHAK Olesya, TERNAVSKY Myroslav, HUZARSKA Lyubov, TRISKA Nazar, OHRENDATA Nataliia. Prospects for oil and gas presence in the south-eastern part of the inner flysch covers of the Ukrainian Carpathians..... 5

KUROVETS Ihor, LYSAK Yulia, CHEPUSENKO Pavlo, MYKHALCHUK Stepan, KUCHER Roman-Danylo. Geological-petrophysical characteristic of Silurian deposits of the Volyn-Podillya edge of the East-European Platform..... 17

BARTASHCHUK Oleksiy. Collision deformations of the Dnieper-Donets Depression. Article 2. Kinematic mechanisms of tectonic inversion..... 32

BRYK Dmytro, GVOZDEVYCH Oleg, KULCHYTSKA-ZHYHAYLO Lesya, PODOLSKYY Myroslav. Technogenic carbonaceous objects of the Chervonohrad Mining and Industrial District and some technical solutions for their using..... 45

KHOKHA Yurii, YAKOVENKO Myroslava, LYUBCHAK Oleksandr, BRYK Dmytro. Equilibrium temperatures of hydrocarbon gas formation in sedimentary strata of the Western oil and gas region of Ukraine (according to thermodynamic modelling)..... 66

Geochemistry

GALAMAY Anatoliy, MENG Fanwei, SYDOR Daria, ZHANG Yongsheng. Peculiarities of chemical composition of Early Paleozoic seawater (study of fluid inclusions in halite of Ordovician Ordos salt basin, China)..... 78

YEROFIEIEV Artem, BEREZOVSKY Ihor. On content, migration and concentration of heavy metals in oils (by the example of the Dnieper-Donets Depression).... 96

SVOREN Yosyp. Bowels of the earth – natural physical-chemical reactor: is the search for natural methane a fundamental science or a technical problem?..... 104

Lithology

POPP Ihor, MOROZ Petro, SHAPOVALOV Mykhailo. Lithological-geochemical types of deposits of Cretaceous-Paleogene flysch of the Ukrainian Carpathians and conditions of their formation..... 116

Anniversaries

PAVLYUK Myroslav, NAUMKO Ihor. Outstanding scientist-geologist-romantic, Academician Yevhen Fedorovych Shniukov (to 90th anniversary from birth)..... 134

**Myroslav PAVLYUK, Volodymyr SHLAPINSKY, Olesya SAVCHAK,
Myroslav TERNAVSKY, Lyubov HUZARSKA,
Nazar TRISKA, Nataliia OHRENDA**

**PROSPECTS FOR OIL AND GAS PRESENCE
IN THE SOUTH-EASTERN PART OF THE INNER FLYSCH COVERS
OF THE UKRAINIAN CARPATHIANS**

We have studied the Cretaceous and Paleogene flysch of the Duklya-Chornohora, Burkut, Rakhiv, Marmarosh and Pieniny covers that in the south-eastern sector of the Ukrainian Carpathians near the Romanian border (Hutsulian segment) distinguish themselves by very inclined overthrust. Spatially the given tectonic units are in so-called hydrothermal fluid, unfavourable on the whole as to the presence of hydrocarbons in it on a large scale. But, within its limits the plots, small in area, with hydrocarbon prevalence in the gas composition are distinguished. Prospects for gas presence in the region should be connected with those of them that spatially are drawn to the Transcarpathian trough. One such section is the Velikobychkovk sector of the Monastyretsky sub-cover, where it is proposed to lay a parametric well 1-Velikiy Bychkov, in order to reveal the possible parautochthon of the Vezhany sub-cover and the Paleogene of the Dilovetsky sub-cover. In addition, according to seismic data, a significant rise in the pre-flysch base is forecast in this section of the Carpathians under the Marmarosh cover. The roof of this foundation at the location of the recommended well 1-Velikiy Bychkov may be at a depth of 5000–5500 m. It may be represented by the youngest deposits of the pre-Alpine complex – the Triassic strata, industrially oil and gas saturated in the neighboring countries.

Keywords: inner flysch covers, hydrothermal fluid, composition of free gases, oil and gas presence, perspective plots, Transcarpathian trough.

- Bobrovnik, M. D. (1973). Nekotoryye dannyye o kollektorskikh svoystvakh porod Flishovykh Karpat. In S. S. Kruglov (Red.), *Perspektivy neftegazonosnosti i napravleniye regionalnykh i poiskovykh rabot na neft i gaz v Ukrainykh Karpatakh* (s. 15–19). Lvov: UkrNIGRI. [in Russian]
- Danilenko, V. A., Leshchukh, R. Y., Makovskyi, S. A., & Shcherba, V. M. (1972). Deiaki osoblyvosti heolohichnoi budovy i perspektyvy naftohazonosnosti Solotvynskoi chastyny Zakarpatskoho prohynu. *Heolohiia i heokhimiia horiuchykh kopalyn*, 32, 8–13. [in Ukrainian]
- Dank, V., Komyati, Ya., Lelkesh, A. et al. (1981). Pannonskiy neftegazonosnyy basseyn. In V. V. Semenovich & Yu. G. Namestnikov (Red.), *Neftegazonosnyye basseyny sotsialisticheskikh stran Evropy (NRB, VNR, GDR, PNR, SRR, SSSR, ChSSR, SFRYu) i respubliki Kuba* (s. 187–230). Moskva. [in Russian]
- Kantolinskiy, S. I. (1967). *Otchet o geologicheskikh issledovaniyakh, provedennykh na pl. Dubove Zakarpatskoy oblasti USSR v 1966 g.* (T. 1). Lvov: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Kantolinskiy, S. I. (1968). *Otchet o poiskovo-syemochnykh rabotakh, provedennykh na pl. Voditsa Zakarpatskoy obl. USSR v 1967 g.* (T. 1). Lvov: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Kantolinskiy, S. I. (1972). *Razrabotka rekomendatsiy po napravleniyu poiskovo-razvedochnykh rabot na yugo-zapadnom sklone Vostochnykh Karpat v r-ne Svalyava–Voditsa Zakarpatskoy obl. USSR po materialam geologicheskikh syemok 1961–1969 gg.* Lvov: Fondy DP “Zakhidukrheolohiia”. [in Russian]

- Kulchitskiy, Ya. O. (1962). *Tektonika i perspektivy neftegazonosnosti yugo-vostochnoy chasti Ukrainskikh Karpat*. Lvov: UkrNIGRI, Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Kulchitskiy, Ya. O. (1966). *Tektonika i perspektivy neftegazonosnosti yuzhnogo sklona Ukrainskikh Karpat* (T. 1). Lvov: UkrNIGRI, Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Maksimov, A. A., & Nemkov, T. I. (1949). *Obyasnitelnaya zapiska k listam geologicheskoy karty M-35-XXXI (Nadvornaya) i L-35-1 (Chivchiny)* (T. 14, ch. 1). Moskva: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Matskiv, B. V., Kovalev, Yu. V., Voloshina, B. V., & Rapp, V. V. (1984). *Otchet o glubin-nom geologicheskoy kartirovani v predelakh listov M-35-133-B, G; L-35-1-A, B za 1980–1984 gg. (Rakhovskiy rudnyy rayon)* (T. 1). Beregovo: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Patrulus, D., Bombitã, G., Krãutner, H., & Krãutner, F. (1968). Notã explicativã la harta geologicã 1 : 200 000, foaia Viseu, Inst. geol.
- Pavliuk, M., Shlapinskiy, V., Savchak, O., & Ternavskiy, M. (2019). Perspektivy naftohazonosnosti pivnichno-zakhidnoi chastyny vnutrishnikh flishovykh pokryviv Ukrainskykh Karpat. *Heolohiia i heokhimiia horiuchykh kopalyn*, 2 (179), 5–20. [in Ukrainian]
- Seletskiy, T. M. (1964). *Tema № 608. Izucheniye gidrogeologicheskikh i gidrokhimicheskikh pokazateley neftegazonosnosti Zakarpatskogo vnutrennego progiba i Vnutrenney anti-klinalnoy zony Karpat* (T. 1). Lvov: UkrNIGRI, Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Shlapinskiy, V. E. (1989). Geokhimicheskiye anomalii Skladchatykh Karpat i ikh svyaz s neftegazonosnostyu. In *Problemy geologii i geokhimii goryuchikh iskopayemykh zapada Ukrainской SSR: tezisy dokladov respublikanskoy konferentsii (Lvov, 2–6 oktyabrya 1989 g.)* (T. 3, s. 77–78). Lvov. [in Russian]
- Shlapinskiy, V. E. (2003). Pryamyie i nepryamyie priznaki neftegazonosnosti Ukrainskikh Karpat kak novyye kriterii eye otsenki. In *Novyye idei v naukakh o Zemle: VI Mezhdunarodnaya konferentsiya* (T. 1, s. 277). Moskva. [in Russian]
- Shlapinskiy, V. Ye. (2015). *Heolohichna budova Skybovoho, Krosnenskoho i Dukliansko-Chornohorskoho pokryviv Ukrainskykh Karpat ta perspektivy yikh naftohazonosnosti*. (Avtoref. dys. kand. heol. nauk). Lviv. [in Ukrainian]
- Spravochnik po neftyanyim i gazovym mestorozhdeniyam zarubezhnykh stran: Kn. 1. Evropa. Severnaya i Tsentralnaya Amerika.* (1976). Moskva: Nedra. [in Russian]
- Voleyshe, V. O. (1970). *Otchet o rezultatakh razvedki Gornotisenskogo mestorozhdeniya myshiakovistykh i uglekislykh vod i otsenka ikh ekspluatatsionnykh zasobov po sostoyaniyu na 25.09.1970 g. (Zakarpatskaya obl.)* (Kn. 1). Kiev: KGRT, Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Voloshin, A. A. (1971). *Geologicheskoye stroyeniye i poleznyye iskopayemyye basseyna verkhnego techeniya reki Tisa (otchet o rezultatakh geologosyemochnykh rabot m-ba 1 : 50 000 i 1 : 25 000, Rakhovskiy rayon)* (T. 1). Beregovo: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Voloshin, A. A. (1973). *Otchet o rezultatakh geologosyemochnykh i geofizicheskikh rabot masshtaba 1 : 50 000 na ploshchadi listov M-34-144-A, V* (T. 1). Beregovo: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Voloshin, A. A. (1976). *Otchet o rezultatakh doizucheniya geologicheskogo stroyeniya v m-be 1 : 50 000 territorii listov M-34-144-B, G i L-34-12-B, vypolnenogo Tyachevskoy geologosyemochnoy partiyey i Zakarpatskoy geofizicheskoy partiyey v 1974–1976 gg.* (T. 1). Beregovo: Fondy DP “Zakhidukrheolohiia”. [in Russian]
- Zhilovskiy, N. I. (1963). *Geologicheskoye stroyeniye i otsenka perspektiv neftegazonosnosti yugo-zapadnogo sklona Ukrainskikh Karpat.* (Dis. kand. geol.-min. nauk). Lvovskiy gosuniversitet, Lvov. [in Russian]

**Ihor KUROVETS, Yulia LYSAK, Pavlo CHEPUSENKO,
Stepan MYKHALCHUK, Roman-Danylo KUCHER**

**GEOLOGICAL-PETROPHYSICAL CHARACTERISTIC
OF SILURIAN DEPOSITS OF THE VOLYN-PODILLYA EDGE
OF THE EAST-EUROPEAN PLATFORM**

Taking into consideration well logging of the Silurian deposits of the Volyn-Podillya plate, the materials of laboratory investigations of petrophysical parameters of reservoir rocks were analyzed and systematized.

Studied were capacity-filtration properties of reservoir rocks as well as their lithological-petrographical and structural-textural features. An analysis of the distribution of petrophysical parameters of the Silurian deposits of the Volyn-Podillya plate was executed by the methods of mathematic statistics. Main statistics and correlation coefficients between individual parameters were calculated, histograms of the distribution of the porosity factor K_{por} and the permeability factor K_{per} , volumetric weight δ and carbonation C in rocks were compiled, regression equations between parameters and their alteration with depth were formed. Petrophysical parameters of the samples available for carbonate and terrigenous rocks of Silurian were analyzed separately.

Executed investigations of petrophysical properties of rocks testify that in the Silurian deposits the carbonate reservoirs with the complex structure of the porous space were distributed. A visible alteration of capacity-filtration parameters of rocks of Silurian deposits is observed with depth. Porosity of rocks decreases with depth, but permeability increases that is a confirmation of the formation of the secondary fractured-cavernous porosity. Increase in the permeability factor with depth is characteristic of carbonate rocks.

According to geological-geophysical data available, the reservoir rocks with better capacity-filtration properties are distributed in the zone of the barrier reef. The best reservoir parameters are characteristic of cavernous dolomites and limestones at the Lokachy area and in the region of Lutsk. Reservoir rocks of porous type are practically absent at depths over 2500 m. Here a significant role in improving of collecting properties of rocks belongs to their fracturing. Microfractures are observed in clayed limestones, marls and clay rocks. Under favourable geodynamic conditions the subvertical zones of disconsolidation occur in which composite reservoir rocks with fracture porosity may be formed.

Keywords: reservoir parameters, Silurian deposits, Volyn-Podillya plate, lithological-petrophysical parameters.

- Artym, I. V., Kurovets, S. S., Zderka, T. V., Yarema, A. V., & Kurovets I. M. (2019). Development of the rocks fracturing model on the Carpathian region example. In *Theoretical and Applied Aspects Paper presented at the 18th International Conference Geoinformatics (EAGE, May 13–16, Kyiv, Ukraine)*. Retrieved from www.scopus.com.
- Chizh, E. I., Rizun, B. P., & Drygant, D. M. (1985). *Istoriya razvitiya organogennykh postroyek silura i razlomnaya tektonika Volyno-Podolia v svyazi s neftegazonosnostyu*. Dep. IGGGI. № 125-B-85. Lvov. [in Russian]
- Dolenko, G. N., Rizun, B. P., Senkovskiy, Yu. N. et al. (1980). *Geologiya i neftegazonosnost Volyno-Podolskoy plity*. Kiev: Naukova dumka. [in Russian]
- Drygant, D. M. (2000). Nyzhnii i serednii paleozoi Volyno-Podilskoi okrainy Skhidno-Yevropeiskoi platformy ta Peredkarpatskoho prohynu. *Naukovi zapysky Derzhavnoho pryrodnavchoho muzeiu, 15*, 24–129. [in Ukrainian]

- Krupskiy, Yu. Z. (2001). *Heodynamichni formuvannia i naftohazonosnist Karpatskoho ta Volyno-Podilskoho rehioniv Ukrainy*. Kyiv: UkrDHRI. [in Ukrainian]
- Krupskiy, Yu. Z., Kurovets, I. M., Senkovskiy, Yu. M., Mykhailov, V. A., Chepil, P. M., Dryhant, D. M. ... Bodlak, V. P. (2014). *Netradytsiini dzhherela vuhlevodniv Ukrainy: T. 2. Zakhidnyi naftohazonosnyi rehion*. Kyiv: Nika-Tsentr. [in Ukrainian]
- Kurovets, I., Drygant, D., Naumko, I., Kurovets, S., & Koltun, Yu. (2012a). Depositional environments of prospective for shale gas Silurian deposits of the East-European Platform, Ukraine. In *Abstracts of the 74th EAGE Conference & Exhibition incorporating SPE EUROPEC 2012 (Copenhagen, Denmark, June 4–7, 2012)* (Extended Abstracts and Exhibitors' catalogue) (CD).
- Kurovets, I., Drygant, D., Naumko, I., Kurovets, S., & Koltun, Yu. (2012b). Geological and physical-chemical characteristics of Lower Paleozoic deposits of Volhyno-Podillya, Western Ukraine. *Biuletyn PIG*, 449, 119–130.
- Kurovets, I., Lysak, Yu., & Chepusenko, P. (2017). Petrofizychna kharakterystyka karbonatnykh vidkladiv syluru Volyno-Podilskoi plyty. *Heolohiia i heokhimiia horiuchykh kopalyn*, 1–2 (170–171), 79–80. [in Ukrainian]
- Kurovets, I. M., & Naumko, I. M. (2009). Petrofizychna i mineralofliuidolohichna kharakterystyka rozrizu deiakykh perspektyvno naftohazonosnykh struktur Lvivskoho paleozoiskoho prohynu. *Naukovi pratsi UkrNDMI NAN Ukrainy*, 5 (ch. 2), 92–98. [in Ukrainian]
- Kurovets, I., Prykhodko, O., Hrytsyk, I., & Chepil, P. (2017). Teoretyko-eksperymentalni zasady diahnostryky netradytsiinykh pokladiv vuhlevodniv za petrofizychnymy kryteriami. *Heolohiia i heokhimiia horiuchykh kopalyn*, 1–2 (170–171), 82–84. [in Ukrainian]
- Kurovets, S. S., Artym, I. V., & Kurovets, I. M. (2018). Researching the fracturing of the reservoir rocks. *Journal of Hydrocarbon Power Engineering*, 5 (1), 1–6.
- Lysak, Yu. Ye. (2012). Petrofizychna kharakterystyka paleozoiskykh vidkladiv Volyno-Podilskoi okrainy Skhidnoievropeiskoi platformy. In *Seismolohichni ta heofizychni doslidzhennia v seismoaktyvnykh rehionakh: tezy dopovidei naukovo konferentsii-seminaru, prysviachenoi 80-richchiu z dnia narodzhennia Tarasa Zynoviiovycha Verbytskoho (Lviv, 29–30 travnia 2012 r.)* (s. 92–94). Lviv: SPOLOM. [in Ukrainian]
- Lysak, Yu. Ye., Shyra, A. I., & Kucher, Z. I. (2016). Rezultaty statystychnoho analizu petrofizychnykh parametriv vidkladiv syluru Lvivskoho paleozoiskoho prohynu. In *Suchasna heolohichna nauka i praktyka v doslidzhenni studentiv i molodykh fakhivtsiv: materialy XII Vseukrainskoi naukovo-praktychnoi konferentsii (Kryvorizkyi natsionalnyi universytet, 24–26 bereznia 2016 r.)* (s. 64–69). Kryvyi Rih: Vydavnychiy tsentr Kryvorizkoho natsionalnoho universytetu. [in Ukrainian]
- Naumko, I. M., Kurovets, I. M., Sakhno, V. E., & Chepusenko, P. S. (2009). Kompleksuvannia mineralofliuidolohichnykh i petrofizychnykh metodiv: netradytsiinyi pidkhid do vyvchennia porid-kolektoriv vuhlevodniv (na prykladi Lvivskoho paleozoiskoho prohynu). *Dopovidi NAN Ukrainy*, 1, 106–113. [in Ukrainian]
- Naumko, I. M., Kurovets, I. M., Zubyk, M. I., Batsevykh, N. V., Sakhno, B. E., & Chepusenko, P. S. (2017). Hydrocarbon compounds and plausible mechanism of gas generation in “shale” gas prospective Silurian deposits of Lviv Paleozoic depression. *Geodynamics*, 1 (22), 21–41.

Oleksiy BARTASHCHUK

COLLISION DEFORMATIONS OF THE DNEIPER-DONETS DEPRESSION

Article 2. Kinematic mechanisms of tectonic inversion

The second article is devoted to the investigation of the natural mechanisms of tectonic inversion of the Dnieper-Donets depression. Using the materials of geological mapping of the territory of the West-Donetsk graben, structural proofs of the destruction of the riftogenic structure by collision tectonic movements of Hercinian and Alpic tectogenesis were obtained. The consequence of the inversion deformations is the formation of the West Donets cover-folding tectonic region within the Lugansk-Komyshuvasky tectonic area of the uplift-folding and the Kalmius-Toretsky region of the scalloped thrust covers, which are divided by the Main anticline.

For the diagnosis of kinematic mechanisms of tectonic inversion, the data of reconstruction of tectonic stress fields and quantitative modeling of deformations of the southern outskirts of the Eastern European Platform were used. It is assumed that the tectonic inversion of the Dnieper-Donets basin began in the Zaal and Pfalz phases of orogenesis due to the collision motions of the compression orogen at the outskirts of Paleotetis. The formation of linear folding occurred in the uplifting-thrust mode in the field of stresses of the oblique left-hand compression of the sub-meridional directions. The kinematic mechanism of the folded deformations determined the longitudinal bending of the layers due to the extrusion of sedimentary geomas from the zone of maximum compression in the axial part to the zones of “geodynamic shadow” – in the direction of the sides of the depression.

In the late Mesozoic and Cenozoic, uplifting-thrust and strike-slip stresses formed echeloned cover-thrust and coulisse-jointed uplift-folded structural paragenesis. According to the results of tectonophysical diagnostics of deformation structures, it was found that under geodynamic conditions of clustering of compression axes in the central part of the West-Donets graben against the reduction of the geological space horizontally and extension of the section due to the formation of the cover-folded allochthon, there were flexural deformations of the primary linear Hercinian folded forms.

Such data can be considered as a kinematic mechanism of tectonic inversion of the invasion of the “tectonic stamp” by the Donets folded structure. Under its influence, the wedge-shaped segment of the tectonic thrust, which was diagnosed by the orcline of the transverse extension of the shallow type, was formed by the repeatedly deposited folds of sedimentary geomas in the articulation zone between the depression and the folded structure. In the front of the thrust were formed folded zones of extrusion of geomas, which consist of coulisse-jointed uplift-anticlines and folded plates-coverings of tectonic thrust. At the apex of the orocline, at the end of the dynamically coupled main thrusts, an advanced tectonic fan of compression is formed. In the rearward of the orocline formed sutures – the roots of folded cover.

Keywords: tectonic inversion, kinematic mechanism of deformation, plates-coverings of the thrust, uplift-folds, orocline of lateral extension.

Bartashchuk, O. (2019a). Evoliutsiia napruzhenno-deformovanoho stanu zemnoi kory Dniprovsko-Donetskoho paleoryftu u fanerozoii [Phanerozoic evolution model of a stress-strain state of the Earth crust at the Dnieper-Donets paleorift]. *Dopov. Nac. akad. nauk Ukr.*, 3, 62–71. [in Ukrainian]

- Bartashchuk, O. (2019b). Koliziini deformatsii Dniprovsko-Donetskoï zapadyny. Statia 1. Tektonika zony zchlenuvannia z Donetskoïu skladchastoïu sporudoïu [Collision deformations of the Dnieper-Donets Depression. Article 1. Tectonics of the articulation zone with the Donets folding structure]. *Geology & Geochemistry of Combustible Minerals*, 3 (180), 76–89. [in Ukrainian]
- Dudnik, V., & Korchemagin, V. (2004). Kimmeriyskoye pole napryazheniy v predelakh Olkhovatsko-Volyntsevskoy antiklinali Donbassa. ego svyaz s razryvnymi strukturami i magmatizmom [The Cimmerian stress field within the Olkhovatsko-Volyntsevsky anticline of the Donbass, its relationship with discontinuous structures and magmatism]. *Geophysical journal*, 26 (4), 75–84. [in Russian]
- Gonchar, V. (2019). Tektonicheskaya inversiya Dneprovsko-Donetskoï vpadiny i Donbassa (modeli i rekonstruktsii) [Tectonic inversion of the Dnieper-Donets depression and the Donbas (models and reconstructions)]. *Geophysical journal*, 41 (5), 47–86. [in Russian]
- Goryaynov, S., & Sklyarenko, Y. (Heads). (2017). *Prohnoz lokalizatsii ta hazonosnosti litologichnykh pastok pivdennoho skhodu DDZ v mezhakh litsenziinykh dilianok HPU «Shebelynkahazvydobuvannia» (Ch. 1. Stvorennia strukturno-heolohichnoi osnovy)* [Forecast of localization and gas-bearing capacity of lithological traps in the southeast of DDZ within the licensed sections of GPU “Shebelinkagazvydobuvannya”. (Part 1. Creating a Structural-Geological Basis)]. (Contract N 100 ShGV 2017-2017 (topic N 34.521/2017-2017)). Kharkiv: UkrNDIGaz. [in Ukrainian]
- Kazmin, V., & Tikhonova, N. (2005). Rannemezozoyskiye okrainnyye morya v Chernomorsko-Kavkazskom regione: paleotektonicheskyye rekonstruktsii [Early Mesozoic marginal seas in Black Sea-Caucasus region: paleotectonic reconstruction]. *Geotektonika*, 5, 20–35. [in Russian]
- Kopp, M. (1991). Strukturnyye risunki, svyazannyye s prodolnymi peremeshcheniyami vnutri skladchatykh poyasov (na primere Sredizemnomorsko-Gimalayskogo poyasa) [Structural patterns of within-fold belts horizontal movements]. *Geotektonika*, 1, 21–36. [in Russian]
- Kopp, M., Kolesnichenko, A., Mostryukov, A., & Vasilev, N. (2017). Rekonstruktsiya kaynozoykskikh napryazheniy/deformatsiy vostoïa Russkoy plity i puti eye primeniya dlya resheniya regionalnykh i prikladnykh zadach [Reconstruction of Cenozoic stress and deformations in the eastern East European platform with its regional and practical application]. *Geodynamics*, 2 (23), 46–67. [in Russian]
- Kopp, M., & Korchemagin, V. (2010). Kaynozoykskiye polya napryazheniy/deformatsiy Donbassa i ikh veroyatnyye istochniki [The Cenozoic stress/deformation fields of the Donets coal basin and their probable sources]. *Geodynamics*, 1 (9), 37–49. [in Russian]
- Korchemagin, V., & Ryaboshtan, Yu. (1987) Tektonika i polya napryazheniy Donbassa [Tectonics and stress fields of Donbass]. In *Polya napryazheniy i deformatsiy v zemnoy kore* [Fields of stress and strain in the Earth’s crust] (pp. 164–170). Moscow: Nauka. [in Russian]
- Rebetskiy, Yu. (2002). Obzor metodov rekonstruktsii tektonicheskikh napryazheniy i prirashcheniy seysmotektonicheskikh deformatsiy [Overview of methods for reconstruction of tectonic stresses and increments of seismotectonic deformations]. In *Tektonika segodnya* [Tectonics today] (pp. 227–243). Moscow: OIFZ of Academy of Sciences of Russia. [in Russian]

**Dmytro BRYK, Oleg GVOZDEVYCH,
Lesya KULCHYTSKA-ZHYHAYLO, Myroslav PODOLSKYY**

**TECHNOGENIC CARBONACEOUS OBJECTS
OF THE CHERVONOHRAH MINING AND INDUSTRIAL DISTRICT
AND SOME TECHNICAL SOLUTIONS FOR THEIR USING**

Ukraine has significant coal resources. Chervonohrad Mining and Industrial District is the main coal complex in the west of Ukraine. In recent years, the average annual coal production in the mines of Chervonohrad Mining and Industrial District has amounted to 1.5 bn t, coal ash varies over a wide range of 25 to 53 %, average coal ash content of about 40 %. Coal mining has produced millions of tons of coal waste every year. Concentration of technogeneuous coal objects (mines, mining infrastructure, coal-mining waste dumps and wastes of coal enrichment) in a relatively small area has caused environmental degradation. Therefore, technological and environmental aspects of carbon-containing technogenic objects are particularly important and actual.

Coal-waste dumps in the territory of Chervonohrad Mining and Industrial District are characterized in detail. The dumps cover different areas – from 9–10 to 29–30 ha, the height of the dumps reaches 62 m at the mostly heights of 25–40 m. The total waste deposit in the dumps of existing mines has a volume of more than 20 million m³.

The coal wastes from Mezhyrichanskaya mine coal-waste dump was investigated to determine the suitability for thermochemical processing. Technical characteristics of taken coal-waster samples is presented.

The technogenic carbonaceous objects and the impact to the environment are evaluated.

The developed and patented technical and technological solutions for the technogenic carbonaceous objects using are considered. It is shown that the concept of industrial development of coal wastes dumps is based on two aspects – extraction of valuable mineral components and energy utilization of carbonaceous wastes of coal production. Its patented as Patents of Ukraine technological schemes for terrestrial process in of solid carbonaceous raw material from dumps and sludges with the production of coal tar and synthesis gas CO + H₂ are presented, as well as the scheme of a system for utilization of heat from coal dump.

Recommendations for the implementation of innovative technologies are based on the results of the laboratory research. The purpose of the resolution is to obtain valuable components and energy from coal wasters while improving the environment.

Keywords: coal, Chervonohrad Mining and Industrial District, coal-waste dumps, carbonaceous wastes, technological solutions, coal tar, synthesis gas.

BP Statistical Review of World Energy 2019. (2019). <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf>

Bryk, D. V., Pavliuk, M. I., & Hvozdevych, O. V. (2010). Heotekhnolohiia de hazatsii metanu vuhilnykh plastiv z vykorystanniam sverdlovynnykh hidromonitoriv. *Ugol Ukrainy*, 11, 42–45. [in Ukrainian]

Bryk, D. V., Gvozdevich, O. V., Nalivayko, Ya. M., Stefanik, Yu. V., & Stepanchikov, A. E. (2000). Izvlecheniye metana ugolnykh mestorozhdeniy s ispolzovaniyem skvazhinogo gidrovruha. *Geotekhnicheskaya mekhanika*, 17, 95–99. [in Russian]

- Buchatska, H., Dvorianska, N., Dvorianskiy, A., & Diakiv, V. (2014). Mineralnyi sklad vidkhodiv vydobutku i zbahachennia vuhillia, yikhni ekzohenni zminy ta vplyv na pryrodni vody za rezultatamy hidroekolohichnoho modeliuвання (Chervonohradskyi hirnyhopromyslovyi raion). *Mineralohichnyi zbirnyk*, 64 (2), 176–194. [in Ukrainian]
- Buchynska, A. V., Hvozdevych, O. V., & Kulchytska-Zhyhailo, L. Z. (2011). Zahalni polozhennia otsinky efektyvnosti system zboru nyzkopotentsiinoho tepla masyviv. In *Stalyi rozvytok terytorii: enerhiia, voda, vidkhody, rekultyvatsiia: materialy Mizhnarodnoi naukovo-tekhnichnoi konferentsii (Lviv–Rudno, 6–8 kvitnia 2011 r.)* (s. 184–192). Lviv: Triada-plius. [in Ukrainian]
- Chekalyuk, E. B., Stefanik, Yu. V., & Bryk, D. V. (1989). Avtorskoye svidetelstvo № 1460072, SSSR. Sposob termicheskoy pererabotki vysokozolnogo topliva. *Byul.*, 7.
- DNVP «Heoinform Ukrainy». (b. d.). *Interaktyvna karta rodovyshch korysnykh kopalyn*. Vziato 15.07.19 z <http://geoinf.kiev.ua/wp/interaktyvna-karta-rodovyshch-korysnykh-kopalyn.htm> [in Ukrainian]
- Holovne upravlinnia statystyky u Lvivskii oblasti. (b. d.). *Bank danykh*. Derzhavna sluzhba statystyky Ukrainy. Vziato 15.07.19 z http://database.ukrcensus.gov.ua/statbank_lviv/Database/24PRYRODA/databasetree_uk.asp [in Ukrainian]
- Hvozdevych, O. V. (2008). Deiaki tekhnichni rishennia dlia tekhnolohii rekultyvatsii Lvivskoho polihonu tverdykh pobutovykh vidkhodiv. In *Polihony tverdykh pobutovykh vidkhodiv: proektuvannia ta ekspluatatsiia, vymohy Yevropeiskoho Soiuzu, Kiotskyi protokol: materialy Mizhnarodnoi naukovo-tekhnichnoi konferentsii (Slavske, 16–18 kvitnia 2008 r.)* (s. 51–66). Lviv: Triada-plius. [in Ukrainian]
- Hvozdevych, O. V., Bryk, D. V., Buchynska, A. V., Podolskyi, M. R., & Kulchytska-Zhyhailo, L. Z. (2018). Patent na korysnu model № 129618, Ukraina. Trubchastyi reaktor hazyfikatsii nekondytsiinykh tverdykh horiuchykh kopalyn. *Biul.*, 21. [in Ukrainian]
- Hvozdevych, O. V., Bryk, D. V., Khokha, Yu. V., & Liubchak, O. V. (2019). Patent na korysnu model № 131556, Ukraina. Sposib kompleksnoi dvostadiinoi nazemnoi termokhimichnoi pererobky vuhillia. *Biul.*, 2. [in Ukrainian]
- Hvozdevych, O. V., Bryk, D. V., Podolskyi, M. R., Buchynska, A. V., & Kulchytska-Zhyhailo, L. Z. (2018). Patent na korysnu model № 124857, Ukraina. Sposib termichnoho pereroblennia vidkhodiv vuhlevydobutku. *Biul.*, 8. [in Ukrainian]
- Hvozdevych, O. V., Pavliuk, M. I., Stefanyk, Yu. V., & Shvedenko, H. V. (2007). Patent na korysnu model № 70030, Ukraina. Sposib rekultyvatsii vidpratsovanoho karieru. *Biul. Prom. vlasn.*, 3. [in Ukrainian]
- Hvozdevych, O., Podolskyi, M., & Kulchytska-Zhyhailo, L. (Uklad.). (2016). *Innovatsiine vykorystannia mistsevykh enerhetychnykh resursiv*. Lviv: Triada plius. [in Ukrainian]
- Hvozdevych, O. V., Stefanyk, Yu. V., Bryk, D. V., Prokopenko, Ya. P., & Horbal, B. M. (2003). Deklaratsiinyi patent na vynakhid UA № 57322. Prystrij dlia de hazatsii tekhnohennoho masyvu. *Biul. Prom. vlasn.*, 6. [in Ukrainian]
- Ivanov, Ye., Yatsukh, O., & Lobanska, N. (2010). Heokhimichne zabrudnennia gruntiv pidpriemstvamy vuhilnoi promyslovosti (na prykladi shakhty “Zarichna”). *Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu imeni V. Hnatiuka. Ser. Heohrafiia. Spetsialnyi vypusk. Stale pryrodokorystuvannia: pidkhody, problemy, perspektyva*, 1 (27), 241–245. [in Ukrainian]
- Knysh, I. B. (2008). Heokhimiia mikroelementiv u porodakh terykona shakhty Vizeiska Lvivsko-Volynskoho kamianovuhilnoho baseinu. *Visnyk Lvivskoho universytetu. Ser. heolohichna*, 22, 58–71. [in Ukrainian]
- Knysh, I., & Karabyn, V. (2010). Heokhimiia mikroelementiv u porodakh terykonu kopalni Mezhyrichanska Lvivsko-Volynskoho kamianovuhilnoho baseinu. *Heolohiia i heokhimiia horiuchykh kopalyn*, 3–4 (152–153), 85–101. [in Ukrainian]
- Lyzun, S. O., Ivantsiv, O. Ye., Dudok, I. V. et al. (2001). Zakonomirnosti rozpodilu metanu u kamianovuhilnykh baseinakh Ukrainy ta perspektyvy yoho vydobutku i vykorystannia. *Heolohiia i heokhimiia horiuchykh kopalyn*, 2, 122–127. [in Ukrainian]

- Ministerstvo enerhetyky ta zakhystu dovkillia Ukrainy. (b. d.). *Vuhilna promyslovist*. Vziato 15.07.19 z http://mpe.kmu.gov.ua/minugol/control/uk/publish/officialcategory?cat_id=194359 [in Ukrainian]
- Nalyvaiko, Ya. M., Stepanchykov, O. O., Stefanyk, Yu. V., Bryk, D. V., & Hvozdevych, O. V. (2001). Deklaratsiinyi patent Ukrainy № 37584. Sverdlovyynnyi hidromonitor. *Biul.*, 4. [in Ukrainian]
- Pavliuk, M. I., Khokha, Yu. V., Bryk, D. V., & Yakovenko, M. B. (2019). Sapropelitove vuhillia zakhodu Ukrainy yak potentsiine dzherelo enerhetychnoi ta khimichnoi syrovyny. In *Nadrokorystuvannia v Ukraini. Perspektyvy investuvannia: VI Mizhnarodna naukovo-praktychna konferentsiia (Truskavets, 8–10 zhovtnia 2019 r.)* (s. 307–311). Kyiv. [in Ukrainian]
- Petlovanyi, M. V., & Medianyuk, V. Y. (2018). Assessment of coal mine waste dumps development priority. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 4, 28–35. doi.org/10.29202/nvngu/2018-4/3
- Rudko, H. I., & Bondar, O. I. (Red.). (2016). *Ekolohichna bezpeka vuhilnykh rodovyshch Ukrainy* (s. 12–17). Kyiv; Chernivtsi: Bukrek. [in Ukrainian]
- Skira, V., Timofeiev, I., Stefanyk, Yu., Stepanchikov, O., & Bryk, D. (1999). Aparatura dlia hlybokoho drenuvannia. In *Postup v naftohazopererobnii i naftokhimichnii promyslovosti: tezy dopovidei II naukovo-tekhnichnoi konferentsii (Lviv, kviten 1999 r.)* (s. 60). Lviv. [in Ukrainian]
- Stepanchikov, A. E., Gvozdevich, O. V., Bashirov, V. V., & Temnov, G. M. (1990). *Skvazhinnyye gidrostruynnyye apparaty dlya intensifikatsii protsessu nefteizvlecheniya*. Moskva: VNIENG. [in Russian]
- Stepanchikov, A. E., Stefanyk, Yu. V., & Hvozdevych, O. V. (2001). Deklaratsiinyi patent Ukrainy № 37471. Sposib sverdlovyynnoi hidroperforatsii ta prystrii dlia yoho zdiisnennia. *Biul. Prom. vlasn.*, 4. [in Ukrainian]
- Volotkovskaya, Yu. A. (2015). Obosnovaniye napravleniya kapitalovlozheniy pri utilizatsii terrikona s ispolzovaniyem ranga toksichnosti. *Ekonomichnyi prostir*, 100, 232–241. http://nbuv.gov.ua/UJRN/ecpros_2015_100_23 [in Russian]
- Zabigaylo, V. E., Vasyuchkov, Yu. F., & Repka, V. V. (1989). *Fiziko-khimicheskiye metody upravleniya sostoyaniyem ugolno-porodnogo massiva*. Kiev: Naukova dumka. [in Russian]

UDC 550.41

**Yurii KHOKHA, Myroslava YAKOVENKO,
Oleksandr LYUBCHAK, Dmytro BRYK**

**EQUILIBRIUM TEMPERATURES
OF HYDROCARBON GAS FORMATION IN SEDIMENTARY STRATA
OF THE WESTERN OIL AND GAS REGION OF UKRAINE
(according to thermodynamic modelling)**

The article reviews the question of interpretation of natural gases component composition from the aspect of their evolution. The parameters available for study, which show a strong correlation with the conditions of formation, migration and accumulation of natural hydrocarbon gases, are selected.

Among these parameters, the ratio of the butanes isomeric form ($i-C_4/n-C_4$) was selected for thermodynamic analysis as a dependable indicator of the kerogen degradations temperature regime. It is shown that the dependence of the $i-C_4/n-C_4$ ratio on the nor-

malized methane content shows the trend of increasing kerogen maturity, and deviations from this trend indicate a distant migration of hydrocarbon fluid from the formation zone to the current deposit.

Analysis of the residence and thermodynamic conditions of hydrocarbons in the deposits of the Western oil and gas region showed that kerogen/gas systems are in a state close to equilibrium, in terms of thermodynamics.

The composition of the gas/kerogen equilibrium system in the conditions of sedimentary thickness for two heat fluxes – 75 and 100 mW/m² was calculated by the method based on Jaynes's formalism. Among hydrocarbons in gases, the content of isomeric forms of butane and pentane, as well as methane, ethane and propane was calculated. The results of the calculations revealed a monotonic dependence of the equilibrium temperature and depth of formation on the ratio of isobutane to n-butane. It was found that the results of thermodynamic calculations coincide with experiments on kerosene pyrolysis and correlate with studies of the composition and residence of natural gases.

Equilibrium formation temperatures were determined for 59 gas, oil and gas condensate fields of the Western oil and gas region, the information on which contained data on the *i*-C₄/*n*-C₄ ratio. Based on the results of calculations, maps of these temperatures distribution within the region were constructed.

The analysis of the maps showed the presence of two distinct temperature maxima, which are concentrated in the Boryslav-Pokuttya oil and gas region and are located at the intersection of regional faults. It has been suggested that the hydrocarbon source is significantly distant from modern deposits for the study region. The results of the calculation are compared with the data obtained using the model of fossil hydrocarbons inorganic origin.

Keywords: butane isomers, gas evolution, formation temperature, Jaynes's formalism.

- Atlas rodovyshch nafty i hazu Ukrainy* (T. 4). (1998). Lviv: Tsentr Yevropy. [in Ukrainian]
- Bell, I. H., Wronski, J., Quoilin, S., & Lemort, V. (2014). Pure and Pseudo-Pure Fluid Thermophysical Property Evaluation and the Open-Source Thermophysical Property Library CoolProp. *Industrial & Engineering Chemistry Research*, 53 (6), 2498–2508.
- Khokha, Yu. V. (2014). *Termodynamika hlybyunnykh vuhlevodniv u prohnovuvanni rehionalnoi naftohazonosnosti*. Kyiv: Naukova dumka. [in Ukrainian]
- Khokha, Yu. V., Liubchak, O. V., & Yakovenko, M. B. (2019). Termodynamika transformatsii kerohenu II typu. *Heolohiia i heokhimiia horiuchykh kopalyn*, 3 (179), 25–40. [in Ukrainian]
- Krupskiy, Yu. Z. (2001). *Heodynamichni umovy formuvannia i naftohazonosnist Karpatskoho ta Volyno-Podilskoho rehioniv Ukrainy*. Kyiv: UkrDHRI. [in Ukrainian]
- Prinzhofer, A., & Battani, A. (2003). Gas Isotopes Tracing: an Important Tool for Hydrocarbons Exploration. *Oil & Gas Science and Technology – Rev. IFP*, 58 (2), 299–311.
- Prinzhofer, A., Mello, M. R., & Takaki, T. (2000). Geochemical Characterization of Natural Gas: A Physical Multivariable Approach and its Applications in Maturity and Migration Estimates. *AAPG Bulletin*, 84 (8), 1152–1172.
- Tisso, B., & Velte, D. (1981). *Obrazovaniye i rasprostraneniye nefiti*. Moskva: Mir. [in Russian]
- Vandenbroucke, M., & Largeau, C. (2007). Kerogen origin, evolution and structure. *Organic Geochemistry*, 38, 719–833.
- Wood, J. M., & Sanei, H. (2016). Secondary migration and leakage of methane from a major tight-gas system. *Nature Communications*, 7. doi:10.1038/ncomms13614

Anatoliy GALAMAY, Fanwei MENG,
Daria SYDOR, Yongsheng ZHANG

**PECULIARITIES OF CHEMICAL COMPOSITION
OF EARLY PALEOZOIC SEAWATER
(study of fluid inclusions in halite of Ordovician Ordos salt basin, China)**

The fluid inclusions in the marine Middle Ordovician halite of the Majiagou Salt Formation of the Ordos Basin (China) have been investigated. In addition to the primary inclusions the secondary ones of several generations were also detected. The fluid inclusions brine chemistry of halite was studied using an ultramicrochemical (UMCA) method, and the homogenization temperature of fluid inclusions was determined in a special thermal chamber designed by V. A. Kalyuzhny

At the post-sedimentation stage, the studied salt strata were exposed to high temperature (58–72 °C) and high (up to several tens of MPa) pressure. Although there are opinions of the inability of primary inclusions in such halite to determine the physical and chemical conditions of sedimentation, however, the informative value of primary inclusions in halite of the Majiagou Formation has remained. The preservation of the integrity (and thus the informative value) of primary inclusions in halite is evidenced by the same chemistry of their brines, which differs from that of secondary inclusions. The sedimentation brines of the basin were concentrated to the middle of halite stage and points to the Na-K-Mg-Ca-Cl seawater.

The physical and chemical conditions of evaporites formation are not known enough. Currently, the results of the brine chemistry of primary fluid inclusions in marine halite are the best indicators of seawater composition in the Phanerozoic. It is established that the magnesium content in the brines of the Lower Paleozoic basins is lower comparing to modern seawater of the corresponding concentration, and the potassium ion concentration is higher. The chemical composition of the concentrated seawater from which the halite was crystallized in the Ordovician salt basin of Ordos, with the exception of the calcium ion content, is similar to the seawater chemistry of the Cambrian and Silurian basins, which indicates the relative constancy of Early Paleozoic seawater chemistry.

Age-related changes in the chemical composition of seawater are always consistent with many quantitatively or qualitatively characterized processes of the Earth's crust evolution. So we believe that the causes that led to more than twice the potassium content of Riphean-Devonian clays, unlike the younger ones, it were also the reason for the increase in potassium content in the Lower Paleozoic marine brines.

The studies conducted also clarify the limits of oscillation of calcium ion content, which determines the type of seawater. Its content in the sedimentary brines of the Ordos basin of the Middle Ordovician reaches 66 g/l at the middle of halite stage. Therefore, at the beginning of the stage of halite precipitation, its content should be approximately 20 g/l (considering its theoretical content of 10 g/l with the modern composition of the atmosphere). Apparently, the cause of the abnormally high calcium content in the early Paleozoic Ocean was the direct flow of it with hydrothermal solutions into the ocean during the activation of global tectonics of the Earth and the increase of solubility of carbonates of continents and ocean floor due to high carbon dioxide atmospheric content.

Keywords: halite, primary inclusions, homogenization temperature, seawater.

Acros, D., & Ayora, C. (1997). The use of fluid inclusions in halite as environmental thermometer: an experimental study. In *XIV ECROFI* (pp. 10–11). Nancy.

- Bao, H. P., Yang, C. Y., & Huang, J. S. (2004). "Evaporation drying" and "reinflusing and redissolving"—a new hypothesis concerning formation of the Ordovician evaporites in eastern Ordos Basin. *Journal of Palaeogeography*, 6, 279–288. [in Chinese with English abstract].
- Berner, R. A., Vandenbrooks, J. M., & Ward, P. D. (2007). Oxygen and evolution. *Science*, 316, 557–558.
- Brennan, S. T., & Lowenstein, T. K. (2002). The major-ion composition of Silurian seawater composition. *Geochimica et Cosmochimica Acta*, 66, 2683–2700.
- Claypool, G. E., Holser, W. T., Kaplan, I. R., Sakai, H., & Zak, I. (1980). The age curves of sulfur and oxygen isotopes in marine sulfate and their mutual interpretation. *Chem. Geol.*, 28, 199–260.
- Das, N., Horita, J., & Holland, H. D. (1990). Chemistry of fluid inclusions in halite from the Salina Group of the Michigan Basin: Implications of Late Silurian seawater and the origin of Sedimentary brines. *Geochimica et Cosmochimica Acta*, 54, 319–327.
- Demicco, R. V., Lowenstein, T. K., Hardie, L. A., & Spencer, R. J. (2005). Model of seawater composition for the Phanerozoic. *Geology*, 33 (11), 877–880.
- Eugster, H. P., Harvie, C. E., & Weare J. H. (1980). Mineral equilibria in a sixcomponent seawater system, Na-K-Mg-Ca-SO₄-Cl-H₂O, at 25 °C. *Geochimica et Cosmochimica Acta*, 44, 1335–1347.
- Feng, Z. Z., Zhang, Y. S., & Jin, Z. K. (1998). Type, origin, and reservoir characteristics of dolostones of the Ordovician Majiagou Group, Ordos, North China platform. *Sedimentary Geology*, 118, 127–140.
- Fox, J. S., & Videtich, P. E. (1997). Revised estimate of δ³⁴S for marine sulfates from the Upper Ordovician: data from the Williston Basin, North Dakota, USA. *Applied Geochemistry*, 12, 97–103.
- Galamay, A. R., & Bukowski, K. (2011). Skład chemiczny badeńskich solanek z pierwotnych ciekłych inkluzji w halicie, basen Zakarpacki (Ukraina). *Geologia (kwart. AGH)*, 37 (2), 245–267.
- Garrels, R., & Mackenzie, F. (1974). *Evolutsiya osadochnykh porod* [Evolution of sedimentary rocks]. Moscow: Mir. [in Russian]
- Geological Survey of Western Australia. Petroleum Operations Division. & Western Australia. Department of Industry and Resources. (2004). *Summary of petroleum prospectivity onshore Western Australia and State waters 2004: Bonaparte, Canning, Officer, Perth, Southern Carnarvon and Northern Carnarvon Basins : 2003*. Geological Survey of Western Australia.
- Goncharenko, G. A., & Moskovsky, O. P. (2004). Osobennosti evolyutsii sostava morskikh rastvorov v fanerozoie [Evolution features of marine solutions composition in the Phanerozoic]. *Proceedings of Voronezh University. Geology*, 2, 48–62. [in Russian]
- Hardie, L. A. (1996). Secular variation in seawater chemistry: An explanation for the coupled secular variation in the mineralogies of marine limestones and potash evaporites over the past 600 m. y. *Geology*, 24, 279–283.
- Holdaway, K. A. (1974). Behavior of fluid inclusions in salt during heating and irradiation. In *Fourth International Symposium on salt* (Vol. 1, pp. 303–312). Cleveland Ohio: Northern Ohio Geological Society.
- Holland, H. D. (2003). The geologic history of seawater. *Treatise on Geochemistry*, 6, 583–625.
- Horita, J., Zimmermann, H., & Holland, H. D. (2002). Chemical evolution of seawater during the Phanerozoic: Implications from the record of marine evaporites. *Geochimica et Cosmochimica Acta*, 66, 3733–3756.
- Kalyuzhny, V. A. (1982). *Osnovy ucheniya o mineraloobrazuyushchikh flyuidakh* [The foundations of teaching about mineral-forming fluids]. Kiev: Naukova dumka. [in Russian]
- Kovalevich, V. M. (1978). *Fiziko-khimicheskiye usloviya formirovaniya soley Stebnikskogo kaliynogo mestorozhdeniya* [Physical and chemical conditions of salts formation of the Stebnik potash deposit]. Kiev: Naukova dumka.

- Kovalevich, V. M. (1990). *Galogenez i khimicheskaya evolyutsiya okeana v fanerozoie* [Halogenesis and chemical evolution of ocean in the Phanerozoic]. Kiev: Naukova dumka. [in Russian]
- Kovalevich, V. M., Peryt, T. M., & Petrichenko, O. I. (1998). Secular variation in seawater chemistry during the Phanerozoic as indicated by brine inclusions in halite. *Geology*, *106*, 695–712.
- Kovalevich, V. M., & Vovnyuk, S. V. (2010). Vekovyie variatsii khimicheskogo sostava rassolov morskikh evaporitovykh basseynov i vod mirovogo okeana [Secular variations in the chemical brines composition of marine evaporite basins and oceans waters]. *Lithology*, *4*, 95–109. [in Russian]
- Kovalevych, V. M., Peryt, T. M., & Dzhinoridze, N. M. (2003). Chemical characteristics of seawater in the Early Cambrian: results of a fluid-inclusion study of halite from the Tyret' Deposit (East Siberia). In D. G. Eliopoulos et al. (Eds). *Mineral Exploration and Sustainable Development* (pp. 693–695). Rotterdam: Millpress.
- Kovalevych, V. M., Peryt, T. M., Zang, W., & Vovnyuk, S. V. (2006). Composition of brines in halite-hosted fluid inclusions in the Upper Ordovician, Canning Basin, Western Australia: new data on seawater chemistry. *Terra Nova*, *18* (2), 95–103.
- Kovalevych, V. M., & Vovnyuk, S. V. (2010). Fluid inclusions in halite from marine salt deposits: are they real micro-droplets of ancient sea water? *Geological Quarterly*, *54* (4), 401–410.
- Kovalevych, V. M., Zang, W-L., Peryt, T. M., Khmelevska, O. V., Halas, S., Iwasinska-Budzyk, I. ... Heithersay, P. S. (2006). Deposition and chemical composition of Early Cambrian salt in the eastern Officer Basin, South Australia. *Australian Journal of Earth Sciences*, *53*, 577–593.
- Large, R. R., Mukherjee, I., Gregory, D., Steadman, J., Corkrey, R., & Danyushevsky, L. V. (2019). Atmosphere oxygen cycling through the Proterozoic and Phanerozoic. *Mineralium Deposita*, *54*, 485–506. <https://doi.org/10.1007/s00126-019-00873-9>
- Lenton, T. M., Daines, S. J., & Mills, B. J. W. (2018). COPSE reloaded: an improved model of biogeochemical cycling over Phanerozoic time. *Earth-Science Reviews*, *178*, 1–28.
- Li, R. X., Guzmics, T., Liu, X. J., & Xie, G. C. (2011). Migration of immiscible hydrocarbons recorded in calcite-hosted fluid inclusions, Ordos Basin: a case study from Northern China. *Russian Geology and Geophysics*, *52*, 1491–1503.
- Lowenstein, T. K., & Timofeeff, M. N. (2008). Secular variations in seawater chemistry as a control on the chemistry of basinal brines: test of the hypothesis. *Geofluids*, *8*, 77–92.
- Lowenstein, T. K., Timofeeff, M. N., Kovalevych, V. M., & Horita, J. (2005). The major-ion composition of Permian seawater. *Geochimica et Cosmochimica Acta*, *69* (7), 1701–1719.
- Matukhin, R. G., Petrichenko, O. Y., & Sokolov, P. N. (1985). Gazovo-zhidkiye vklyucheniya v galite kak pokazatel usloviy formirovaniya devonskikh solenosnykh otlozheniy Sibiri [Gas-liquid inclusions in halite as an indicator of the conditions of the Siberia Devonian salt sediments formation]. In *Litologo-fatsialnyye i geokhimicheskkiye problemy solenakopleniya* [Lithological-facies and geochemical problems of salt accumulation] (pp. 194–203). Moscow: Nauka. [in Russian]
- McCaffrey, M. A., Lazar, B., & Holland, H. D. (1987). The evaporation path of seawater and the coprecipitation of Br and K with halite. *Journal of Sedimentary Petrology*, *57*, 928–937.
- Ogg, J. G., Scotese, C. R., Hou, M., Chen, A., Ogg, G. M., & Zhong, H. (2019). Global Paleogeography through the Proterozoic and Phanerozoic: Goals and Challenges. *Acta Geologica Sinica* (English Edition), *93* (1), 59–60.
- Petrichenko, O. Y. (1989). *Epigenez evaporitov* [Epigenesis of evaporites]. Kiev: Naukova dumka. [in Russian]
- Petrychenko, O. Y. (1973). *Metody doslidzhennia vkluchen u mineralakh halohennykh porid* [Methods of inclusions investigation in salt rock minerals]. Kyiv: Naukova dumka. [in Ukrainian]

- Petrychenko, O. Y., Peryt, T. M., & Chechel, E. I. (2005). Early Cambrian seawater chemistry from fluid inclusions in halite from Siberian evaporates. *Chem. Geol.*, 219, 149–161.
- Roedder, E. (1984). The fluids in salt. *Am. Mineralogist*, 69, 413–439.
- Scotese, C. R. (2014). *Atlas of Silurian and Middle-Late Ordovician Paleogeographic Maps* (Mollweide Projection). (Maps 73–80, Vol. 5). The Early Paleozoic, PALEOMAP Atlas for ArcGIS, PALEOMAP Project, Evanston, IL.
- Strakhov, N. M. (1962). *Osnovy teorii litogeneza* [Fundamentals of the theory of lithogenesis] (Vol. 3). Moscow: AS USSR. [in Russian]
- Valyashko, M. G. (1962). *Zakonomernosti formirovaniya mestorozhdeniy soley* [The principle of forming of salt deposits]. Moscow: MGU. [in Russian]
- Vinogradov, A. P., & Ronov, A. B. (1956). Evolyutsiya khimicheskogo sostava glin Russkoy platformy [Evolution of the chemical composition of clays of the Russian Platform]. *Geochemistry*, 2, 3–18. [in Russian]
- Wang, B. Q., & Al-Aasm, I. S. (2002). Karst-controlled diagenesis and reservoir development; example from the Ordovician mainreservoir carbonate rocks on the eastern margin of the Ordos basin, China. *AAPG Bulletin*, 86, 1639–1658.
- Yang, Y., Li, W., & Ma, L. (2005). Tectonic and stratigraphic controls of hydrocarbon systems in the Ordos basin: a multicycle cratonic basin in central China. *AAPG Bulletin*, 89, 255–269.
- Zharkov, M. A., Zharkova, T. M., & Merzlyakov, G. A. (1978). K probleme evolyutsii solevogo sostava vod Mirovogo okeana [To the problem of waters salt composition evolution of the World Ocean]. *Geology and Geophysics*, 3, 3–18. [in Russian]

UDC 550.423

Artem YEROFIEIEV, Ihor BEREZOVSKY

**ON CONTENT, MIGRATION AND CONCENTRATION
OF HEAVY METALS IN OILS
(by the example of the Dnieper-Donets Depression)**

Literature review and analysis of previous studies of the problem was carried. The main scientific works on the research topic, as well as the main directions and stages of the study are indicated. Similar studies that were conducted on the territory of Ukraine are considered.

The results of the study of heavy metals in oil samples taken from a large oil and gas region from more than thirty deposits of Ukraine are presented. All current and non-working fields are considered.

The geological structure of the oil and gas province, as well as the main geochemical features of the formation of mineral deposits are considered. The main forms of finding target metals, as well as possible ways of transferring these elements in the earth's crust are given.

Samples were investigated using x-ray fluorescence and neutron activation analysis. The obtained research data in the framework of two selected methods are combined for analysis. The results obtained within the same geological structure are compared with each other to determine the effect of the physical conditions of sediment formation on the micro-component composition of crude oil. They also compared the effect of physical conditions on the properties of oil and their ability to accumulate heavy metals. Possible causes of the abnormal accumulation of heavy metals due to the close occurrence of oil and formation water are noted.

According to the results obtained, a graph is constructed of the dependence of the mineralization of oil on its depth. An exponential graphical approximation is presented to display the general trend of dependence.

Possible sources and ways of migration and accumulation of heavy metals in hydrocarbons are analyzed. The concept of the migration of heavy metals in oil is proposed in conjunction with the ore mineralization of adjacent and adjacent deposits.

Possible causes of differences in the concentrations of heavy metals in oil of various geological structures are indicated, as well as the main possible causes of measurement errors and complications in the selection of each of the analysis methods are specified.

Keywords: migration, heavy metals, petroleum, X-ray fluorescence spectroscopy, petroleum geochemistry, organometallic compounds.

- Ahmad, D. M., Hafizan, J., & Kamaruzaman, Y. (2015). Oil spill related Heavy Metal: a Review. *Malaysian Journal of Analytical Sciences*, 48 (1), 1348–1360.
- Akpoveta, O. V., & Osakwe, S. A. (2014). Determination of Heavy Metal Contents in Refined Petroleum. *IOSR Journal of Applied Chemistry*, 7 (6), 1–2.
- Barwise, A. J. G. (1990). Role of nickel and vanadium in petroleum classification. *Energy Fuels*, 4 (6), 647–652.
- Ishchenko, L. V. (2018). Oreolnı vody rtutnykh rudnykh poliv Donbasu yak rezultat evoliutsii hidrotermalnykh system. *Science Rise*, 9, 6–10. [in Ukrainian]
- Khlibyshyn, Yu. Ya., Mokhammad Shakir Abd Al-Ameri, Hrynyshyn, O. B., & Pochapska, I. Ya. (2013). Doslidzhennia dystyliatnoi chastyny vysokosirkovoi nafty Orkhovytskoho naftovoho rodovyscha. *Visnyk Natsionalnoho universytetu "Lvivska politekhnikha"*, 761, 462–465. [in Ukrainian]
- Lazarenko, E. K., Panov, B. S., & Pavlishin, V. I. (1975). *Mineralogiya Donetskogo basseyna*. Kiev: Naukova dumka. [in Russian]
- Madu, A. N., & Iwuoha, G. A. (2011). Extent of heavy metals in oil samples in escravos, Abiteye and Malu Platforms in Delta State Nigeria Njoku. *Learning Publics Journal of Agriculture and Environmental Studies*, 2 (2), 41–44.
- Shnyukov, E. F., Gozhik, P. F., & Krayushkin, V. A. (2007). Vanadiy i nikel v prirodnykh neftyakh Azii. Afriki. Evropy. Severnoy i Yuzhnoy Ameriki. *Dopovidi NAN Ukrainy*, 3, 137–141. [in Russian]
- Sukhanov, A. A., & Petrova, Yu. E. (2008). Resursnaya baza poputnykh komponentov tyazhelykh neftey Rossii. *Neftegazovaya geologiya. Teoriya i praktika*, 3, 1–11. [in Russian]
- Suyarko, V. G. (1988). Geokhimicheskiye osobennosti podzemnykh vod Donbassa. *Geokhimiya*, 5, 738–746. [in Russian]
- Suyarko, V. G. (2006). *Geokhimiya podzemnykh vod vostochnoy chasti Dneprovsko-Donetskogo avlakogena*. Kharkov: KhNU imeni V. N. Karazina. [in Russian]
- Suiarko, V. H., Zahnitko, V. M., & Lysyenko, H. V. (2010). *Strukturno-geokhimichne prohnovuvannia skupchen vuhlevodniv (na prykladi Zakhidno-Donetskoho hrabenu)*. Kyiv: IHNS NAN ta MNS Ukrainy. [in Ukrainian]
- Suiarko, V. H., Zahnitko, V. M., & Reshetov, I. K. (2008). Ridkisini elementy v hidrotermalnykh vodakh Donbasu. *Visnyk Kharkivskoho natsionalnoho universytetu imeni V. N. Karazina*, 803, 70–74. [in Ukrainian]
- Wilberforce, J. O. (2016). Profile of Heavy Metals in Crude Oil Commonly Consumed for Medicinal Purposes in Abakaliki. *IOSR Journal of Pharmacy and Biological Sciences*, 11 (3), 43–44.
- Yakutseni, S. P. (2010). Glubinnaya zonalnost v obogashchennosti uglevodorodov tyazhelymi elementami-primesyami. *Neftegazovaya geologiya. Teoriya i praktika*, 5 (2), 1–7. [in Russian]
- Zalia, M. A., Kamaruzaman, W., & Ahmad, W. (2015). Concentration of heavy metals in virgin, used, recovered and waste oil: a spectroscopic study. *Procedia Environmental Sciences*, 30, 201–204.

Yosyp SVOREN

**BOWELS OF THE EARTH – NATURAL PHYSICAL-CHEMICAL REACTOR:
IS THE SEARCH FOR NATURAL METHANE
A FUNDAMENTAL SCIENCE OR A TECHNICAL PROBLEM?**

It is shown that the hypothesis of organic origin of hydrocarbons doesn't respond to the presence of a dominant concentration of methane in sediments, deposits, "shale" series and so on, hence prospecting and exploration for hydrocarbon deposits in them are conducted in most cases intuitively, but not on the fundamental scientific basis.

Experimental studies based on the heating of slightly modified organic matter (peat) show that up to 200 °C in the process of its decomposition the following gases were delivered (vol. %): CO₂ = 49.5; H₂O = 49.3; CH₄, C₂H₆, C₃H₈, N₂, H₂, SO₂, H₂S within 1.2 % in total.

It is confirmed that there is no coal methane, there is no shale gas-methane, but there is methane of one genesis with slightly different isotope composition of carbon, but synthesized according to the same mechanism in the high-thermobaric processes that after migration into the earth's crust accumulated in the form of deposits in cavities of coal seams, terrigenous units, sandstones and so on.

Prospecting for pool-deposits of hydrocarbons should be carried out in conformity with developed "new technology of determination of prospects for oil and gas presence in the local area", "physical-chemical model of synthesis of hydrocarbons and the way of geochemical searching for their occurrences", "new theory of hydrocarbon synthesis and genesis in the earth's lithosphere: abiogenic-biogenic dualism".

Keywords: fluid inclusions, minerals, methane, origin of hydrocarbons, exploration, pool-deposits, new technologies.

- Davydenko, M. M., & Svoren, Y. M. (1994). Sposib lokalnoho prohnozuvannya zbaha-chenykh dilianok zolotorudnykh poliv. *Promyslova vlasnist. Ofitsiyni biuleten*, 3. [in Ukrainian]
- Naumko, I. M. (2006). *Fliuidnyi rezhym mineralohenezu porodno-rudnykh kompleksiv Ukrainy (za vkluchenniamy u mineralakh typovykh parahenezysiv)*. (Avtoref. dys. d-ra heol. nauk). Instytut heolohii i heokhimii horiuchykh kopalyn NAN Ukrainy, Lviv. [in Ukrainian]
- Naumko, I. M., Kurovets', I. M., Zubyk, M. I., Batsevych, N. V., Sakhno, B. E., & Chepusenko, P. S. (2017). Hydrocarbon compounds and plausible mechanism of gas generation in "shale" gas prospective Silurian deposits of Lviv Paleozoic depression. *Geodynamics*, 1 (22), 26–41.
- Naumko, I. M., Pavliuk, M. I., Svoren, I. M., Zubyk, M. I. (2016). Hazy vuhilnykh rodovyshch: nove vyrishennia problemy syntezu–henezysu metanu. *Dopovidi NAN Ukrainy*, 3, 61–68. [in Ukrainian]
- Naumko, I. M., & Svoren, I. M. (2003). O vazhnosti glubinnogo vysokotemperaturnogo flyuida v sozdanii usloviy dlya formirovaniya mestorozhdeniy prirodnykh uglevodorodov v zemnoy kore. In *Novyye idei v naukakh o Zemle: Materialy VI Mezhdunarodnoy konferentsii (Moskva. 8–12 aprelya 2003 g.)* (T. 1. s. 249). Moskva. [in Russian]
- Naumko, I., & Svoren, I. (2014). Novi tekhnolohii poshukiv korysnykh kopalyn, osnovani na doslidzhenniakh fliuidnykh vkluchen u mineralakh. In *Aktualnyye problemy poiskovoy i ekologicheskoy geokhimii: Sbornik tezisov Mezhdunarodnoy nauchnoy konferentsii (Kiyev. 1–2 iyulya 2014 g.)* (s. 23–25). Kiev: Interservis. [in Ukrainian]

- Svoren, I. M. (1984). *Primesi gazov v kristallakh mineralov i drugikh tverdykh telakh, ikh sposoby izvlecheniya, sostav, forma nakhozheniya i vliyaniye na svoystva veshchestv.* (Avtoref. dis. kand. tekhn. nauk). Institut geologii i geokhimiï goryuchikh iskopayemykh AN USSR, Lvov. [in Russian]
- Svoren, Y. M. (1992). Pytannia teorii henezysu pryrodnykh vuhlevodniv ta shliakhy poshuku yikh pokladiv. In *Tektoheniz i naftohazonosnist nadr Ukrainy: tezy dopovidei naukovoï narady (20–22 zhovtnia 1992 r.)* (s. 143–145). Lviv. [in Ukrainian]
- Svoren, Y. M. (2008). Termobarometriia i heokhimiia haziv prozhytkovo-vkraplenoi mineralizatsii u vidkladakh naftohazonosnykh oblastei i metalohenichnykh provintsii: pryroda vuhilnogo metanu. *Ugol Ukrainy*, 8 (620), 42–46. [in Ukrainian]
- Svoren, Y. (2013). Termobarometriia ta heokhimiia haziv prozhytkovo-vkraplenoi mineralizatsii u vidkladakh naftohazonosnykh oblastei i metalohenichnykh provintsii: defekty v mineralakh – dzherelo informatsii pro protsesy mineraloutvorennya. *Mineralohichnyi zbirnyk*, 63 (2), 91–97. [in Ukrainian]
- Svoren, Y. (2018). Vlastyvist hlybynnoho abiohennoho metanovmisnoho vysokotermobarnoho fliuidu utvoriuvaty vuhillia. *Heolohiia i heokhimiia horiuchykh kopalyn*, 3–4 (176–177), 105–109. [in Ukrainian]
- Svoren, I. (2019). Pro novyi pidkhyd do vyznachennia teplotvornosti pryrodnoho hazu, yakyi postachaiut spozhyvacham, ta yoho kubometrobarometriiu. *Heolohiia i heokhimiia horiuchykh kopalyn*, 2 (179), 84–89. [in Ukrainian]
- Svoren, Y. M., & Davydenko, M. M. (1994). Sposib vyznachennia perspektyvy naftohazonosnosti lokalnoi ploshchi. *Promyslova vlasnist. Ofitsiïnyi biuletyn*, 4. [in Ukrainian]
- Svoren, Y. M., & Davydenko, M. M. (1995). Termobarometriia i heokhimiia haziv prozhytkovo-vkraplenoi mineralizatsii u vidkladakh naftohazonosnykh oblastei i metalohenichnykh provintsii. *Dopovidi NAN Ukrainy*, 9, 72–73. [in Ukrainian]
- Svoren, Y. M., Davydenko, M. M., Haievskiy, V. H., Krupskiy, Yu. Z., & Pelypchak, B. P. (1994). Perspektyvy termobarometrii i heokhimiï haziv prozhytkovo-vkraplenoi mineralizatsii u vidkladakh naftohazonosnykh oblastei i metalohenichnykh provintsii (novyi naukovyi napriamok v heolohii). *Heolohiia i heokhimiia horiuchykh kopalyn*, 3–4 (88–89), 54–63. [in Ukrainian]
- Svoren, Y. M., & Naumko, I. M. (2000). Nova tekhnolohiia vyznachennia henezysu vuhlevodnykh haziv. In *Nafta i haz Ukrainy* (T. 1, s. 118). Ivano-Frankivsk: UNHA. [in Ukrainian]
- Svoren, I. M., & Naumko, I. M. (2003). Rol adiabaticheskikh yavleniy v protsessakh nakopleniya-kontsentratsii i prevrashcheniya uglevodorodsoderzhashchikh veshchestv v litosfere Zemli. In *Novyye idei v naukakh o Zemle: Materialy VI Mezhdunarodnoy konferentsii (Moskva. 8–12 aprelya 2003 g.)* (T. 1, s. 257). Moskva. [in Russian]
- Svoren, Y. M., & Naumko, I. M. (2006). Nova teoriia syntezy i henezysu pryrodnykh vuhlevodniv: abiohenno-biohennyi dualizm. *Dopovidi NAN Ukrainy*, 2, 111–116. [in Ukrainian]
- Svoren, Y., & Naumko, I. (2012). Boryslavske vuhlevodneve rodovyshe: problemy dlia rozdumiv. In *Stan, problemy ta perspektyvy naftohazovoi promyslovosti Ukrainy: Zbirnyk tez dopovidei Mizhnarodnoi nauково-praktychnoi konferentsii (Lviv, 7–9 veresnia 2012 r.)* (s. 16). Lviv: Vydavnytstvo Lvivskoi politekhniki. [in Ukrainian]
- Svoren, I. M., Naumko, I. M., & Davydenko, M. M. (1998). Nova tekhnolohiia vyznachennia perspektyvy naftohazonosnosti lokalnoi ploshchi. In *Nafta–Haz Ukrainy – 1998: Materialy V Mizhnarodnoi konferentsii (Poltava, 15–17 veresnia 1998 r.)* (T. 1, s. 111–112). Poltava: UNHA. [in Ukrainian]
- Svoren, J. M., Naumko, I. M., Kovalyshyn, Z. I., Bratus, M. D., & Davydenko, M. M. (1999). New technology of local forecast of enriched areas of gold ore fields. In *Naukovi osnovy prohnozuvannya, poshukiv ta otsinky rodovyshech zolota: Materialy Mizhnarodnoi naukovoï konferentsii (Lviv, 27–30 veresnia 1999 r.)* (s. 121–125). Lviv: Vydavnychiy tsentr LDU im. I. Franka.

Ihor POPP, Petro MOROZ, Mykhailo SHAPOVALOV

**LITHOLOGICAL-GEOCHEMICAL TYPES OF DEPOSITS
OF CRETACEOUS-PALEOGENE FLYSCH
OF THE UKRAINIAN CARPATHIANS
AND CONDITIONS OF THEIR FORMATION**

The results of lithological, mineralogical and geochemical investigation of Cretaceous-Paleogene flysch deposits of the Ukrainian Carpathians are cited here. There are three main lithological-geochemical types of these deposits which differ in the composition of rock-forming ingredients of biogenic origin ($\text{SiO}_2^{\text{biog}}$, CaCO_3 , C_{org}): grey limestone-clayey-terrigenous (type-I), non-carbonate or low-carbonate-clayey-terrigenous (type-II), and black carbonate-silica-terrigenous-clayey (type-III). The deposits of the first type are attributed to alkaline-oxic (oxic-calcitic), the second – to acid and low-alkaline oxic (oxic with redeposited glauconite), the third – to reducing (siderite, dolomite or ferrodolomite and low-reducing calcitic) and strong by reducing (primary-sulfidic or hydrogen sulfidic) mineralogical-geochemical facies. The forming of the Barremian-Albian (Shypot suite; Spas suite) and Oligocene (Menilite suite; Dusynska suite) organic-rich sediments in the Ukrainian Carpathians we associate with the phase of oceanic anoxic events OAE-1 and OAE-4 in the Carpathian segment of the Tethys, where anoxic reducing environments favoured to fossilization of huge amount of the dispersed organic matter. The structural-fabric features and composition of separate lithological types of silicites and diagenetic concretions of the Lower Cretaceous and Oligocene of the Ukrainian Carpathians show that their sedimentogenesis and diagenesis took place in conditions of strong oxygen deficit. The studied siliceous rocks can be considered as indicators of the anoxic events in the Carpathian segment of Tethys ocean. It is shown, that alkaline-reducing environments which was the most favourable for the diagenetic transformation of sedimentary organic matter in to petroleum hydrocarbons, prevailed in the organic-rich deposits of Oligocene age.

Keywords: sedimentogenesis, diagenesis, silica, carbonate, sulfides, organic matter, mineralogical-geochemical facies, Cretaceous-Paleocene flysch, Ukrainian Carpathians.

- Afanasyeva, I. M. (1983). *Litogenez i geokhimiya flishevoy formatsii severnogo sklona Sovetskikh Karpat*. Kiev: Naukova dumka. [in Russian]
- Gabinet, M. P. (1985). *Postsedimentatsionnyye preobrazovaniya flisha Ukrainiskikh Karpat*. Kiev: Naukova dumka. [in Russian]
- Gabinet, M. P., Gabinet, L. M. (1991). K geokhimii organicheskogo veshchestva bituminoznykh argillitov flishevoy formatsii Karpat. *Geologiya i geokhimiya goryuchikh iskopayemykh*, 76, 23–31. [in Russian]
- Gabinet, M. P., Kulchitskiy, Ya. O., Matkovskiy, O. I. (1976). *Geologiya i poleznyye iskopayemye Ukrainiskikh Karpat* (Ch. 1). Lvov: Izdatelstvo Lvovskogo universiteta. [in Russian]
- Kennet, Dzh. (1987). *Morskaya geologiya* (T. 2). Moskva: Mir. [in Russian]
- Kholodov, N. M., & Nedumov, R. I. (1991). O geokhimicheskikh kriteriyakh poyavleniya serovodnogo zarazheniya v vodakh drevnikh vodoyemov. *Izvestiya AN SSSR, ser. geologicheskaya*, 12, 74–82. [in Russian]
- Koltun, Y. V. (1993). Source rock potential of the black shale formations of the Ukrainian Carpathians. *Acta Geologica Hungarica*, 3 (36), 251–261.
- Koltun, Yu. V. (2000). Heneratsiia vuhlevodniv u flishovykh vidkladakh Vnutrishnoi zony Peredkarpatskoho prohynu. *Heolohiia i heokhimiia horiuchykh kopalyn*, 4, 26–33. [in Ukrainian]

- Konyukhov, A. I. (1987). *Osadochnyye formatsii v zonakh perekhoda ot kontinenta k okeanu*. Moskva: Nedra. [in Russian]
- Maslakova, N. I. (1986). Planktonnyye foraminifery opornogo razreza golovninskoy svity Sovetskikh Karpat. *Paleontologicheskii sbornik*, 23, 5–11. [in Russian]
- Moroz, P. V. (2003). Osoblyvosti rozpodilu mikroelementiv u bituminoznykh kreidovykh vidkladakh shypotskoi svity Ukrainykykh Karpat. *Heolohiia i heokhimiia horiuchykh kopalyn*, 3–4, 83–89. [in Ukrainian]
- Naydin, D. P., Pokhpalaynen, V. P., Kats, Yu. I., & Krasilov, V. A. (1986). *Melovoy period. Paleogeografiya i paleookeanologiya*. Moskva: Nauka. [in Russian]
- Popp, I. (2012a). Heokhemichni umovy sedimentohenezu i diiahenezu kreidovo-paleohenovykh vidkladiv Ukrainykykh Karpat. *Pratsi Naukovoho tovarystva im. Shevchenka. Heolohichniy zbirnyk*, 30, 162–182. [in Ukrainian]
- Popp, I. (2012b). Mineraloho-heokhimichni fatsii vidkladiv kreidovo-paleohenovoho fli-shu Ukrainykykh Karpat. *Mineralohichniy zbirnyk*, 2 (62), 206–215. [in Ukrainian]
- Popp, I. T., & Senkovskiy, Yu. M. (2003). Biohenni vuhletsvmisni sylitsyty barrem-albu i olihotsenu Ukrainykykh Karpat – svidchennia okeanichnykh bezkysnevykh podii. Chastyna 1. Petrohrafii i stadiini peretvorennia. *Heolohiia i heokhimiia horiuchykh kopalyn*, 3–4, 65–82. [in Ukrainian]
- Popp, I. T., Senkovskiy, Yu. M., & Haievska, Yu. P. (2004). Biohenni vuhletsvmisni sylitsyty barrem-albu i olihotsenu Ukrainykykh Karpat – svidchennia okeanichnykh bezkysnevykh podii. Chastyna 2. Paleookeanohrafichni umovy kremnenahromadzhennia. *Heolohiia i heokhimiia horiuchykh kopalyn*, 2, 95–107. [in Ukrainian]
- Popp, I. T., Senkovskiy, Yu. M., Haievska, Yu. P., & Semeniuk, M. V. (2004). Heolohopaleookeanohrafichni i heokhimichni aspekty litohenezu eotsen-olihotsenovykh vidkladiv Ukrainykykh Karpat (u konteksti problemy “oceanic anoxic events”). *Heolohiia i heokhimiia horiuchykh kopalyn*, 1, 41–56. [in Ukrainian]
- Rozanov, A. G., Volkov, I. I., Sokolov, V. S. et al. (1976). Okislitelno-vosstanovitelnyye protsessy v osadkakh Kaliforniyskogo zaliva i prilegayushchey chasti Tikhogo okeana. In *Biogeokhimiya diageniza osadkov okeana* (s. 96–135). Moskva: Nauka. [in Russian]
- Senkovskiy, Yu. M., Hryhorchuk, K. H., Koltun, Yu. V., Hnidets, V. P., & Radkovets, N. Ya. (2018). *Litohenez osadovykh kompleksiv okeanu Tetis. Karpato-Chornomorskyi sehment*. Kyiv: Naukova dumka. [in Ukrainian]
- Senkovskiy, Yu. M., Koltun, Yu. V., Hryhorchuk, K. H., Hnidets, V. P., Popp, I. T., & Radkovets, N. Ya. (2012). *Bezkysnevi podii okeanu Tetis*. Kyiv: Naukova dumka. [in Ukrainian]
- Senkovskiy, Yu. M., Popp, I. T., & Moroz, P. V. (2001). Heokhimichni umovy utvorennia sulfidno-kremenysto-karbonatnykh konkretisii u bituminoznykh nyzhnokreidovykh i olihotsenovykh vidkladakh Ukrainykykh Karpat. *Pratsi Naukovoho tovarystva im. Shevchenka. Heolohichniy zbirnyk*, 5, 71–76. [in Ukrainian]
- Tishchenko, P. Ya., Pavlova, G. Yu., Zyuss, E. et al. (2001). Shchelochnoy rezerv porovykh vod Okhotskogo morya v mestakh vydeleniya metana. *Geokhimiya*, 6, 658–664. [in Russian]
- Volkov, I. I. (1984). *Geokhimiya sery v osadkakh okeana*. Moskva: Nauka. [in Russian]
- Vyalov, O. S., Gavura, S. P., Danysh, V. V. et al. (1981). *Istoriya geologicheskogo razvitiya Ukrainykykh Karpat*. Kiev: Naukova dumka. [in Russian]
- Vyalov, O. S., Gavura, S. P., Danysh, V. V. et al. (1988). *Stratotipy melovykh i paleogenovykh otlozheniy Ukrainykykh Karpat*. Kiev: Naukova dumka. [in Russian]
- Olszewska, B., & Szydło, A. (2017). Environmental stress in the northern Tethys during the Paleogene: a review of foraminiferal and geochemical records from the Polish Outer Carpathians. *Geological Quarterly*, 3 (61), 682–695.

- Pearson, P. N., McMillan, I. K., Wade, B. S., Jones, T. D., Coxall, H. K., Bown, P. R., & Lear, C. H. (2008). Extinction and environmental change across the Eocene-Oligocene boundary in Tanzania. *Geology*, 2 (36), 179–182.
- Schlanger, S. O., & Jenkyns, H. C. (1976). Cretaceous oceanic anoxic events: causes and consequences. *Geologie en Mijnbouw*, 55 (3–4), 179–184.

PAVLYUK Myroslav, NAUMKO Ihor. Outstanding scientist-geologist-romantic, Academician Yevhen Fedorovych Shniukov (to 90th anniversary from birth)