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Remote Sensing Neotectonic Research on Oil and Gas Perspective Structures on the Example of the Dnieper-Donets Basin

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Abstract

Different methods of structural and geomorphological analysis to solve problems of oil and gas searching at different stages of the work (from regional to detailed) are observed. There are the most acceptable for the Dnieper-Donets Basin are: hypsometric terrain analysis (construction of the morphotectonic structural contours maps); analysis of relief differentiation (degree of horizontal and vertical relief differentiation); morphographic techniques. A priori structural and geomorphological information in the software product ArcGIS, as well as satellite images Sich-2, Landsat–7 ETM+, Landsat–8 OLI, shuttle radar topography mission - SRTM and structural contours scheme based on SRTM data are used.
The result of this comprehensive research is the Scheme of the relative neotectonic activity of the Dnieper-Donets Basin.

Key words: oil and gas structure, remote sensing, structural and geomorphological analysis, morfotektoizogips, neotectonic scheme.

The Neogene-Quaternary period of the Earth's crust formation is of high importance in the oil and gas deposits location and hydrocarbon migration. The ancient faults are updated, new faults laid and activation of foundation's block movements' are occurred during the Neogene-Quaternary period. The local structural forms growth and rearrange occur in the sedimentary cover. The neotectonic activity of the Dnieper-Donets Basin deep structures was contributed to the formation of the relief and its structure peculiarities and this activity can be interpreted using satellite imagery.

There are different methods of structural and geomorphological analysis used for different areas for the solving problems connected with finding oil and gas structures at the different stages of the research works (from regional to detail). The most appropriate methods for the Dnieper-Donets Basin are as follows:

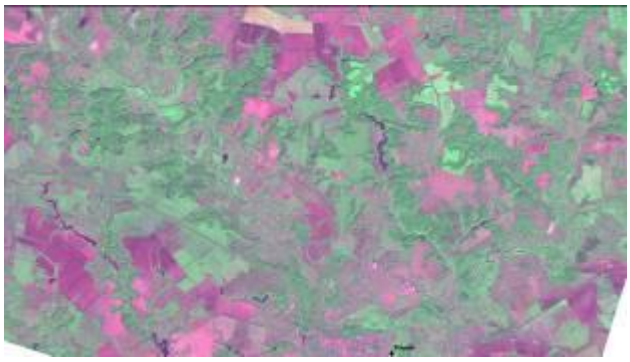
- hypsometric analysis of relief (construction of the morphotectonic structural contours maps);
- analysis of relief differentiation (degree of horizontal and vertical relief differentiation);
- morphography techniques.

In the first case, the analysis is conducted for both hypsometric zoning of the territory and assessment of the interconnection between relief and tectonics.

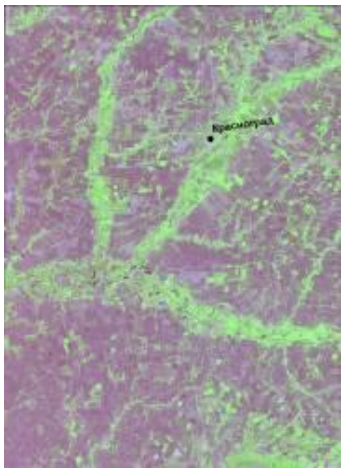
In the second case, the structural interpretation is the following: zones of the increasing dissection degree of relief are identified with the Neogene-Quaternary structural uplift, and zones of depression - with the possible Neogene-Quaternary subsidence.

In the third case, the planned picture of the Earth's surface is investigated based on aerospace materials. Morphography elements, which identify structures in plans, are divided by their form on straightened, arc-shaped and planar.

The main purpose of the structural and geomorphological studies (SGS) during the regional researches conduction was the investigation or rectification of the tectonic structure, which include large oil-gas regions, and local structures. A priori structural and geomorphological information in the software product ArcGIS, as well as satellite images Sich-2, Landsat–7–ETM+, Landsat–8–OLI (Fig.1), shuttle radar topography mission - SRTM and structural contours scheme based on SRTM data (Fig.2) are used in these studies.



A



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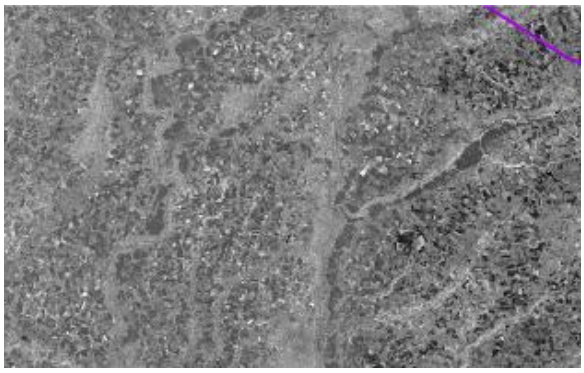

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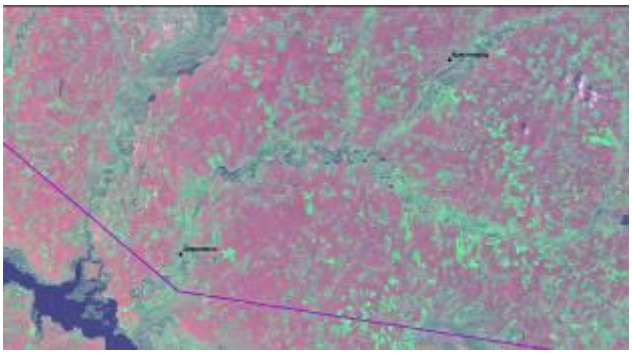
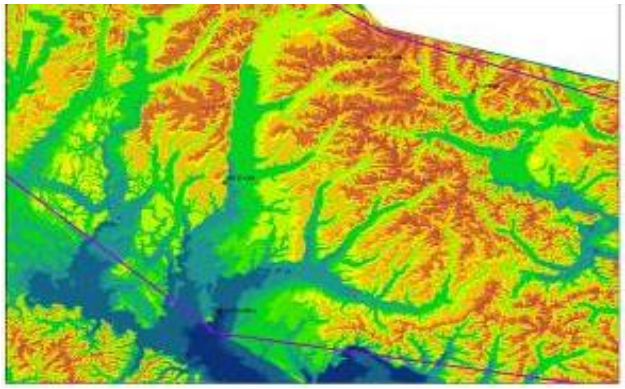
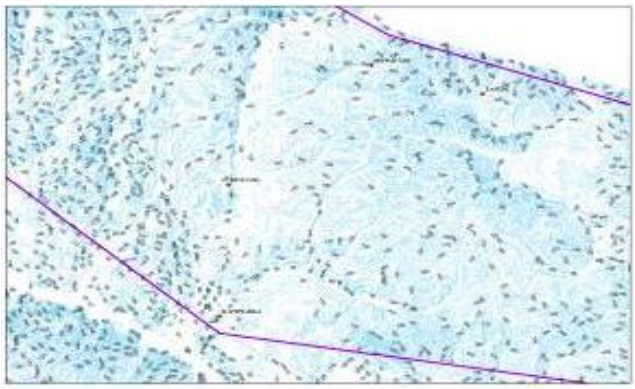


D

Fig.1. The Dnieper-Donets Basin: A, B – satellite imagery Sich-2 (2012); C - satellite image (Landsat–7–ETM+, 2002); D - satellite imagery (Landsat— OLI, 2013)



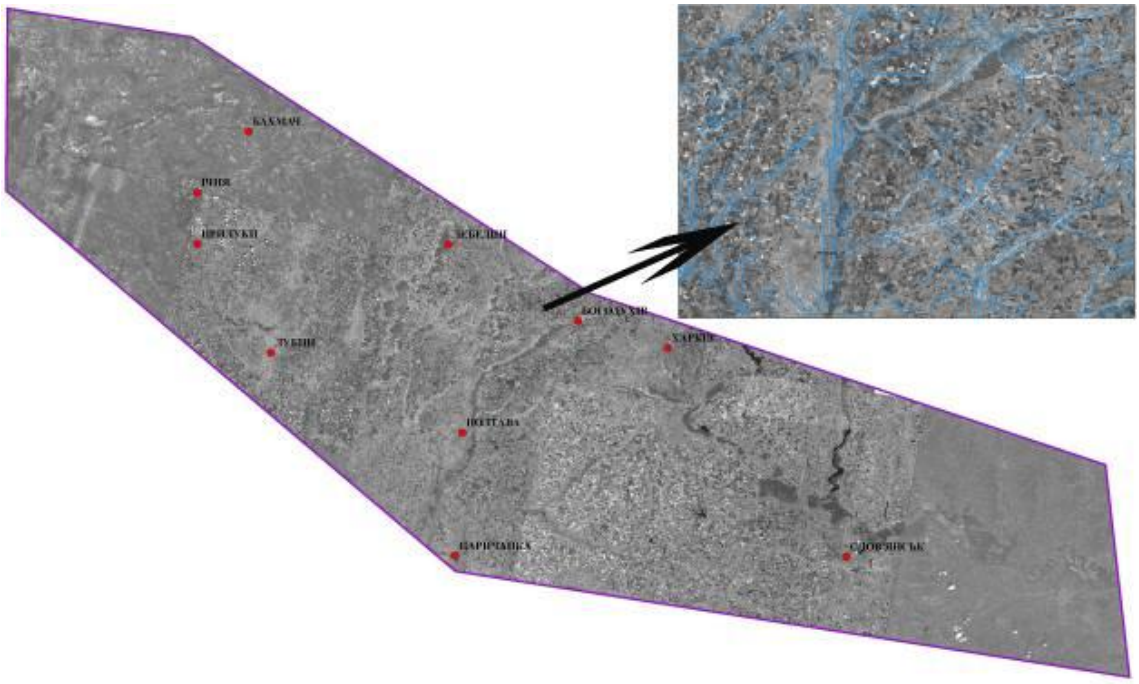
A



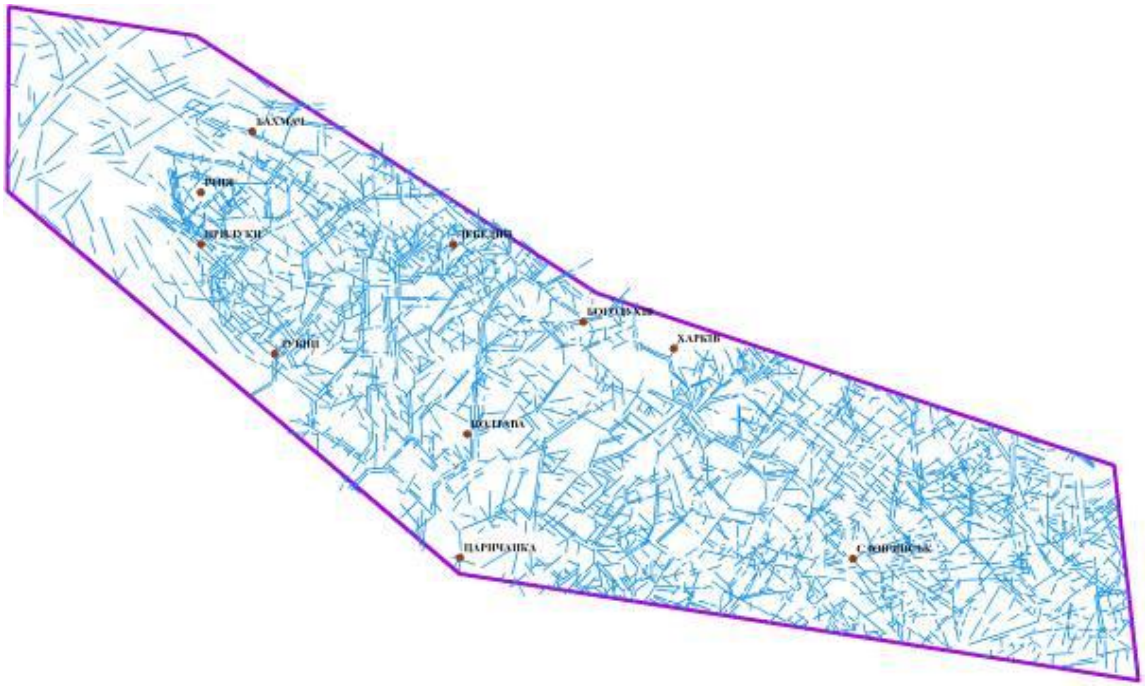
B

Fig.2. The Dnieper-Donets Basin: A – shuttle radar topography mission image (SRTM); B – scheme the structural contours (based on SRTM)

At the first stage, the scheme of the structural decryption was established based on aforementioned satellite imagery, on which lineaments (Fig.3) and their zones (Fig.4) were marked. The result of these procedures was the structural decryption scheme of the Dnieper-Donets Basin (Fig.5).

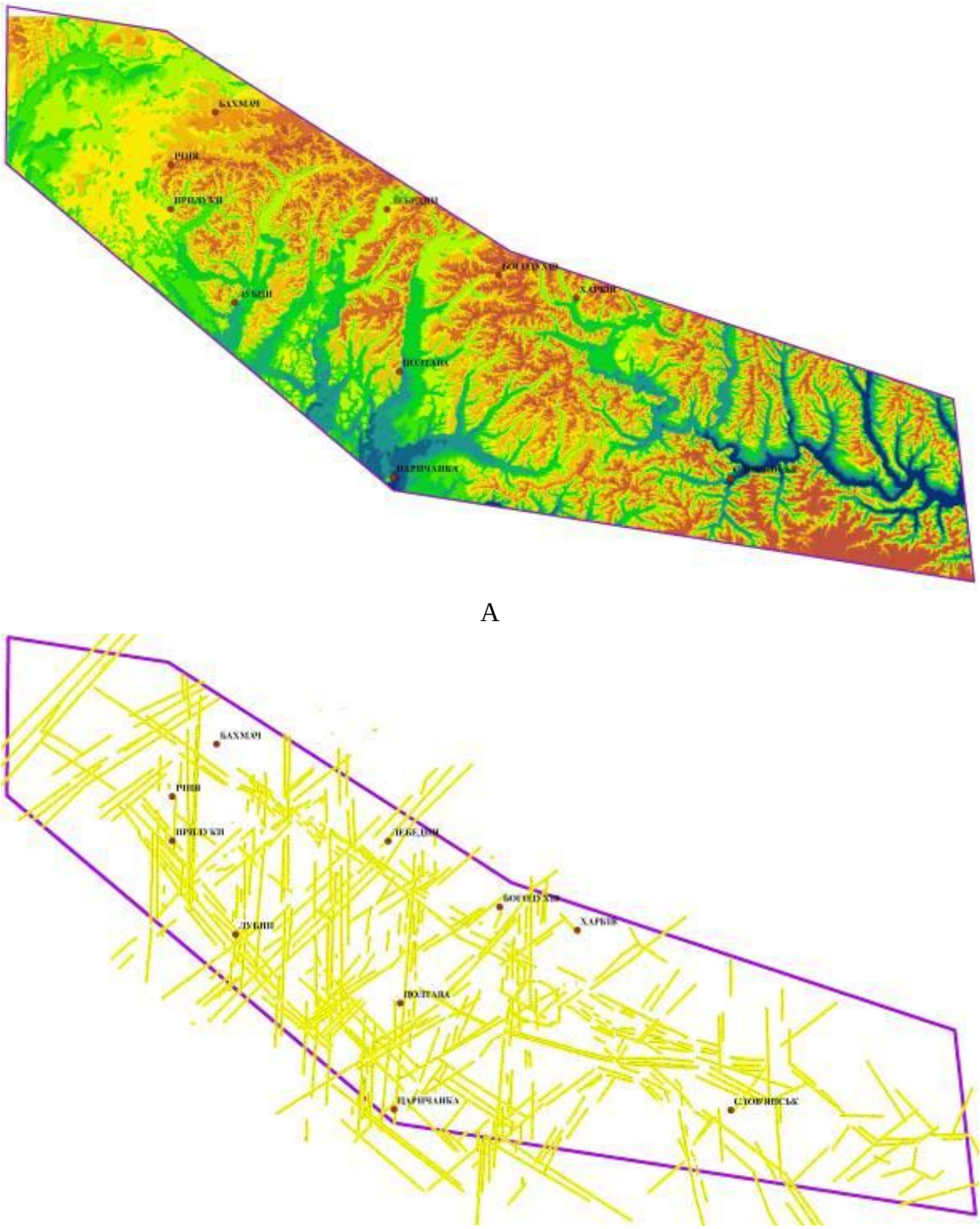


A



B

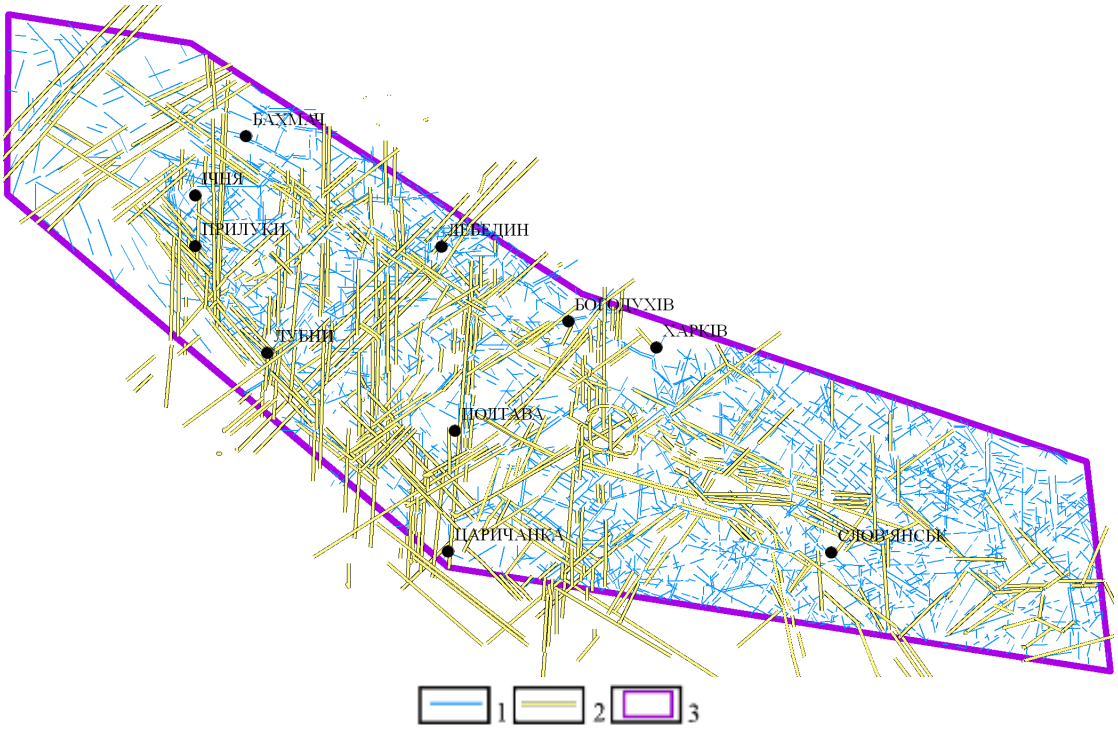
Fig.3. The Dnieper-Donets Basin: the scheme of lineaments (B) based on remote sensing from Landsat–7–ETM+ (A)



A

B

Fig.4. The Dnieper-Donets Basin: the scheme of lineaments (B) based on shuttle radar topography mission (A)



Legend: 1 - lineaments; 2 – lineaments zones; 3 - the research area

Fig.5. The Dnieper-Donets Basin: the resulting scheme of the relief structural identification based on materials of satellite imagery

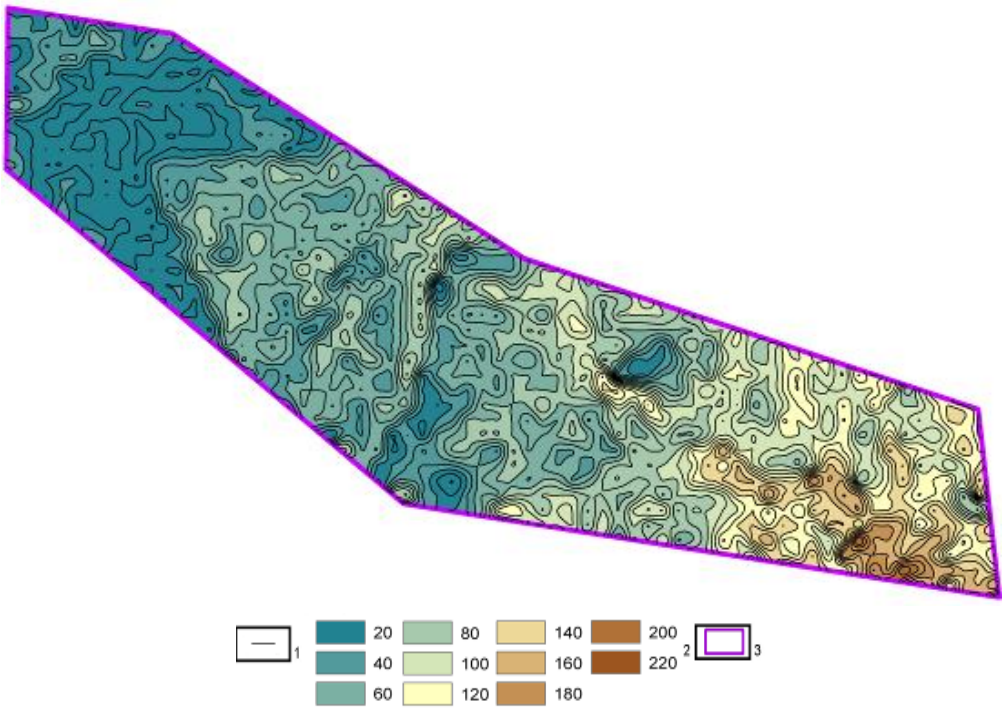
Thus, there are lineament zones of the north-western strike can be observed as well on the performed scheme. These zones have inherited ravines and valleys, most of which are oriented parallel to the marginal faults of the Dnieper-Donets Basin and longitudinal cuts off power within the northern and southern near edge zones and the northern edge. As a result, there are the following associations were traced:

1) the north-western apophysis of the salt stocks cap rocks connected with these marginal faults;

2) the coming of hydrocarbons out to the day surface connected with intersection nodes with such cross sectional dislocations;

The north-eastern sectional dislocations can be identified less clearly by short extension young erosion topographical formations. Obviously, this is associated with a later activation of neotectonic movements on the surface of ancient faults. Moreover, there are traced the salt stocks u-turn of the Dnieper-Donets Basin in the south-eastern part. Submeridional and sublatitudinal faults more clearly, but still fragmentary, are shown in relief's north-western part of the Dnieper-Donets Basin, where they inherited by the valleys of big rivers that were laid, obviously, by the updated ancient fault structures which may extend from the Ukrainian Crystalline Massif through the Dnieper-Donets Basin in Voronezh anteclise.

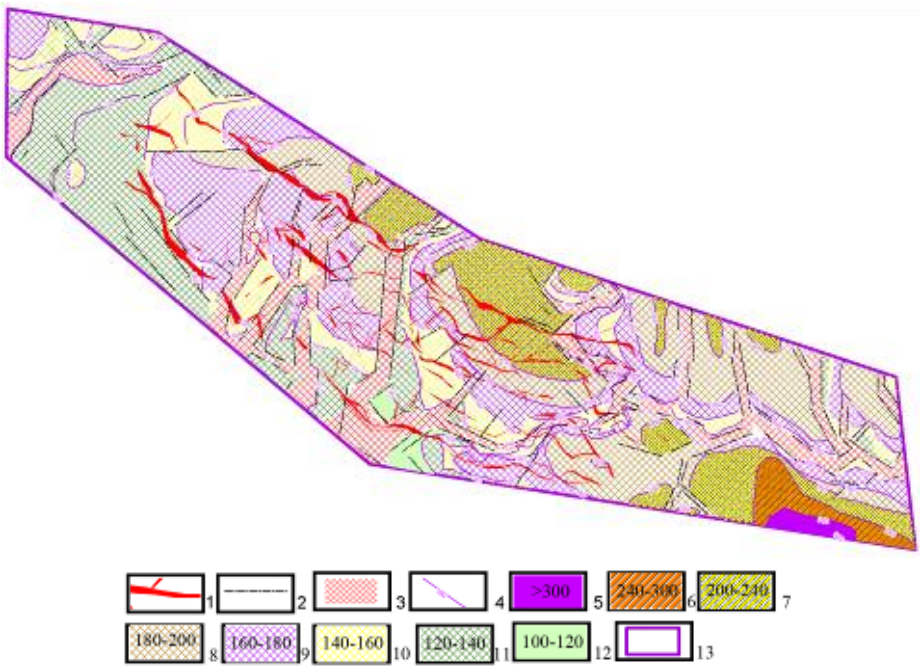
At the next stage diagram of the relief vertical differentiation is constructed (Fig.6). For these studies the SRTM is used, which greatly simplifies the process of materials' construction and interpretation [1]. The analysis of the scheme allowed establishing the connection between the degree of vertical differentiation of relief and tectonic movements.



Legend: 1 – structural contours of relief vertical differentiation, m; 2 - level vertical differentiation; 3 – study area

Fig.6. The Dnieper-Donets Basin: the vertical differentiation of relief (based on SRTM)

According to SRTM the authors carried out the hypsometric relief analysis and built the map of morphotectonic structural contours (Fig.7).

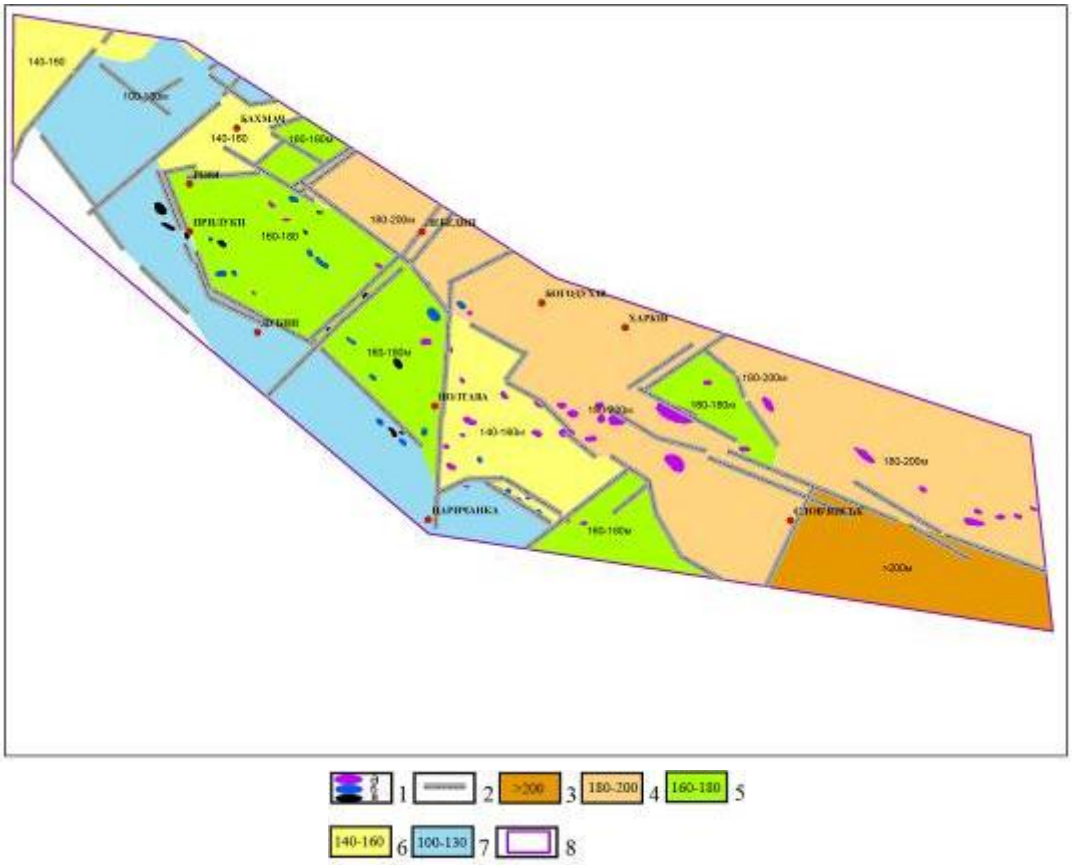


Legend: 1 - faults in the basement; 2 - lineaments and their zones; 3 – unconsolidation zones; 4 - morphotectonic structural contours; 5-12 scale of height, m; 13 – study area

Fig.7. The Dnieper-Donets Basin. The morphotectonic structural contours scheme (based on SRTM)

The method involves the reconstruction of relief. Thus, differently amplitude block structure of the recent relief is defined quite clearly: there are stand out the most elevated blocks, which allows draw conclusions about the positive deformation of the Earth's surface. The neotectonic activity the Dnieper-Donets Basin's deep structures led the displaying of these structures' features of relief's forms depression. Thus, the edges are associated with the uplifted areas of relief, and the depression areas are - with an axial part of the Dnieper-Donets Basin. The structural contours block structure of reconstructed relief with relative range of these blocks motions is performed on the built morphotectonic structural contours scheme as well.

The result of comprehensive research is the scheme of the Dnieper-Donets Basin relative neotectonic activity (Fig.8).



Legend: 1 – deposits: а – natural gas, б – oil-gas, в – crude oil; 2 – blocks' boundaries; 3–7 - scale of the relative neotectonic activity, m; 8 – study area

Fig.8. The Dnieper-Donets Basin. Scheme of the relative neotectonic activity

Our studies provide an opportunity to identify areas that are characterized by varying intensity of neotectonic movements.

The maximum relative amplitude of neotectonic movements - 200 m and more common for the northern edge and the eastern part of the Dnieper-Donets Basin. At the same time, there are the sharp increasing of neotectonic activity and the number of high blocks with high activity while their size reducing in the eastern part. Oil and gas structures in this part of the Dnieper-Donets Basin are characterized by high amplitudes. High values of the neotectonic amplitudes are typical for most of the salt stocks that occur in the recent relief in the form of the positive relief deformations.

Moreover, negative deformations were formed under the stocks that stopped their growth in the Paleogene or had negative direction of movements.

Thus, famous Turutynske, Huhrynsk-Chernetchynske, Yuliyivske and Skvortsivske deposits located within the northern edge and northern near edge zone are confined to regions of the maximum neotectonic activity.

Mean values of relative neotectonic amplitudes - about 160-200 meters - are typical mainly for near edge zone of crystalline basement - Makeyevkske, Lubensk-Isachkivske, Pliskivsk-Lysohorske, Talalaevske, Novotroitske, Radiansk-Koziyivske and others. Therefore, here are concentrated lineaments, which form elongated north-western zones that overlap with less powerful north-eastern zones and the layout of a significant amount of oil, gas condensate and natural gas deposits are related to them.

Within the southern edge of the Dnieper-Donets Basin amplitudes of relative neotectonic movements are much smaller and generally do not exceed 130 meters. However, there are a number of hydrocarbons deposits there and eastern of the Vorskla river district are observed: Livenske, Holubivske, Bohatoyske. Obviously, this is connected with the presence of a significant fractured zone of basement and sedimentary rocks, which may be hydrocarbon transportation routes.

Low values of the relative neotectonic amplitudes of 100-130 m, are occurred on the slopes of deflections and sloping monoclinale of the basement.

Thus, within the studied area of the Dnieper-Donets Basin the following regularity is observed:

- the bulk of hydrocarbons confined to moderate (150-200 m) neotectonic active areas;
- oil deposits are located within the north-western part of the Dnieper-Donets Basin (160-180 m);
- gas condensate deposits are located in the South-eastern part of the Dnieper-Donets Basin (180-200 m).

Consequently, we can conclude that finding of hydrocarbons deposits at the north edge, which is characterized by high amplitudes of relative neotectonic movements, greatly increases its oil and gas prospects due to favorable conditions for the formation of capacitive fracture and fractured-porous reservoirs in the crystalline basement's rocks.

References

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Неотектонические исследования по материалам дистанционного зондирования Земли при поиске структур перспективных на нефть и газ на примере Днепровско-Донецкой впадины

З.М. Товстюк, Т.А. Ефименко, О.В. Титаренко, М.О. Свиденюк

Резюме

В статье рассматриваются разные приемы структурно-геоморфологического анализа для решения задач поиска нефтегазоносных структур на различных стадиях проведения работ (от региональных до детальных). Для Днепровско-Донецкой впадины наиболее приемлемыми оказались следующие: гипсометрический анализ рельефа (построение карт морфотектоизогипс); анализ расчленения рельефа (степень горизонтального и вертикального расчленения рельефа); морфографические приемы. При этих исследованиях используются структурная и геоморфологическая информация в программном продукте ArcGIS, а также космические снимки Сич-2, Landsat-7 ETM +, Landsat-8 OLI, радарная топографическая съемка SRTM и схема изогипс по данным SRTM.

Результатом комплексных исследований стала схема относительной неотектонической активности Днепровско-Донецкой впадины.

ნეოტექტონიკური გამოკვლევები დედამიწის დისტანციური ზონდირების მასალების მიხედვით გაზისა და ნავთობის პერსპექტიული სტრუქტურების ძიებისას დნეპროპეტროვსკ-დონეცკის ქვაბულის მაგალითზე

ზ.მ.ტოვსტიუკი, ტ.ა.ეფიმენკო, ო.ვ.ტიტარენკო, მ.ო.სვიდენიუკი

რეზიუმე

სტატიაში განიხილება სტრუქტურულ-გეომორფოლოგიური ანალიზის სხვადასხვა ხერხები, ნავთობგაზური სტრუქტურების ძიების ამოცანების გადაწყვეტისათვის, სამუშაოების ჩატარების სხვადასხვა სტადიაზე (რეგიონალურიდან დეტალურამდე). დნეპროვსკ-დონეცკის ქვაბულისათვის ყველაზე მისაღები აღმოჩნდა შემდეგი: რელიეფის გიფსომეტრიული ანალიზი(მორფოტექტოიზოგიფსების ანალიზი); რელიეფის დანაწევრების ანალიზი(რელიეფის ჰორიზონტული და ვერტიკალური დანაწევრების ხარისხი); მორფოლოგიური ხერხები. ამ გამოკვლევების დროს გამოიყენება სტრუქტურული და გეომორფოლოგიური ინფორმაცია პროგრამულ პროდუქტში ArcGIS, აგრეთვე კოსმოსური სურათები Сич-2, Landsat-7 ETM+, Landsat-8 OLI, რადარული ტოპოგრაფიული გადაღება SRTM და იზოგიფსების სქემა SRTM-ის მონაცემების მიხედვით.

კომპლექსური გამოკვლევების შედეგია დნეპროვსკ-დონეცკის ქვაბულის ფარდობითი ნეოტექტონიკური აქტივობის სქემა.