



Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph.
Geology,
31(3), 469-483.

[doi:10.15421/112243](https://doi.org/10.15421/112243)

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Journ. Geol. Geograph. Geoecology, 31(3), 469-483

Classification of deposits of the Dnipro-Donetsk oil and gas region by the content of metals in oils

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Received 24.01.2022;

Received in revised form 17.02.2022;

Accepted 18.07. 2022

Abstract. The issues considered in the paper bear a direct relation to the disputable geochemical problems of the origin of oil – one of the main sources of modern energy generation. Features of metal distribution in oils have not been studied yet, and natural classifications of oil fields of the Dnipro-Donets depression according to their contents have

not been developed before. That stipulates the scientific novelty of the obtained results. Topicality and practical implications of the carried out studies are mainly in the fact the determined features of metal contents in oils and the classifications of deposits developed on their basis will favor the elaboration of a set of predictive criteria for industrial accumulations of hydrocarbons and scientific substantiation of geological-economic, technological, and environmental estimation of their use. The objects of long-term studies include 36 oil fields: Bakhmatske; Prylutske; Krasnozaiarske; Kachalivske; Kremenivske; Karaikozovske; Korobochkynske; Kulychykhinske; Lipovodolynnske; Monastyrishchynske; Matlakhivske; Malosorochynske; Novomykolayivske; Perekopivske; Prokopenkivske; Radchenkovske; Raspashnovske; Sofiyivske; Sukhodolivske; Solontsiivske; Solokhivske; Talalayivske; Trostianetske; Turutynske; Kharkovtsivske; Shchurynske; Yuryivske; Yaroshivske; Khukhrianske; Sahaidatske No 1; Sahaidatske No 13; Kybytsivske No 5; Kybytsivske No 51; Kybytsivske No 52; Kybytsivske No 56; and Kybytsivske No 1. They are located within the large tectonic structure of Eastern-European platform – Dnipro-Donets depression. The fields form the Dnipro-Donets oil and gas area of Ukraine. The paper is based on the results of studies of not less than 30 oil samples from each of the fields aimed at identification of metal content with the help of X-ray fluorescence analysis using energy-dispersion spectrometer «Sprut» SEF 01. Natural classification of oil fields in terms of content of each of the considered element have been developed basing on the results of cluster analyses implemented in terms of professional software platforms of versions STATISTICA 13.3 and IBM SPSS Statistics 22. The main scientific value of the obtained results is represented by the following: the development of natural classifications of oil fields of the Dnipro-Donets depression according to the results of cluster analysis of the content of metals, sulfur, and V/Ni ratio and substantiation of 5 new geochemical criteria for the division of fields formed by oils generated mostly by abiogenic or biogenic processes.

Key words: oil, deposits, Dnipro-Donetsk depression, cluster analysis, dendrogram, classification, V / Ni ratio, genesis.

Класифікація родовищ Дніпровсько-Донецької нафтогазоносної області по вмісту металів у нафтах

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Анотація. Представлені результати багаторічних геохімічних досліджень стосовно вмістів металів: алюмінію, ртуті, хрому, марганцю, заліза, цинку, кобальту, нікелю та ванадію, а також загальної концентрації цих металів і сірки у нафтах з 36 родовищ основного нафтогазоносного регіону України – Дніпровсько-Донецької западини: Бахмачського, Прилуцького, Краснозаярського, Качалівського, Кременівського, Карайкозовського, Коробочинського, Куличихинського, Ліповодолинського, Монастирищенського, Матлаховського, Малосорочинського, Ново-Миколаївського, Перекопівського, Прокопенківського, Радченківського, Распашновського, Софіївського, Суходолівського, Солонцівського, Солохівського, Талалаївського, Тростянського, Турутинського, Західно-Харьковцівського, Шурина, Юр'ївського, Ярошівського, Хухрянського,

Сагайдацького №1, Сагайдацького №13, Кибицівського №5, Кибицівського №51, Кибицівського №52, Кибицівського №56, Кибицівського №1. За результатами кластерного аналізу вперше розроблено природні класифікації цих родовищ за переліченими показниками і співвідношенню V / Ni які наведено в роботі у вигляді дендрограм. Показано що за результатами кластерного аналізу вибірок середні значення показників, що значимо відрізняються між окремими родовищами чи групами родовищ в установлених рядах можна інтерпретувати в термінології якісної оцінки, як: аномально низькі; низькі; нижче середніх; середні; вище середніх; високі; аномально високі. Аналіз результатів досліджень і їх інтерпретація у генетичному сенсі із порівнянням з трьома різними геохімічними критеріями відношення походження нафт до абіогенних або біогенних джерел нафтогенезу згідно існуючим уявленням надало можливість встановити по перше родовища, які за кожним із цих уявлень відносяться до сформованих переважно абіогенною речовиною, по друге, встановити та проаналізувати збіги та відмінності у переліку цих родовищ. Обґрунтовано, що порівняльний аналіз результатів кластеризації розглянутих родовищ за вмістом у нафтах таких абіогенних елементів як Hg і Al за результатами їх кластеризації по концентраціям Cr, Co і V показує, що сукупність родовищ, які відносяться до кластерів з високим і аномально високим вмістом Cr, Co і V відрізняється від переліку родовищ з високим та аномально високими концентраціями Hg і Al тільки відсутністю Юр'ївського родовища, а між собою – повністю збігаються. Таким чином, високі та аномально високі вмісти Cr, Co і V в нафтах досліджених родовищ, виходячи з логіки попередніх досліджень, можна використовувати як більш суворіший критерій їх поділу на дві принципово різні групи – родовища сформованими переважно нафтами біогенного походження та родовища, що містять нафту суттєво абіогенної генерації. У цьому плані, на наш погляд, згідно встановлених раніше закономірностей, має сенс розглядати в якості критерія виділення родовищ з нафтою суттєво абіогенного походження, крім концентрацій Cr, Co і V ще й співвідношення Cr / Ni та Co / Ni.

Ключові слова: нафта, родовища, Дніпровсько-Донецька западина, кластерний аналіз, дендрограма, класифікація, співвідношення V / Ni, генезис.

Introduction.

Attention to the problems of accumulation and migration of metals in oil is connected with the topical scientific and practical issues concerning genesis of hydrocarbons, with the possibility of their industrial extraction while oil processing aimed at their further selling as the accompanying raw material as well as with the possibility to determine ecological risks of using those oils as the raw material to produce petrochemicals – first of all, petrol and diesel fuel. As is known, oils of different world regions contain micro-amounts of metals. High content of metals, i.e. vanadium and nickel, are also a serious problem while processing oil raw material as it results in irreversible deactivation of catalysts as a result of metal sedimentation on an active surface, blocking of pore space, and destruction of a catalyst structure. Besides, inorganic compounds of vanadium formed while oil processing favour high-temperature corrosion of the equipment surface, shortened service life of the turboactive, diesel, and boiler plants, gas corrosion of active elements of the gas turbine engines, and increased environmentally harmful emission into the environment. Along with that, metals, including the rare and rare-earth ones, are valuable accompanying components, which content in oils and residuals of oil processing can even exceed their content in some ore-bearing sources (Shpirt et al., 2013). However, industrial production of metals (i.e. vanadium) from the oil raw material has not been developed yet though the world oil-processing practice has the technologies for accompanying production of concentrates with high content of different

metals. In particular, certain foreign countries get about 8% of the general worldwide-produced vanadium from the oil raw material; in some countries this percentage even reaches 20% (the USA) (Raja, 2013). Apart from that, the availability and content of metals in oils from different deposits makes it possible to identify regularities of their migration and concentration in the hydrocarbon systems. In this context, such metals as vanadium, mercury, cobalt, nickel, iron, manganese, aluminium, titanium, chromium, and zink should be emphasized as for their industrial and environmental significance.

General necessity in the classification of oils and their fields is stipulated by the reasons of both scientific and practical nature; thus, the classifications should be as rational as possible, i.e. they should reflect both indicated aspects. The difficulties in developing such classifications arise due to the complexity and variety of oil composition (even in different wells within one and the same, from the geological viewpoint, geological formation (oil-and-gas bearing traps) and their certain variations as for the metal content during the extraction), insufficient knowledge concerning oil genesis, necessity to analyze numerous classification parameters to select the optimal and most informative ones, i.e. the parameters containing information on the sources of an oil substance, nature of its transformation during the oil genesis process, and a geochemical type of the forming oil. Taking into consideration a metal-bearing feature of oils, they are divided into the ones being rich (> 10 ppm) and poor (< 1 ppm) in metals as well as the ones from the viewpoint of prevailing of some specific metal. In terms of V, Ni, and Fe content, there are «vanadium» (V > Ni

> Fe), «iron» (Fe > V > Ni), and «nickel» (Ni > Fe > V) types (Nukenov & Punanova, 2001).

One of the first systematization of oils according to their general characteristics of metal content was represented by Barwise A. J. G. in 1990. He considered chemical composition, physical properties, and content of metals in oil samples (Barwise, 1990). Later, in 2007, Ye.F. Shnjukov with his coauthors published a rather interesting paper about vanadium and nickel content in natural oils of the world (Shnjukov et al., 2007). He studied in detail the heavy metal concentrations in the natural oils worldwide in terms of their genesis. One year later in 2008, A.A. Suhanov analyzed the current state of the evaluation of accompanying oil components (including heavy metals) as the sources of high-quality rare-metal raw material (Suhanov & Petrova, 2008). In 2010, S.P. Jakuceni published the results of studying the interconnection of deep hydrocarbon zonality and oil saturation with heavy elements-admixtures (Jakuceni, 2010). The paper emphasizes the available correlation dependence of the heavy metal contents in oils with the depth of oil field occurrence. In 2014, O.V. Akpoveta and S.A. Osakwe analyzed the content of heavy metals in oil products from the Nigerian fields (Agbor) (Akpoveta & Osakwe, 2014). The authors point out that a high level of the heavy metal content in oils can be of serious environmental threat. In Ukraine such studies were carried out in 2013 concerning high-sulfur oil of the Subcarpathian Depression (Hlibyshyn et al., 2013). This paper not only studies the fraction composition and physicochemical properties of light fractions separated from the oil of Orkhovyske oil field but also considers a potential content of the fractions, for which their density, refractive index, molecular mass, and sulfur content are determined. A little bit later, Wilberforce J. O. investigated a the content of heavy metals in crude oil used in medicine (Wilberforce, 2016). The paper studies the levels of Cd, Ni, V, and Pb with the help of atomic-absorption spectrophotometry. As a result, the average concentration of metals was determined with the emphasis on their influence on human organisms. Earlier, a series of papers (Ishkov, 2009; Ishkov & Koziy, 2013; Ishkov & Koziy, 2014; Ishkov & Koziy, 2017; Ishkov et al., 2013; Ishkov & Nagornyj, 2005; Ishkov & Lozovoj, 2001; Ishkov et al., 2003; Kozar et al., 2020; Koziy & Ishkov, 2018) have already considered certain features of geochemistry and distribution of metals in caustobioliths of the deposits within the Dnipro-Donets Depression.

This paper deals with the results of recent studies of the features of metal distribution and contents

in oils for further development of the objective (natural) classification of the key 36 operating oil fields of the main oil-and-gas bearing region of Ukraine, Dnipro-Donets Depression, with the help of cluster analysis. It should be noted that such studies have not been conducted before; which determines the scientific novelty of the obtained results. Solution of such a problem will favour the elaboration of a set of predictive criteria of industrial accumulations of hydrocarbons and scientific substantiation of the geological-economic, technological, and environmental estimation of their use. In its turn, it defines the topicality and practical value of the carried out studies.

The paper involves statistic, informational, geochemical, and analytical methods of the research based on the following: covering a wide range of factual material in terms of the content of metal complexes contained in the oils of different Dnipro-Donets Depression fields as well as specifying the laws for metal distribution in oils and laboratory studies of metal distributions in oils for correcting and substantiation of the results of natural observations.

Research methodology.

The factual basis of the study is represented by the results of analysis of metal content in the oils of 36 fields: Bakhmachske, Prylutske, Krasnozaiarske, Kachalivske, Kremenivske, Karaikozovske, Korobochkynske, Kulychykhinske, Lipovodolynnske, Monastyrishchynske, Matlakhivske, Malosorochynske, Novomykolayivske, Perekopivske, Prokopenkivske, Radchenkovske, Raspashnovske, Sofiyivske, Sukhodolivske, Solontsivske, Solokhivske, Talalayivske, Trostianetske, Turutynske, Zakhidno-Kharkovtsivske, Shchurynske, Yuryivske, Yaroshivske, Khukhrianske, Sahaidatske #1, Sahaidatske #13, Kybytsivske #5, Kybytsivske #51, Kybytsivske #52, Kybytsivske #56, and Kybytsivske #1. Not less than 30 oil samples from each of the fields were studied with the help of X-ray fluorescence analysis using energy-dispersion spectrometer «Sprut» SEF 0; the studies were aimed at metal content identification. The time of spectrum accumulation is 600 s. The analyst is A.M. Yerofoiev. The analysis was prepared and carried out according to the standard ASTM D 4927 – Determination of an ultimate composition of lubricants by the method of X-ray fluorescence spectroscopy with the dispersion along the wave length. The following samples were used as the standard samples of metal admixtures: RM 23 (DSZU (State Standard Reference Samples) 022.122-00) IVS 0243:2001 with the attested values of Cd, Mn, Pb, Zn; RM 24 (DSZU 022.123-00) IVS 0244:2001 with the

attested values of Fe, Co, Cu, Ni; and RM 26 (DSZU 022.125-00) IVS 0246:2001 with the attested values of V, Mo, Ti, Cr.

As is known, a classification procedure is the systematization of the objects according to the preset signs. An objective reason for the practical significance of a classification is represented by complex problems of storage, search, and use of huge empiric data archives. There the necessity to shorten the amount of those data without losing too much information arises. The usual procedures here are cluster analysis, taxonomy, object recognition, and factorial analysis.

One of the most effective procedures of simplification and minimization of data masses to make their content interpretation easier is clusterization. Currently, the clusterization procedures are widely used in biology (to eliminate spatial and temporary groupings of organisms under homogeneous conditions, to group similar genome sequences, to define genotypes etc.). The same procedures are applied in medicine (to classify antibiotics according to their types of antibacterial activity, for automatic singling out of different tissues types in a 3D image in positron-emissive tomography etc.), in marketing (to process data of different surveys, singling out of new consumer types, market division for creating personalized proposals etc.). The clusterization procedures are used in computer sciences (to determine population niches formed during the operation of evolutionary algorithms, in segmentation of images for boundary determination and object recognition etc.). Nevertheless, only some cases of successful application of cluster analysis are known in geological studies so far (Ishkov et al., 2003; Koziy & Ishkov, 2018) despite its exclusive simplicity and visual clarity. Along with that, a cluster analysis not only solves a problem of object systematization in an easier and visually more clear way but also has its undisputable advantage – the result of its application is not connected with any loss of even an insignificant share of the initial information concerning object differences or sign correlations.

It is important that contrary to other methods used while solving different classification problems, cluster analysis does not require apriori assumptions concerning a data set, which does not restrict submission of the objects under consideration; this analysis makes it possible to analyze natural parameters of different data types (interval data, frequencies, binary data etc.). Use of cluster analysis for classification has certain advantages as it helps to divide numerous analyzed objects and signs into the homogeneous groups or clusters as well as to identify the internal structure (at different hierarchical levels) of the sam-

pling body. At the same time, like any other method, cluster analysis has certain disadvantages. In particular, composition and number of clusters depend on the selected grouping criteria («classification strategies»), and application of different methods, that meet different conceptual approaches to the singling out of taxons for similar samplings, can result in considerably different outcomes (Ishkov et al., 2003; Koziy & Ishkov, 2018). Consequently, in contrast to other methods of multidimensional statistics, cluster analysis is characterized by the strong dependence of the obtained results on the apriori settings of a researcher at a content level. In our case, the apriori settings include the following: nonavailability of any hypotheses concerning a number of clusters, their structure and shape; reaching maximum visualization of the deposit division in terms of classes at different scale levels; use of a clusterization method (algorithm) for the most stable division of the whole number of oil fields being studied.

Cluster analysis considers that: a) the selected characteristics assume principally the desirable division into clusters; b) measure units (scale) are selected correctly.

Thus, selection of a scale in the classification procedure plays a considerable role. As a rule, to reduce the initial information to one scale it should be normalized somehow. Since a metal content in oil fields being considered fills the whole range of values rather uniformly without considerable anomalies, which exceed greatly a typical scattering, normalization of the initial values of metal contents of each field is done by the formula: $X_{i\text{norm.}} = (X_i - X_{\text{max.}}) / (X_{\text{max.}} - X_{\text{min.}})$, where $X_{i\text{norm.}}$ is a unit normalized value of the metal content in oil, X_i is a unit value of the metal content in oil, $X_{\text{max.}}$ is a maximum value of the metal content in oil, $X_{\text{min.}}$ is a minimum value of the metal content in oil. To complete the specified tasks, the analysis involved clusterization of the oil fields performed by a weighed centroid method; it was implemented in the professional statistic programme platforms «STATISTICA» and «SPSS», which selection was substantiated earlier in (Ishkov et al., 2003; Koziy & Ishkov, 2018); after that, the clusterization results were analyzed. That has made it possible to interpret the obtained geochemical information in a genetic sense.

The paper applied programme versions STATISTICA 13.3 and IBM SPSS Statistics 22.

Research results.

A dendrogram of clusterization of the fields in terms of aluminium content in oil (Fig.1) helps single

out quite clearly seven main groups of clusters: 2, 1.2, 1.1.2, 1.1.1.1, 1.1.1.2.2, 1.1.1.2.1.1, and 1.1.1.2.1.2. Like in other similar cases, at the qualitative level we will consider by convention that they meet sequentially the following: abnormally low contents, low contents, lower-than-medium contents, medium contents, higher-than-medium contents, high contents, and abnormally high contents. That approach was substantiated earlier in (Yerofieiev et al., 2021). It should be pointed out that the conventional nature of this distribution lies mainly in using the term «medium content» to identify clusters that occupy only a medium position in the clusterization dendrogram in terms of concentration of the considered elements.

The mean aluminium content in oils of the considered fields of the Dnipro-Donets oil-and-gas production area (DDOGBA) makes up 14.17 ± 3.64 ppm; an average value is 4.24 ppm. Since according to the Shapiro-Wilk test results, distribution density of this parameter meets a lognormal law (like for all other metals) but not the normal (Gaussian) one, we will apply (like in any further similar cases) average values of the parameters to characterize the central tendency in a sampling. Note that in terms of geochemistry the background content values are always lower than their mean values in a general sampling as they are calculated as the characteristics of central tendency in a sampling while extracting the abnormally high values of the parameters from its volume; and in this sense they meet roughly the median values.

The abnormally low aluminium content in oils is connected with cluster 1.1.1.1 represented by the following fields: Radchenkivske, Monastyrishchynske, Kremenivske, Bakhmachske, Shchurynske, and Sukhodolivske. The average aluminium content value within the cluster is 1.38 ppm at the average value variations within the fields from 0.76 ppm (Radchenkivske field) to 1.92 ppm (Sukhodolivske field). Cluster 1.1.1.2.1.1 is formed by the following fields: Khukhrianske, Malosorochynske, Trostianetske, Karaikozovske, Novomykolayivske, and Raspashnovske with a low average value of aluminium content within the field from 2.43 (Khukhrianske field) to 3.52 ppm (Raspashnovske field) at the average cluster value of 2.99 ppm. Cluster 1.1.1.2.1.2 covers the fields of Korobochkynske, Lipovodolynnske, Solontsivske, Yaroshivske, Solokhivske, Prokopenkivske, Zakhidno-Kharkovtsivske, Perekopivske, Talalayivske, Matlakhivske, and Krasnozaiarske with the lower-than-medium aluminium concentration in oils from 3.89 ppm (Korobochkynske field) to 4.7 ppm (Krasnozaiarske field) at the cluster average value of 4.22 ppm which meets practically a median value. The average content of 5.38 ppm – 5.77

ppm is peculiar for the oils of Kachalivske, Prylutske, and Tturutynske fields that form cluster 1.1.1.2.2 at the average cluster content of 5.62 ppm. A higher-than-medium content (7.04 – 7.92 ppm) is specific respectively for the fields of Sofiyivske and Kulychykhinske of cluster 1.1.2. A high content (20.0 – 27.1 ppm) is connected with cluster 1.2, uniting respectively the fields of Sahaidatske #1 and Yuryivske at the average cluster value of 23.55 ppm. Such fields as Kybytsivske #1, Sahaidatske #13, Kybytsivske #5, Kybytsivske #56, Kybytsivske #52, and Kybytsivske #51 form cluster 2 that corresponds to the fields with the abnormally high aluminium concentrations in oils (from 40 ppm to 80 ppm, at the average cluster value of 57.5 ppm).

A dendrogram of clusterization of the deposits in terms of mercury content in oil (Fig.2) helps identify visually seven cluster groups: 1.1.1.1.1.1, 1.1.1.1.1.2, 1.1.1.1.2, 1.1.1.2, 1.2, and 2. The average mercury content in the DDOGBA deposits is 0.44 ± 0.13 ppm; the median one is 0.097 ppm. Cluster 1.1.1.1.1.1 is made up by the deposits of Talalayivske, Kachalivske, Solokhivske, Kulychykhinske, Prylutske, Lipovodolynnske, Malosorochynske, Sofiyivske, Sofiyivske, Sukhodolivske and with the abnormally low mercury content in oils from 0.0007 ppm (Talalayivske field) to 0.01 ppm (Sukhodolivske, Sofiyivske, Malosorochynske, Lipovodolynnske, and Prylutske fields) at the average cluster content of 0.007. Low content values from 0.02 ppm (Bakhmachske field) to 0.035 ppm (Shchurynske field) in oils are connected with the fields of Bakhmachske, Trostianetske, Yaroshivske, Perekopivske, Solontsivske, Shchurynske, and Karaikozovske of cluster 1.1.1.1.1.2 with the average mercury content within the cluster being 0.026 ppm. Cluster 1.1.1.1.2 includes the deposits of Prokopenkivske and Turutynske with the lower-than-medium content being 0.05 ppm. Cluster 1.1.1.2 is represented by the fields of Raspashnovske, Krasnozaiarske, Krasnozaiarske, Radchenkivske, Radchenkivske, Monastyrishchynske, Zakhidno-Kharkovtsivske, and Khukhrianske with the mercury content in oils from 0.14 ppm (Raspashnovske field) to 0.2 (Zakhidno-Kharkovtsivske and Khukhrianske fields) with the average cluster value of 0.18 ppm. Cluster 1.1.2 is made up by the fields of Kremenivske and Novomykolayivske with the corresponding mercury content in oils being 0.323 ppm – 0.39 ppm, with the average cluster concentrations of 0.36 ppm being higher-than-medium in terms of general sampling of the fields. Cluster 1.2 is formed by the fields of Kybytsivske #52, Sahaidatske #1, Kybytsivske #56, Yuryivske, Kybytsivske #5, and Kybytsivske #1 where mercury content in oils varies from 0.7 ppm (Kybyt-

sivske #52 field) to 1.4 ppm (Kybytsivske #1 field), and the overall high average cluster content is 1.14 ppm. Two fields of Sahaidatske #13 and Kybytsivske #51 with the abnormally high mercury content in oils, being from 3.0 ppm to 3.4 ppm respectively, forms cluster 2 with the average value of 3.2 ppm.

During clusterization of the DDOGBA fields in terms of chromium concentration in oils (Fig.3), seven cluster groups were specified: 1.1.1.1.1, 1.1.1.1.2, 1.1.1.2, 1.1.2, 1.2, 2.1, and 2.2. The average chromium content in the fields under consideration is 2.04 ± 0.61 ppm; a median value is 0.275 ppm. Cluster 1.1.1.1.1 involves the fields of Kremenivske, Korobochkynske, Monastyrishchynske, Solokhivske, Sukhodolivske, Yaroshivske, Malosorochynske, Yuryivske, Novomykolayivske, and Sofiyivske with the abnormally low index of chromium content in oils: from 0.01 ppm (Kremenivske, Korobochkynske, and Monastyrishchynske fields) to 0.06 ppm (Novomykolayivske and Sofiyivske fields) at the average content of 0.031 ppm. Low values of chromium content in oils, being from 0.09 ppm (Karaikozovske field) to 0.14 ppm (Bakhmachske, Lipovodolynnske, and Prokopenkivske fields), are associated with the fields of Karaikozovske, Shchurynske, Prylutske, Solontivske, Bakhmachske, Lipovodolynnske, and Prokopenkivske of cluster 1.1.1.1.2 with the average cluster content of 0.125 ppm. Cluster 1.1.1.2 consists of the oil deposits of Perekopivske, Trostianetske, Zakhidno-Kharkovtsivske, Radchenkivske, Talalayivske, Kachalivske, Krasnozaiarske, Turutynske, Matlakhivske, and Raspashnovske with the lower-than-medium content being from 0.25 ppm (Perekopivske field) to 0.61 ppm (Raspashnovske field) with the average cluster content of 0.423 ppm. Cluster 1.1.2 is represented only by Kulychykhinske deposit with the average value of chromium concentration in oil being 0.93 ppm. Cluster 1.2 is also formed by one field, Khukhrianske, with the higher-than-medium content being 3.9 ppm. High chromium contents in oils are observed in the deposits of Sahaidatske #13, Kybytsivske #56, Kybytsivske #5, Kybytsivske #52, Kybytsivske #51, and Sahaidatske #1 of cluster 2.1 with the values from 0.71 ppm (Sahaidatske #13 and Kybytsivske #56 fields) to 10.2 ppm (Sahaidatske #1 field) at the average cluster concentration of 8.33 ppm. Cluster 2.2 is formed only by Kybytsivske #1 field with the abnormally high content being 13.1 ppm.

During clusterization of the DDOGBA fields as for manganese content in oils (Fig.4), seven cluster groups were identified: 1.1.1.1.1, 1.1.1.1.2.1, 1.1.1.1.2.2, 1.1.1.2, 1.1.2, 1.2, and 2. The average manganese content in the oil fields is 0.41 ± 0.05

ppm; the median one is 0.3 ppm. Cluster 1.1.1.1.1 contains the following oil fields: Matlakhivske, Perekopivske, Novomykolayivske, Monastyrishchynske, Malosorochynske, and Korobochkynske with the abnormally low manganese content from 0.068 ppm (Matlakhivske field) to 0.131 ppm (Korobochkynske field) at the average cluster value of 0.102 ppm. Cluster 1.1.1.1.2.1 covers such deposits as Prokopenkivske, Kremenivske, Lipovodolynnske, Solontivske, Krasnozaiarske, Yaroshivske, Kachalivske, Raspashnovske, Prylutske, Khukhrianske, and Sukhodolivske with the low content from 0.18 ppm (Prokopenkivske field) to 0.27 ppm (Sukhodolivske field); the average manganese concentration in the oils of this cluster is 0.23 ppm. The deposits of Sofiyivske and Talalayivske form cluster 1.1.1.1.2.2 with the lower-than-medium content being from 0.3 ppm to 0.3058 ppm respectively; the average content value within the cluster is 0.3029 ppm. The average concentrations are 0.373 ppm (Bakhmachske field) – 0.452 ppm (Trostianetske field) in terms of the following fields: Bakhmachske, Radchenkivske, Kulychykhinske, Karaikozovske, Turutynske, Solokhivske and Trostianetske of cluster 1.1.1.2 with the average cluster value of 0.403 ppm. Cluster 1.1.2 is made up by the following fields: Zakhidno-Kharkovtsivske, Kybytsivske #52, Shchurynske, Kybytsivske #1, and Sahaidatske #1 with the higher-than-medium value from 0.547 ppm (Zakhidno-Kharkovtsivske field) to 0.719 ppm (Sahaidatske #1 field) at the average cluster value being 0.604 ppm. Cluster 1.2 is represented by such oil fields as Kybytsivske #5, Kybytsivske #51, and Sahaidatske #13 with the high value of manganese concentrations from 0.9 ppm (Kybytsivske #5 field) to 0.95 ppm (Sahaidatske #13 field) in terms of average cluster content of 0.924 ppm. The abnormally high content is associated only with the Yuryivske field of cluster 2 with the value of 1.6 ppm.

A dendrogram of clusterization of the DDOGBA fields in terms of iron content in oils (Fig. 5) represents a clear and unambiguous structure of clusters, i.e. 1.1.1.1.1, 1.1.1.1.2.1, 1.1.1.1.2.2, 1.1.1.2, 1.1.2, 1.2, and 2. The average iron content in the oils here is 16.76 ± 6.48 ppm; the median one is 4.43 ppm.

The abnormally low iron content is represented by the following fields: Malosorochynske, Korobochkynske, Yuryivske, Zakhidno-Kharkovtsivske, Novomykolayivske, Khukhrianske, Kremenivske, Sofiyivske, Yaroshivske, and Sukhodolivske of the cluster 1.1.1.1.1 with the values from 0.12 ppm (Malosorochynske field) to 1.86 ppm (Sukhodolivske field) at the average cluster value of this parameter is 1.18 ppm. A low content is found in the fields of Radchen-

kovske, Monastyrishchynske, Shchurynske, Trostianetske, Kybytsivske #56, Lipovodolynnske, Kybytsivske #51, Prylutske, and Bakhmachske of cluster 1.1.1.2.1 with the values from 3.5 ppm (Radchenkowske field) to 4.46 ppm (Bakhmachske field) at the average cluster value of 3.96 ppm. Cluster 1.1.1.2.2 is formed by the fields of Kybytsivske #52, Kybytsivske #5, Kybytsivske #1, Solokhivske, and Perekopivske with the lower-than-average values from 5.2 ppm (Kybytsivske #52 field) to 6.22 ppm (Perekopivske field) at the average cluster value is 5.67 ppm. Cluster 1.1.1.2 is formed by the fields of Prokopenkivske, Sahaidatske #1, Sahaidatske #13, Kulychykhinske, Turutynske, Kachalivske, and Karaikozovske with the average values from 9.19 ppm (Prokopenkivske field) to 18.71 ppm (Karaikozovske field); the average iron content in the oils of this cluster is 15.59 ppm. The higher-than-average iron contents are peculiar for the oils of such deposits as Solontsivske, Talalayivske, and Raspashnovske of cluster 1.1.2 with the values from 28.7 ppm (Solontsivske field) to 48.5 ppm (Raspashnovske field); the average iron content in terms of the cluster is 36.07 ppm. Cluster 1.2 contains just Matlakhivske field with the high iron content is 89.2 ppm. The abnormally high iron content in oil is found only in case with Krasnozaiarske field of cluster 2 with the content of 221 ppm.

While analyzing a clusterization dendrogram for the DDOGBA fields as for zink content in oils (Fig. 6) the following seven clusters can be defined: 1.1.1.1, 1.1.1.2.1, 1.1.1.2.2, 1.1.2, 1.2.1, 1.2.2, and 2. The average zink content in those fields is 0.67 ± 0.24 ppm; an average value is 1.095 ppm. Cluster 1.1.1.1 is formed by the fields of Karaikozovske, Kremenivske, Korobochkynske, Malosorochynske, Yaroshivske, Yuryivske, Monastyrishchynske, and Lipovodolynnske with the abnormally low zink content varying from 0.08 ppm (Karaikozovske field) to 0.41 ppm (Lipovodolynnske field) at the average cluster value being 0.275 ppm. The low zink content in the oils is characteristic for the fields of Kulychykhinske, Novomykolayivske, Trostianetske, Zakhidno-Kharkovtsivske, Perekopivske, Sukhodolivske, and Turutynske of cluster 1.1.1.2.1 with the values of 0.63 – 0.84 ppm (Kulychykhinske and Turutynske fields respectively) at the average value of 0.75 ppm. Cluster 1.1.1.2.2 consists of the following fields: Solokhivske, Prokopenkivske, Sofiyivske, Shchurynske, and Bakhmachske with the lower-than-average values from 0.94 ppm (Solokhivske field) to 1.16 ppm (Bakhmachske field); the average cluster value here is 1.07 ppm. The medium concentrations are associated with cluster 1.1.2 that

includes the fields of Talalayivske, Radchenkowske, Khukhrianske, Kachalivske, and Prylutske with the values from 1.4 ppm (Talalayivske field) to 1.8 ppm (Prylutske field) at the average cluster value of this parameter is 1.56 ppm. Cluster 1.2.1 is formed by the fields of Solontsivske, Matlakhivske, Kybytsivske #51, and Kybytsivske #5 with the more-than-medium values from 2.34 ppm (Solontsivske field) to 2.9 ppm (Kybytsivske #5 field) at the average cluster content of 2.565 ppm. Cluster 1.2.2 is represented by the following deposits: Krasnozaiarske, Kybytsivske #56, Sahaidatske #1, and Kybytsivske #1 with the high zink concentrations in oils from 3.29 ppm (Krasnozaiarske field) to 3.5 ppm (Kybytsivske #1 field); the average cluster content is 3.373 ppm. The abnormally high content is found in three deposits: Kybytsivske #52, Sahaidatske #13, and Raspashnovske of cluster 2 with the content of 4.8 – 5.6 ppm (Kybytsivske #52 and Raspashnovske fields respectively) at the average cluster value is 5.2 ppm.

Clusterization of the DDOGBA fields in terms of cobalt content in the oils (Fig.7) helped identify seven clusters: 1.1.1.1.1, 1.1.1.1.2, 1.1.1.2, 1.1.2, 1.2, 2.1, and 2.2. The average cobalt content in the considered deposits is 0.38 ± 0.13 ppm; a median value is 0.02 ppm.

Cluster 1.1.1.1.1 is formed by the fields of Karaikozovske, Korobochkynske, Khukhrianske, Solontsivske, Lipovodolynnske, Yaroshivske, Kremenivske, Novomykolayivske, Sofiyivske, Yuryivske, Solokhivske, and Shchurynske with the abnormally low cobalt content being 0.001 ppm (Karaikozovske field) – 0.007 ppm (Shchurynske field) at the average cobalt concentration within the cluster being 0.004 ppm. Clusters 1.1.1.1.2 cover the following deposits: Trostianetske, Monastyrishchynske, Radchenkowske, and Zakhidno-Kharkovtsivske with the low content values of 0.09 ppm (Trostianetske field) – 0.01 ppm (Monastyrishchynske, Radchenkowske, and Zakhidno-Kharkovtsivske fields) at the average cluster content being 0.0975 ppm. Cluster 1.1.1.2 is represented by the fields of Matlakhivske, Prokopenkivske, Talalayivske, Perekopivske, Krasnozaiarske, Raspashnovske, and Sukhodolivske with the lower-than-medium concentrations being 0.02 ppm (Matlakhivske, Prokopenkivske, and Talalayivske fields) – 0.04 ppm (Sukhodolivske field) at the average element concentration in the oil fields of the cluster being 0.026 ppm. The medium concentrations form cluster 1.1.2 that unites the deposits of Kachalivske, Bakhmachske, Prylutske, Turutynske, and Malosorochynske with the cobalt value from 0.0571 ppm (Kachalivske field) to 0.0889 ppm. Cluster 2 is formed only by Kuly-

chykhinske field with the higher-than-medium value of 0.1614 ppm. The high contents are peculiar for the deposits of Kybytsivske #56, Sahaidatske #13, Sahaidatske #1, Kybytsivske #52, Kybytsivske #5, and Kybytsivske #1 of cluster 2.1 with the values of 1.2 ppm (Kybytsivske #56 field) – 2.3 ppm (Kybytsivske #1 field) at the average cluster content of 1.7 ppm. The abnormally high cobalt content is found in Kybytsivske #51 field of cluster 2.2 with the element content in oil is 2.8 ppm.

The analysis of clusterization of the DDOG-BA fields as for nickel content in the oils (Fig.8) shows seven clusters: 1.1.1.1, 1.1.1.2.1, 1.1.1.2.2, 1.1.2.1, 1.1.2.2, 1.2, and 2. The average nickel content in the oils is 6.88 ± 1.66 ppm; an average value is 2.91 ppm. Cluster 1.1.1.1 is formed by such fields as Kachalivske, Kulychykhinske, Perekopivske, Shchurynske, Yaroshivske, Korobochkynske, Sahaidatske #1, Zakhidno-Kharkovtsivske, Trostianetske, Solokhivske, Kremenivske, Solontsivske, and Sofiyivske with the abnormally low values of nickel content being 0.35 ppm (Kachalivske field) – 1.57 ppm (Sofiyivske field). The low value is associated with the following deposits: Krasnozaiarske, Sahaidatske #13, Radchenkovske, Malosorochynske, Talalayivske, Novomykolayivske, Matlakhivske, and Turutynske of cluster 1.1.1.2.1 with the values from 2.17 ppm (Krasnozaiarske field) to 3.06 ppm. Cluster 1.1.1.2.2 is represented by the fields of Karaikozovske, Yuryivske, and Lipovodolynnske with the lower-than-medium content of 4.07 ppm (Karaikozovske field) – 4.25 ppm (Lipovodolynnske field). The average contents are found in the deposits of Kybytsivske #5, Kybytsivske #52, and Monastyrishchynske of cluster 1.1.2.1 with the values of 6.4 ppm (Kybytsivske #5 field) – 6.61 ppm (Monastyrishchynske field). The higher-than-medium content is associated with the deposits of Prylutske, Kybytsivske #56, Kybytsivske #51, and Kybytsivske #1 of cluster 1.1.2.2 with the concentrations of 7.77 ppm (Prylutske field) – 9.5 ppm (Kybytsivske #1 field). Cluster 1.2 is represented only by Raspashnovske deposit with the high value of 17.6 ppm. The abnormally high nickel content is shown in the fields of Sukhodolivske, Prokopenkivske, Bakhmachske, and Khukhrianske of cluster 2 with the content values being from 29.1 ppm (Sukhodolivske field) to 38.1 ppm (Khukhrianske field).

A clusterization dendrogram in terms of vanadium content (Fig. 9) makes it possible to find seven clusters: 1.1.1.1, 1.1.1.2, 1.1.2, 1.2, 2.1.1, 2.1.2, and 2.2. The average vanadium content in the DDOG-BA oils is 5.65 ± 1.47 ppm; the concentration of 1.01 ppm corresponds to a median value. Cluster 1.1.1.1

is made up by the fields of Karaikozovske, Korobochkynske, Zakhidno-Kharkovtsivske, Kachalivske, Sukhodolivske, Lipovodolynnske, Novomykolayivske, Trostianetske, Krasnozaiarske, Perekopivske, Shchurynske, Solontsivske, and Monastyrishchynske with the abnormally low vanadium content from 0.02 ppm (Karaikozovske, Korobochkynske, and Zakhidno-Kharkovtsivske deposits) to 0.17 ppm (Monastyrishchynske deposit) at the average value of this parameter 0.08 ppm. Cluster 1.1.1.2 involves the fields of Kulychykhinske, Turutynske, Bakhmachske, Sofiyivske, and Kremenivske with the low content being 0.32 ppm (Kulychykhinske field) – 0.82 ppm (Kremenivske field) at the average cluster value of 0.56 ppm. Cluster 1.1.2 is shown by the deposits of Matlakhivske, Yaroshivske, Radchenkovske, Prylutske, Raspashnovske, Solokhivske, and Malosorochynske with the lower-than-medium concentration 1.2 ppm (Matlakhivske field) – 2.17 ppm (Malosorochynske field); the average cluster content is 1.64 ppm. Khukhrianske field of cluster 1.2 has a medium content with the value of 3.8 ppm. Cluster 2.1.1 is formed by the deposits of Yuryivske, Talalayivske, and Prokopenkivske with the higher-than-medium values from 9.5 ppm (Yuryivske deposit) to 13.2 ppm (Prokopenkivske deposit) at the average cluster concentration of 11.63 ppm. The following fields are characterized by high contents: Kybytsivske #5, Sahaidatske #1, Kybytsivske #52, and Kybytsivske #56 of cluster 2.1.2 with the values of 16.0 ppm (Kybytsivske #5 field) – 18.0 ppm (Kybytsivske #56 field); the average cluster value is 17.0 ppm. Cluster 2.2 is represented by such deposits as Sahaidatske #13, Kybytsivske #5 1, and Kybytsivske #51 with the abnormally high vanadium content from 23.0 ppm (Sahaidatske #13 field) to 31.0 ppm (Kybytsivske #51 field) at the average cluster value of 27.33 ppm.

Clusterization of the DDOG-BA deposits in terms of contents of the considered metals in oils (Fig.10) helped identify seven clusters: 1.1.1.1, 1.1.1.2, 1.1.2.1.1, 1.1.2.1.2, 1.1.2.2, 1.2, and 2. The average general content of metals in the considered oil fields is 52.59 ± 7.49 ppm; an average value of these parameters is 45.54 ppm. Cluster 1.1.1.1 unites the fields of Kremenivske, Shchurynske, Malosorochynske, Trostianetske, Perekopivske, Sofiyivske, Lipovodolynnske, and Solokhivske with the abnormally low general content of metals from 5.9 ppm (Kremenivske field) to 14.97 ppm (Solokhivske field) at the average cluster value 10.79 ppm. Cluster 1.1.1.2 is formed by the following fields: Prylutske, Karaikozovske, Kulychykhinske, and Turutynske with the low content values of 22.43 ppm (Prylutske

field) to 30.0 ppm (Turutynske field) at the average cluster value of this parameter 27.15 ppm. Cluster 1.1.2.1.1 is represented just by Solontsiyske deposit with the lower-than-medium values 37.78 ppm. A medium content is peculiar for the following deposits: Bakhmachske, Kachalivske, Korobochkynske, Monastyrishchynske, Novomykolayivske, Radchenkivske, Yuryivske, Sukhodolivske, Talalayivske, Yaroshivske, Sahaidatske #13, Khukhrianske, and Kybytsivske #52 of cluster 1.1.2.1.2 with the values from 41.04 ppm (Bakhmachske deposit) to 52.04 ppm (Kybytsivske #52 deposit) at the average cluster value of 46.94 ppm. Cluster 1.1.2.2 is made up only by Prokopenkivske deposit with the higher-than-medium concentrations 60.24 ppm. The following deposits have high general contents of metals: Sahaidatske #1, Raspashnovske, Kybytsivske #5, Kybytsivske #56, Matlakhivske, and Kybytsivske #1 of cluster 1.2 with the values of 71.73 ppm (Sahaidatske #1 field) – 108.2 ppm (Kybytsivske #1 field) at the average cluster value of 93.49 ppm. The abnormally high general content of metals in the oils is represented by the deposits of Kybytsivske #51 and Krasnozaiarske of cluster 2 with the concentration values of 148.33 – 233.96 ppm respectively at the average cluster value of 191.15 ppm.

A clusterization dendrogram of the deposits in terms of sulphur content in oils (Fig. 11) includes seven main clusters: 1.1.1, 1.1.2.1.1, 1.1.2.1.2, 1.1.2.2, 1.2, 2.1, and 2.2. The average sulphure content of the considered deposits is 0.206 ± 0.36 ppm; a median value is 0.113 ppm. Cluster 1.1.1 is represented by such deposits as Shchurynske, Krasnozaiarske, Zakhidno-Kharkovtsovskivske, Kachalivske, Sukhodolivske, Trostianetske, and Karaikozovskivske with the abnormally low content of sulphur from 0.006 ppm (Shchurynske deposit) to 0.032 ppm (Karaikozovskivske deposit) at the average cluster value 0.022 ppm. Cluster 1.1.2.1.1 covers the following deposits: Novomykolayivske, Raspashnovske, Matlakhivske, Perekopivske, Talalayivske, Korobochkynske, and Lipovodolynskivske with the low values of sulphur content in oils from 0.073 ppm (Novomykolayivske deposit) to 0.094 ppm (Lipovodolynskivske deposit) at the average value of 0.084 ppm. Cluster 1.1.2.1.2 involves such fields as Monastyrishchynske, Radchenkivske, Turutynske, Yaroshivske, Kulychykhivske, Solokhivske, and Sofiyivske with the lower-than-medium sulphur content in oils from 0.1 ppm (Monastyrishchynske deposit) to 0.13 ppm (Sofiyivske deposit) at the average concentration of 0.114 ppm. Such deposits as Malosorochynskivske, Kremenivske, Bakhmachske, and Solontsiyske of cluster 1.1.2.2 have the average sulphur content

with the values of 0.151 ppm (Malosorochynskivske deposit) – 0.155 ppm (Solontsiyske deposit) at the average value 0.153 ppm. Cluster 1.2 is represented by the fields of Sahaidatske #1, Kybytsivske #56, Prylutske, Khukhrianske, and Kybytsivske #1 with the higher-than-medium content from 0.237 ppm (Sahaidatske #1 field) to 0.31 ppm (Kybytsivske #1 field) at the average sulphur content 0.283 ppm. The high sulphur content is specific for the deposits of Kybytsivske #52, Yuryivske, and Kybytsivske #5 of cluster 2.1 with the values of this parameter from 0.52 ppm (Kybytsivske #52 field) to 0.59 ppm (Kybytsivske #5 field); the average cluster value is 0.55 ppm. The fields of Kybytsivske #51, Sahaidatske #13, and Prokopenkivske of cluster 2.2 are characterized by the high sulphur content in oils from 0.67 ppm (Kybytsivske #51 field) to 0.8 ppm (Prokopenkivske field) at the average content being 0.74 ppm.

The analysis of a clusterization dendrogram for the DDOGBA deposits in terms of vanadium-nickel ratio in the oils (Fig. 12) helped single out seven clusters: 1.1.1.1.1.1, 1.1.1.1.1.2, 1.1.1.1.2, 1.1.1.2, 1.2, and 2. The average value of the V / Ni ratio in the oils is 1.66 ± 0.61 ; a median value is 0.321. Cluster 1.1.1.1.1.1 is represented by the deposits of Sukhodolivske, Karaikozovskivske, Lipovodolynskivske, Bakhmachske, Zakhidno-Kharkovtsovskivske, Novomykolayivske, Monastyrishchynske, Korobochkynske, and Krasnozaiarske with the abnormally low values of this parameter from 0.001375 (Sukhodolivske field) to 0.041475 (Krasnozaiarske field) at the average cluster value of 0.01732. Such low values as 0.6422 – 0.150559 are associated with the deposits of Trostianetske, Khukhrianske, Raspashnovske, Solontsiyske, Kachalivske, and Turutynske of cluster 1.1.1.1.1.2. Cluster 1.1.1.1.2 involves the oil fields of Prylutske, Shchurynske, Perekopivske, Sofiyivske, Matlakhivske, and Prokopenkivske with the lower-than-medium values of the V / Ni ratio being 0.216164 (Prylutske field) – 0.420382 (Prokopenkivske field); the average cluster value of the ratio is 0.323288. Cluster 1.1.1.2 is formed by the following deposits: Radchenkivske, Kulychykhivske, Kremenivske, and Malosorochynskivske with the average values of the V / Ni ratio from 0.561181 (Radchenkivske field) to 0.797794 (Malosorochynskivske field); the average cluster value in the oils is 0.68079. Cluster 1.1.2 includes the deposits of Solokhivske, Yaroshivske, Kybytsivske #56, Yuryivske, Kybytsivske #5, Kybytsivske #52, Kybytsivske #1, Kybytsivske #51, and Talalayivske with the higher-than-medium values being 1.774064 (Solokhivske field) – 4.206897 (Talalayivske field)

at the average cluster value of the V / Ni ratio being 2.694036. A high value of the V / Ni ratio is 10, which is characteristic only for the Sahaidatske #13 oil of cluster 1.2. In terms of the Sahaidatske #1 oils of cluster 2, the V / Ni ratio reaches its maximum value of 20.

The paper (Punanova, 2020) expresses the idea that the availability of such «abiogenic elements» as Al and Hg in oils indicates the participation of deep fluids in the oil genesis. Using quite extended factual materials, M.A. Lur'e and F.K. Shmydt speak in favour of the effect of deep gas-fluid flows of mantle origin on the S content in oils. E.F. Shnjukov with the co-authors pays special attention to vanadium and nickel concentrations in oils not only as the basis for solving industrial-environmental and economic prob-

lems of oil field development but also for the fundamental scientific developments in the sphere of its origin. They have substantiated a geochemically identical V / Ni ratio as the only reliable evidence of the genetic origin of natural oils, i.e. they originate from the same sources. In this context, the authors emphasize that the ratio of these elements has three levels: < 0.1; 0.1 – 1.0; > 1.0. They believe that the level of > 10 corresponds to the accumulations of «deep, abiotic oil-and-gas formation with their own exclusive capacity of producing genetically related oils for more than 500 mln years» (Shnjukov et al., 2007). Thus, there is every indication to interpret and evaluate the informativeness of the results of the performed cluster analyses in terms of each deposit, at least in terms of genetic ideas.

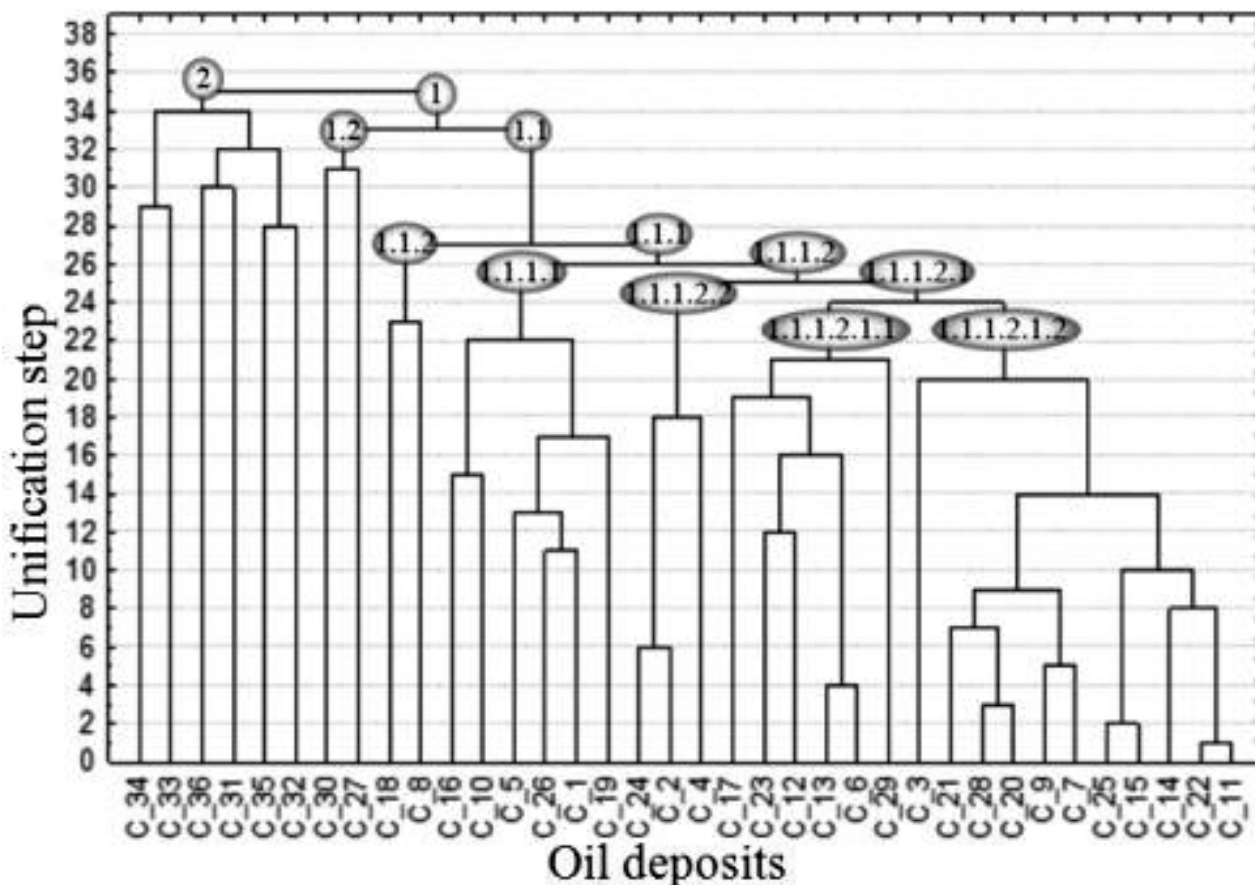


Fig 1. Dendrogram of the results of clusterization by the weighed centroid method in terms of Al content in oils. Symbols:

1, 2, 1.1, 1.2, 2.1, 2.2, 2.3 – clusters; C_1 – Bakhmachske deposit, C_2 – Prylutske deposit, C_3 – Krasnozaiarske deposit, C_4 – Kachalivske deposit, C_5 – Kremenivske deposit, C_6 – Karaikozovske deposit, C_7 – Korobochkynske deposit, C_8 – Kulychykhinske deposit, C_9 – Lipovodolynnske deposit, C_10 – Monastyrishchynske deposit, C_11 – Matlakhivske deposit, C_12 – Malosorochynske deposit, C_13 – Novomykolayivske deposit, C_14 – Perekopivske deposit, C_15 – Prokopenkivske deposit, C_16 – Radchenkovske deposit, C_17 – Raspashnovske deposit, C_18 – Sofiyivske deposit, C_19 – Sukhodolivske deposit, C_20 – Solontivske deposit, C_21 – Solokhivske deposit, C_22 – Talalayivske deposit, C_23 – Trostianetske deposit, C_24 – Turutynske deposit, C_25 – Kharkovtviske deposit, C_26 – Shchurynske deposit, C_27 – Yuryivske deposit, C_28 – Yaroshivske deposit, C_29 – Khukhrianske deposit, C_30 – Sahaidatske #1 deposit, C_31 – Sahaidatske #13 deposit, C_32 – Kybytsivske #5 deposit, C_33 – Kybytsivske #51 deposit, C_34 – Kybytsivske #52 deposit, C_35 – Kybytsivske #56 deposit, C_36 – Kybytsivske #1 deposit.

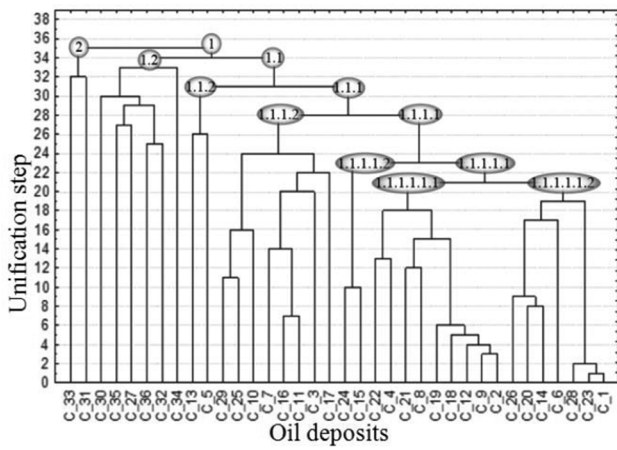


Fig 2. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Hg content in oils. Symbols are similar to Fig 1.

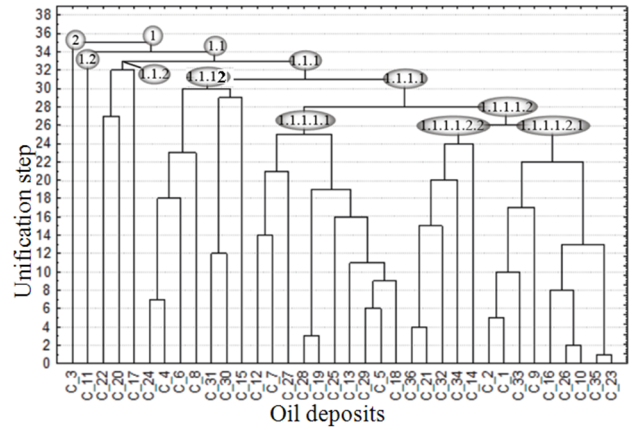


Fig 5. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Fe content in oils. Symbols are similar to Fig 1.

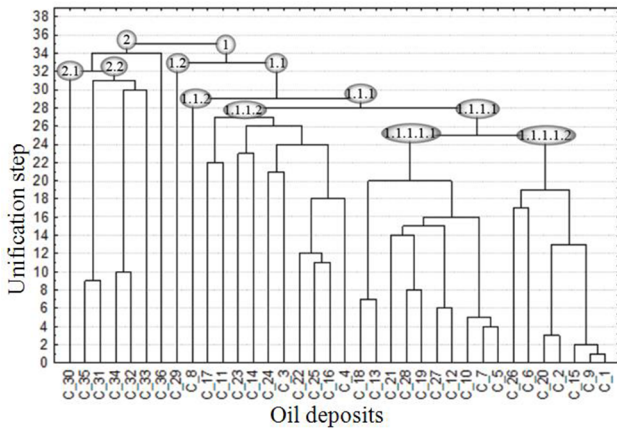


Fig 3. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Cr content in oils. Symbols are similar to Fig 1.

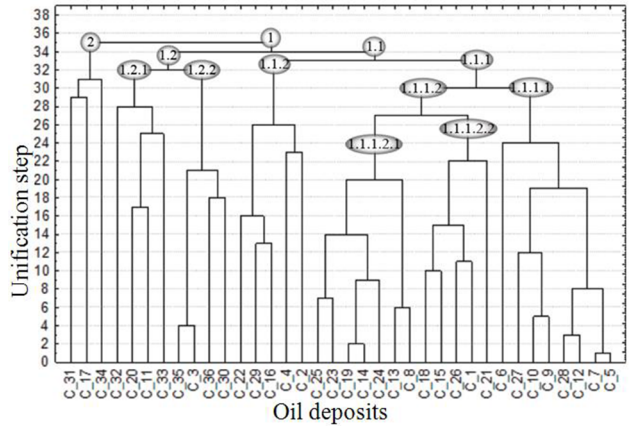


Fig 6. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Zn content in oils. Symbols are similar to Fig 1.

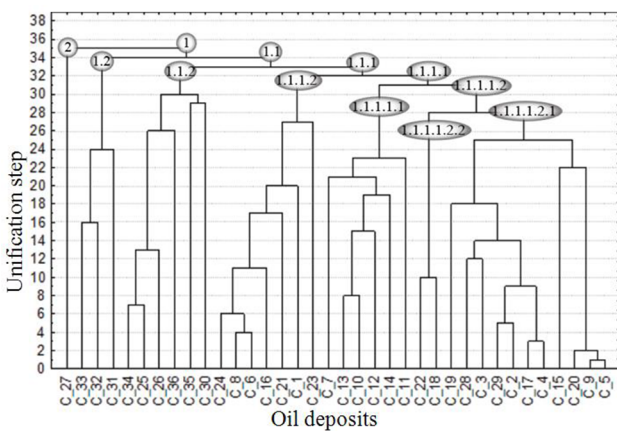


Fig 4. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Mn content in oils. Symbols are similar to Fig 1.

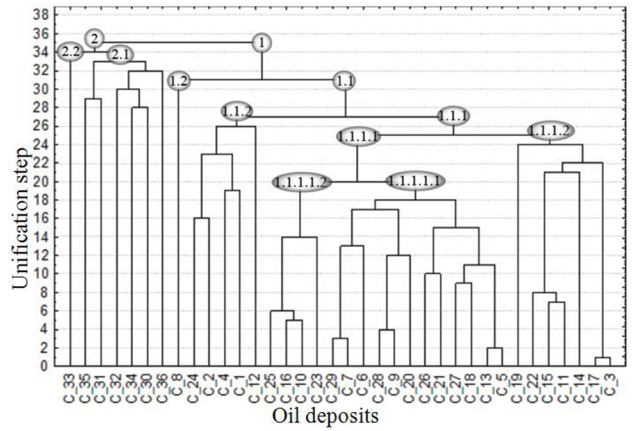


Fig 7. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Co content in oils. Symbols are similar to Fig 1.

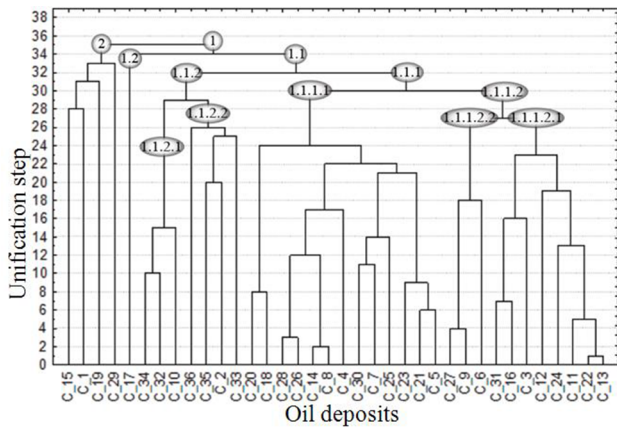


Fig 8. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of Ni content in oils. Symbols are similar to Fig 1.

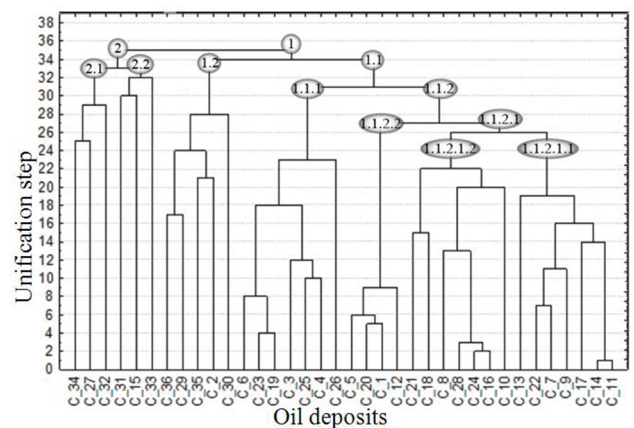


Fig 11. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of S content in oils. Symbols are similar to Fig 1.

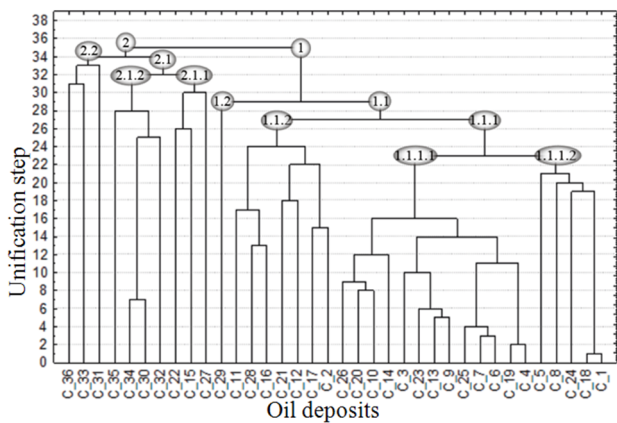


Fig 9. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of V content in oils. Symbols are similar to Fig 1.

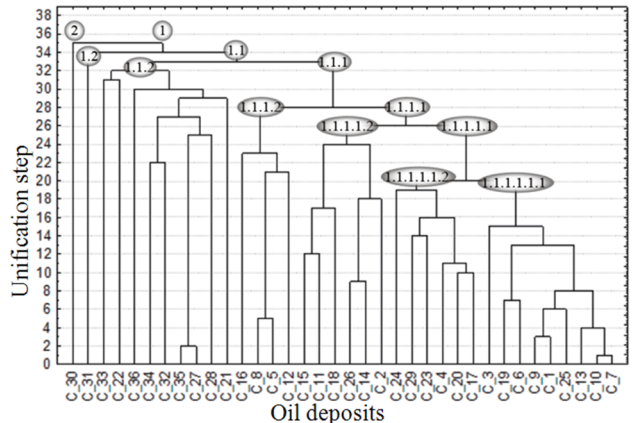


Fig 12. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of V / Ni ratio in oils. Symbols are similar to Fig 1.

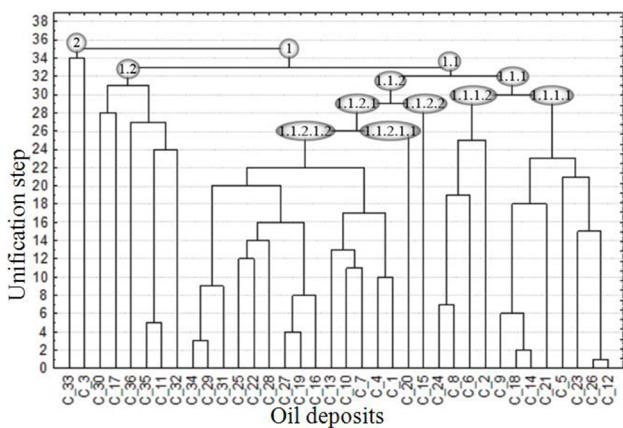


Fig 10. Dendrogram of the results of clusterization by the weighed centroid method of the deposits in terms of general content of the considered metals in oils. Symbols are similar to Fig 1.

Conclusions

While analyzing the research results, it is possible to draw the following conclusions:

1. It has been identified that according to the conclusions in the paper (Shnjukov et al., 2007) oils of the considered deposits are divided into 3 genetically related groups in terms of the V/ Ni ratio. Group 1 (the ratio of V/Ni < 0.1) includes the oils of the following deposits: Sukhodolivske, Karaikozovske, Lipovodolynske, Bakhmachske, Zakhidno-Kharkovtshivske, Novomykolayivske, Monastyrishchynske, Korobochkynske, Krasnozaiarske, Trostianetske, Khukhrianske, and Raspashnovske (cluster 1.1.1.1.1.1.1 and cluster 1.1.1.1.1.2 partially); group 2 (the ratio of V / Ni: 0.1 – 1.0) involves the deposits of Solontsivske, Kachalivske, Turutynske, Prylutske, Shchurynske, Perekopivske, Sofiyivske, Matlakh-

ivske, Prokopenkivske, Radchenkivske, Kulychykhinske, Kremeniivske, and Malosorochynske (cluster 1.1.1.1.2 partially, clusters 1.1.1.1.2 and 1.1.1.2 completely); group 3 (the ratio of V / Ni > 1.0) includes the fields of Solokhivske, Yaroshivske, Kybytsivske #56, Yuryivske, Kybytsivske #5, Kybytsivske #52, Kybytsivske #1, Kybytsivske #51, Talalayivske, Sahaidatske #13, and Sahaidatske #1 (these fields form clusters 1.1.2, 1.2, and 2) (Fig. 12). We consider that some overlapping among the deposits of groups 1 and 2 in cluster 1.1.1.1.2 demonstrates the possibility of hybridization of those oils during their migration from the indigenous oil sources.

2. Thus, according to (Shnjukov et al., 2007), in terms of the V / Ni ratio the areas of deep abiogenic oil-and-gas formation took part in the oil genesis of the following deposits: Solokhivske, Yaroshivske, Kybytsivske #56, Yuryivske, Kybytsivske #5, Kybytsivske #52, Kybytsivske #1, Kybytsivske #51, Talalayivske, Sahaidatske #13, and Sahaidatske #1.

3. It has been proved that in terms of the content of such «abiogenic elements» (Punanova, 2020) as Al and Hg, the clusters with high and abnormally high contents of those metals (in both cases those are clusters 2, 1.2 (Fig. 1 and Fig. 2)) include the same deposits: Yuryivske, Kybytsivske #1, Sahaidatske #13, Kybytsivske #5, Kybytsivske #56, Kybytsivske #52, Kybytsivske #51, and Sahaidatske #1. According to these criteria, the mentioned deposits were formed from the oils of abiogenic sources. Attention should be paid to the fact that such deposits as Solokhivske, Talalayivske, and Yaroshivske, which also contain the abiogenic-origin oils in terms of the first criterion (Shnjukov et al., 2007), are not included into this list. We believe that it demonstrates that the high and abnormally high contents of those elements are a more rigorous criterion for genetic interpretations of geochemical information aimed at determining the oil origin and which is possibly connected with the regional features of the overall geological and chemical development of the considered area.

4. It has been determined that according to the ideas developed in the paper (Lur'e & Shmydt, 2018) in terms of sulphur content only deposits of Kybytsivske #52, Yuryivske, Kybytsivske #5, Kybytsivske #51, Sahaidatske #13, and Prokopenkivske (Fig. 11) belong to the ones formed by the oils of purely abiogenic genesis (clusters with the deposits where S content in oils is of the high (cluster 2.1) and abnormally high (cluster 2.2) values). However, if we take into account another group of deposits, where sulphur content in oils meets the higher-than-medium values (cluster 1.2), the list can be complemented by the

fields of Sahaidatske #1, Kybytsivske #56, Prylutske, Khukhrianske, and Kybytsivske #1.

5. It has been substantiated that a comparative analysis of the results of clusterization of the considered deposits in terms of content of such «abiogenic elements» as Hg and Al (Punanova, 2020) with the results of their clusterization in terms of Cr, Co, and V concentrations demonstrates that the totality of the deposits belonging to the clusters with the high and abnormally high Cr, Co, and V content (clusters 2.1, 2.2 (Fig. 3); 2.1, 2.2 (Fig. 7); and 2.1.2 i 2.2 (Fig. 9) respectively) differ from the ones with the high and abnormally high Hg and Al concentrations only in the absence of Yuryivske deposit but show complete similarity against each other. Consequently, basing on the materials represented in (Punanova, 2020), the high and abnormally high contents of the considered elements in oils can be used as a more rigorous criterion of their division into two principally different groups – the deposits formed mostly by the biogenic-origin oils and the ones containing oils of purely abiogenic generation. In this context, we think that according to the regularities specified in (Shnjukov et al., 2007) it is quite reasonable to consider the Cr / Ni and Co / Ni ratios as the criterion of singling out the oils of purely abiogenic origin apart from the criterion of Cr, Co, and V concentrations.

6. Taking into consideration the fact that the concentrations of metals in the oils of the Dnipro-Donets Depression fields are the geochemical indicators of their general ontogenesis, such analyzed factors as a general content of metals and a content of Ni, Fe, Zn, and Mn require further studies and interpretations in terms of genetics.

7. While comparing a list of deposits that can be added to the ones formed by the abiogenic-origin oil, the criteria indicated in (Shnjukov et al., 2007; Lur'e & Shmydt, 2018; Punanova, 2020) can be used to define their considerable differences. We believe that it may be connected with a general methodology of their identification. These criteria were determined basing on the results of the analysis carried out with the help of different devices, according to different methodologies, at different periods of time, and by different researchers. In this context, our studies demonstrate their certain advantage.

The main **scientific significance of the obtained results** is in the development of natural classifications of the Dnipro-Donets Depression deposits basing on the results of cluster analysis in terms of metals and sulphur content as well as the V / Ni ratio, substantiation of 5 new geochemical criteria to divide the deposits formed by the oils generated mainly by abiogenic or biogenic processes.

The main **practical value of the carried out studies** is the determining the concentrations and possibility of further predictions for metal contents in the oils of the considered fields. In its turn, that makes it possible to solve certain topical problems practically: a series of industrial and raw-material problems based on the estimation of metal-bearing nature of oils since the ore raw material as the content of some elements can sometimes exceed ore concentrations, and there is the possibility of their accompanying industrial extraction from the by-products while their processing; technological problems stipulated by the certain negative influence of some elements contained in oils on the equipment while their extracting and processing; environmental problems when oil processing and extraction (to a lesser extent) are accompanied by the formation of high concentrations of compounds of potentially hazardous toxic metals (aluminium, mercury etc.) being rather environmentally-unfriendly.

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