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ВУГЛЕВОДНЕВИЙ ПОТЕНЦІАЛ НАДР УКРАЇНИ ТА ГОЛОВНІ НАПРЯМИ ЙОГО ОСВОЄННЯ

HYDROCARBON POTENTIAL IN ENTRAILS OF THE EARTH OF UKRAINE AND MAIN TREND OF ITS DEVELOPMENT

(Матеріал друкується мовою оригіналу)

У статті схарактеризовано сучасний стан вуглеводневої бази України – однієї з небагатьох країн-піонерів у сфері нафтогазової геології та індустрії. На сьогодні діапазон нафтогазоносності держави майже повністю відповідає глобальним показникам. Першочерговими завданнями геологорозвідувальних робіт на нафту й газ є дорозвідка великих родовищ і реанімація продуктивних горизонтів із використанням новітніх методів. Однак головні перспективні напрями пов'язані з освоєнням вуглеводневого потенціалу в рифогенно-карбонатних комплексах (РКК), глибокостанурених відкладах, кристалічному фундаменті, неантиклінальних пастках у піщаних тілах, а також нетрадиційних джерел вуглеводнів. РКК можуть містити досить великі родовища у відкладах турнейського та візейського ярусів Східного нафтогазоносного регіону України. З групами барових тіл пов'язані відкриті в Дніпровсько-Донецькій западині газоконденсатні родовища із чималими запасами. Загальна оцінка 0,5 умовних одиниць палива є мінімальною для прогнозних ресурсів ВВ у піщаних тілах різновікових поліфазіальних комплексів нафтогазоносних регіонів України. Підтверджено наявність суперколекторів – інтервалів інтенсивної тріщинуватості й кавернозності в зонах сучасних тектонічних напруг. За низкою критеріїв інтервали розущільнених колекторів дуже поширені на глибинах 5–7 км. На багатьох родовищах з них отримано великі стійкі дебіти газу. Надзвичайно великими є можливості освоєння вуглеводневого потенціалу різновікового й передусім докембрійського кристалічного фундаменту. Нафтогазоносні регіони України, насамперед Східний, у перспективі є невичерпними джерелами нетрадиційного природного газу (сланцевого та центральнобасейнового), пов'язаного з малопроникними теригенними колекторами. Не варто забувати й про майже невичерпні альтернативні джерела природного газу (метан, розчинений у підземних водах і чорноморських газогідратах).

Ключові слова: вуглеводневий потенціал, родовища нафти й газу, колектори, пастки.

The article deals with the current state of mineral and raw hydrocarbon base of Ukraine. The main promising directions of geological exploration for oil and gas are identified and determined: in reef-carbonate complexes, deep-seated petroliferous complexes, crystalline basement, non-anticlinal traps in sandy bodies, non-traditional HC sources.

Keywords: hydrocarbon potential, oil and gas fields, reservoirs, traps.

Ukraine are among of very limited number of countries-pioneers in the petroleum geology and hydrocarbon industry fields. There is no line in development of oil and gas (from prospecting and exploration on land and sea and different technical problems – up to and including oil and gas transport, building of gas-holders and so on), where Ukraine was not among pioneers. And at the present time in spite of long-term intensive mining, hydrocarbon potential of Ukraine is sufficiently powerful. In this respect the very significant is the fact that all ranges of oil and gas bearingness practically completely correspond to the Worlds ranges. So, the stratigraphic range of petroliferous formation in Ukraine is from pre-Cambrian to Pliocen including. Ukraine hydrocarbon and bitumen accumulation reservoirs are represented with all known sedimentary rocks and facies. The depth interval

of commercial hydrocarbons pools distribution varies from first hundred meters almost to 7 km and apparently more than 8 km.

Deep petroliferous basins in Ukraine various from typically paleorift to subduction and accretion types.

Phase-geochemical diapason includes all known in the World types of hydrocarbons natural systems: from all kinds of natural bitumens and heavy oils to various gas-condensates (including pools of critical state) and all types of hydrocarbon gases. To this should be added that Ukrainian oils gascondensates and gases are distinguished with high quality and not contained admixed toxically components.

The oil-and-gas promising territories in Ukraine occupy about 80 % of total Ukrainian territory. Three petroliferous regions are known in our country (fig. 1):

– Eastern (Dnieper-Donets) region including Dnieper-Donets depression with adjacent monoclinical slopes of the

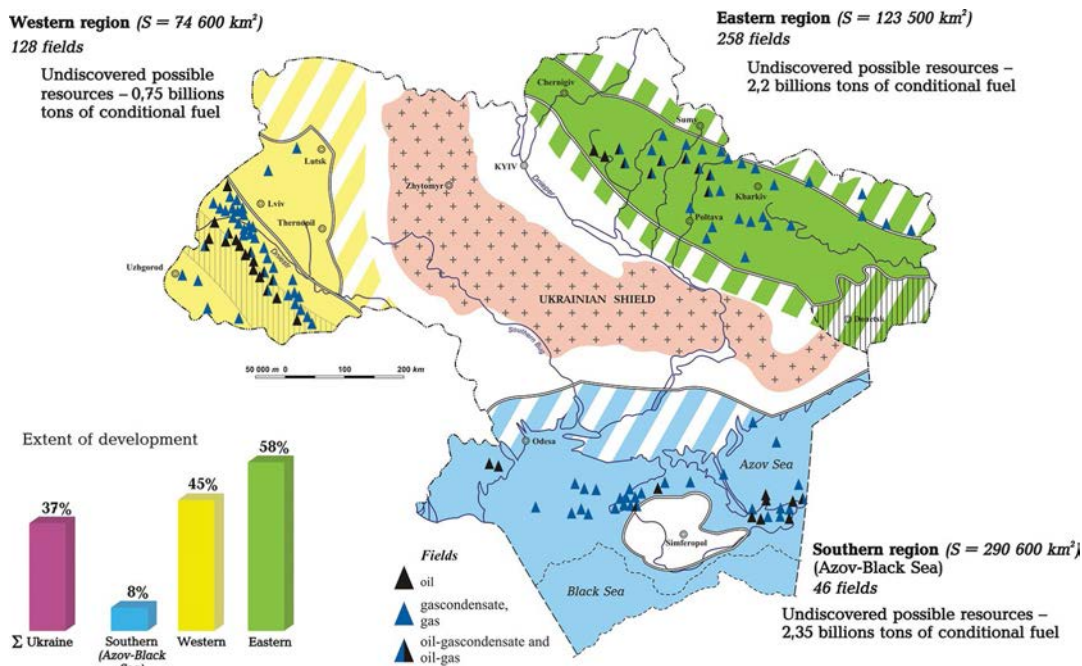


Fig. 1. Petroliferous regions of Ukraine

Voronezh crystalline massive and the Ukrainian shield, and also ukrainian segment of Donets basin;

- the Western region includes together with pre-Carpathian foredeep and Transcarpathian deep, Lviv Paleozoic deep and Volyno-Podolian outskirts of East-European platform;
- the Southern (Azov-Black sea) region is the most geotectonically-heterogenous (it includes the southern slope of Ukrainian shield, Pre-Dobrogean, Indol-Kuban and Northern Azov deeps, Karkinit-Northern Crimean-deep, North-Western and pre-Kerchian shelves of the Black sea).

The degree of development of hydrocarbon resources of the Eastern region achieves 58 %. 252 oil, gascondensate, gas and heterophase fields are discovered here. Nevertheless, this region leads both by unprospected HC resources category C₁ + D (~ 2,2 billions ton of conventional fuel) and by so-called stock of structures (in other words, by number of determined according to geologic-geophysical investigation predicted-prospecting target objects) that account for 326.

124 oil and gas fields are discovered in the Western region.

The degree (stage) of development its hydrocarbon resources run as high as 45 %. Unprospected (undiscovered) resources account for 0,75 billions tons of conventional fuel. The stock of structures (target objects) is 165.

46 oil, gas and gascondensate fields are discovered in the Southern region. The degree of its development run as high as only 8 %, the stock of structures – target objects are 50.

Altogether in Ukraine over the whole preceding period it was extracted near 2 billions tons of conv. fuel. The amount of unprospected (undiscovered) HC resources (by category C₁ + D) is 5.3 billions tons of conv. fuel. This assessment is particularly minimal because it does take account a number of considerable promising lines of oil and gas prospecting. But even this the most reliable and justified part of the predicted HC resources is more than twice as large as the cumulative extraction of hydrocarbons from geological formation of Ukraine. And this is only part of the potential HC resources.

It is precisely potential resources characterize HC potential of geological formation of Ukraine. Indicated 5.3 billions ton of conv.

fuel are those that are provided by above mentioned stock of structures (target objects). These are far from distinct anticline structures as it was in the past but and geophysics (particularly seismic) prospecting are quite another. The total stock of such target objects are sufficiently large. Their number is above 540 objects.

Top priority task is additional prospecting of the largest fields (fig. 2) and reanimation of exsouted productive reservoirs by the application of present-day methods. But the main strategic trends are connected with prospecting of reef-carbonate complexes and local bodies, deep and superdeep (more than 5,5–6 km) horizons, nontraditional and alternative resources.

Reef-carbonate complexes of Ukraine are very promising for oil and gas. The world’s characteristics of HC resurses testify that not only for oil but also for gas and condensate by no means less than the HC resources of terrigenous reservoirs. It is sufficient to mention that the most gas fields connected with Permian and Triassic (South Pars) and Jurassic (Iolotan) carbonate formations.

Carbonate formations of various geological age play great role in Eastern, Western and especially Southern petroliferous regions. Their HC potential are proved, but their degree of development of their potential HC resources no more than 10 %. The main part of carbonate reservoirs resources doesn’t appears in those 5,3 billions of conv. fuel. Ukrainian because ukrainian petroleum geologists and geophysicists had been for many years under wrong impression that carbonate formations are tight “plates” (Visean “plate”, Bashkirian “plate” an so on) and play the role of regional oil-gas proof thicknesses. But closer examination of them allowed to establish and mapped a

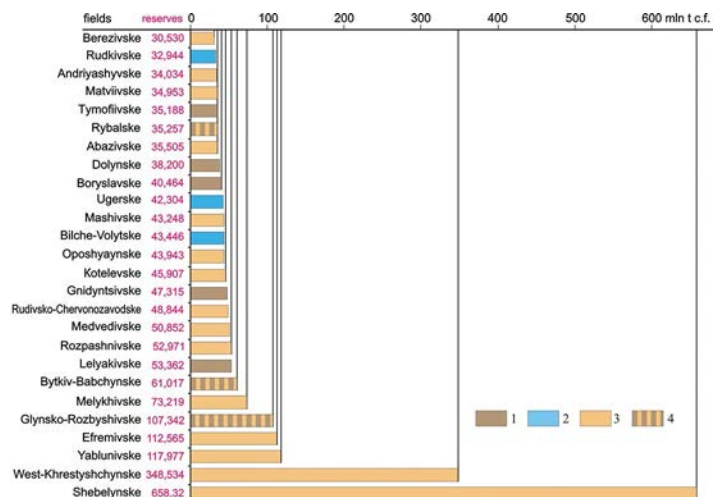


Fig. 2. Fields of Oil and Gas-bearing Regions of Ukraine with recoverable reserves from 30 to 700 million tons of Hydrocarbons 1 – oil; 2 – gas; 3 – gas-condensate; 4 – oil-gas-condensate

number of barrier-reef zones and megatolls in the Devonian (fig. 3, 4), Lower Carboniferous (fig. 5, 6) and Lower Permian of Dnieper-Donets depression; in upper Jurassic of Pre-Carpathian foredeep (fig. 7) in the Silurian Volyn-Podolian (fig. 8) in upper Jurassic of the Azov-Black sea region (fig. 9). There are plausible evaluations for separate segments of reef-carbonate

complexes. Minimal summary assessment of those segments is above 5 billions tons of conventional fuel. It should be emphasized that great fields may be connected with carbonate reservoirs (fig. 10 – for example). The number of such target objects are sufficiently great.

Non-anticline terrigenous traps. Their prospecting is very important separate trend of exploration for oil and gas pools and development of HC potential in all petroliferous regions of Ukraine. Non-anticline traps are connected substantially with various types of sandstone bodies and all of them are distributed in great stratigraphic and sedimentary-facies range in Ukrainian petroliferous region (fig. 11). As experience of old petroliferous provinces (such as Volga-Ural, Midcontinent and

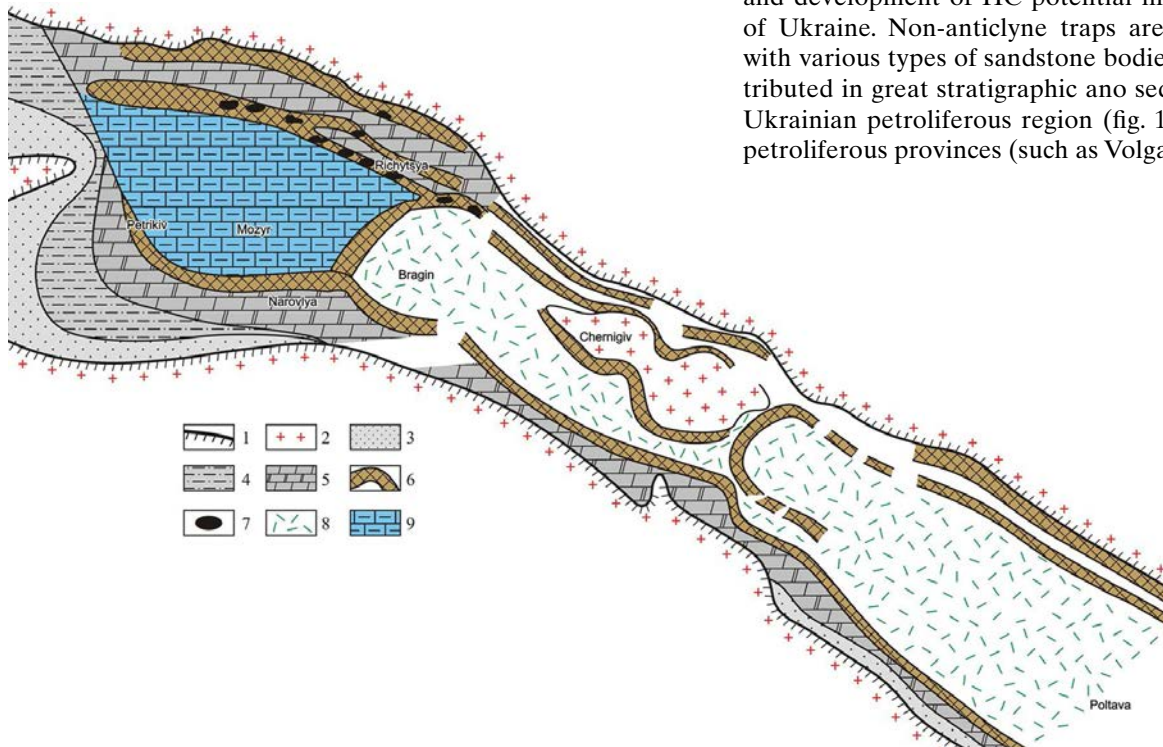


Fig. 3. Schematic map of the distribution of the Lower Famennian reef-carbonate zones in the Pripjat and Dnieper-Donets depressions

1 – boundaries of the distribution of Devonian sediments; 2 – crystalline rocks of the Precambrian basement; 3 – clastic deposits; 4 – sandy-clay deposits; 5 – clay-carbonate deposits; 6 – reef zones; 7 – fields; 8 – volcanic and volcanic deposits; 9 – domonikites

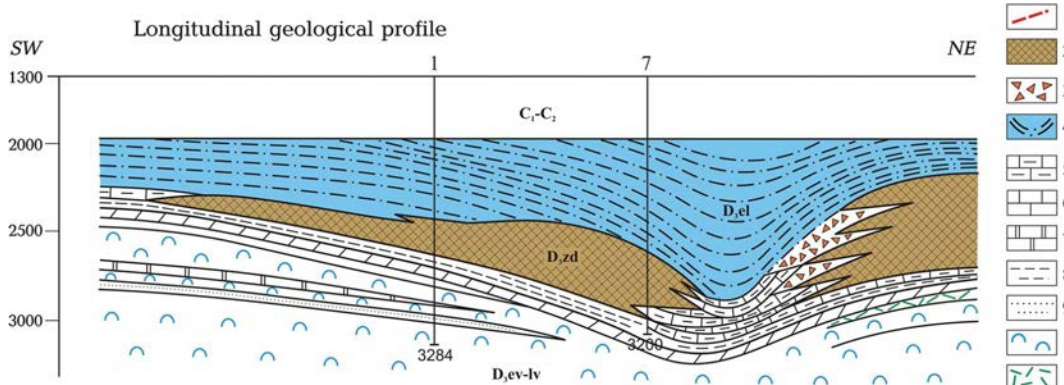
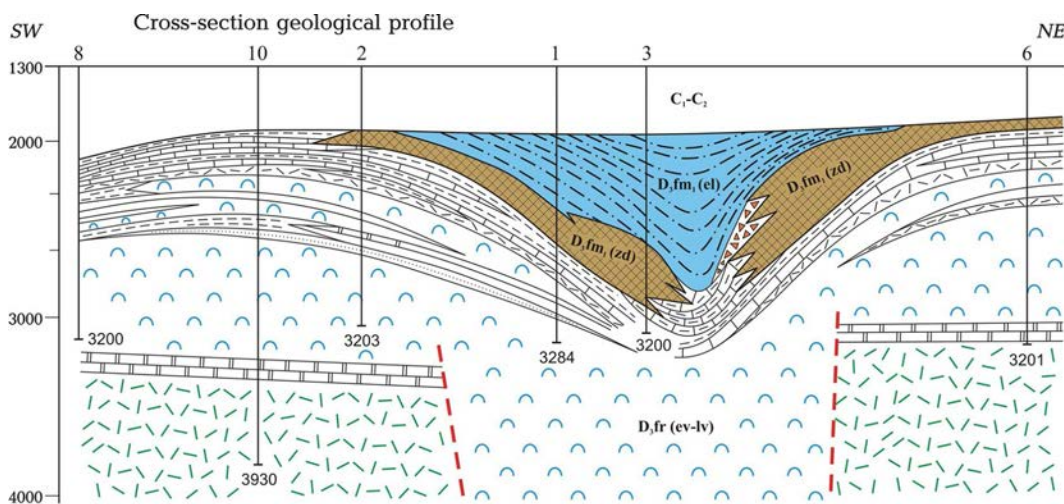


Fig. 4. Zadonsko-Yeletski reefs on the slopes of the Osmakovsky Early Famennian paleo-depression (North at board zone DDD. Borkovska Area)

1 – faults; 2 – zadonski reef-carbonate bodies; 3 – carbonate-clastic deposits of the pre-reef plume; 4 – eletski flyschoid terrigenous deposits; 5 – depressed dominoids; 6 – limestones; 7 – dolomites; 8 – mudstones; 9 – sandstones; 10 – salt; 11 – volcanics

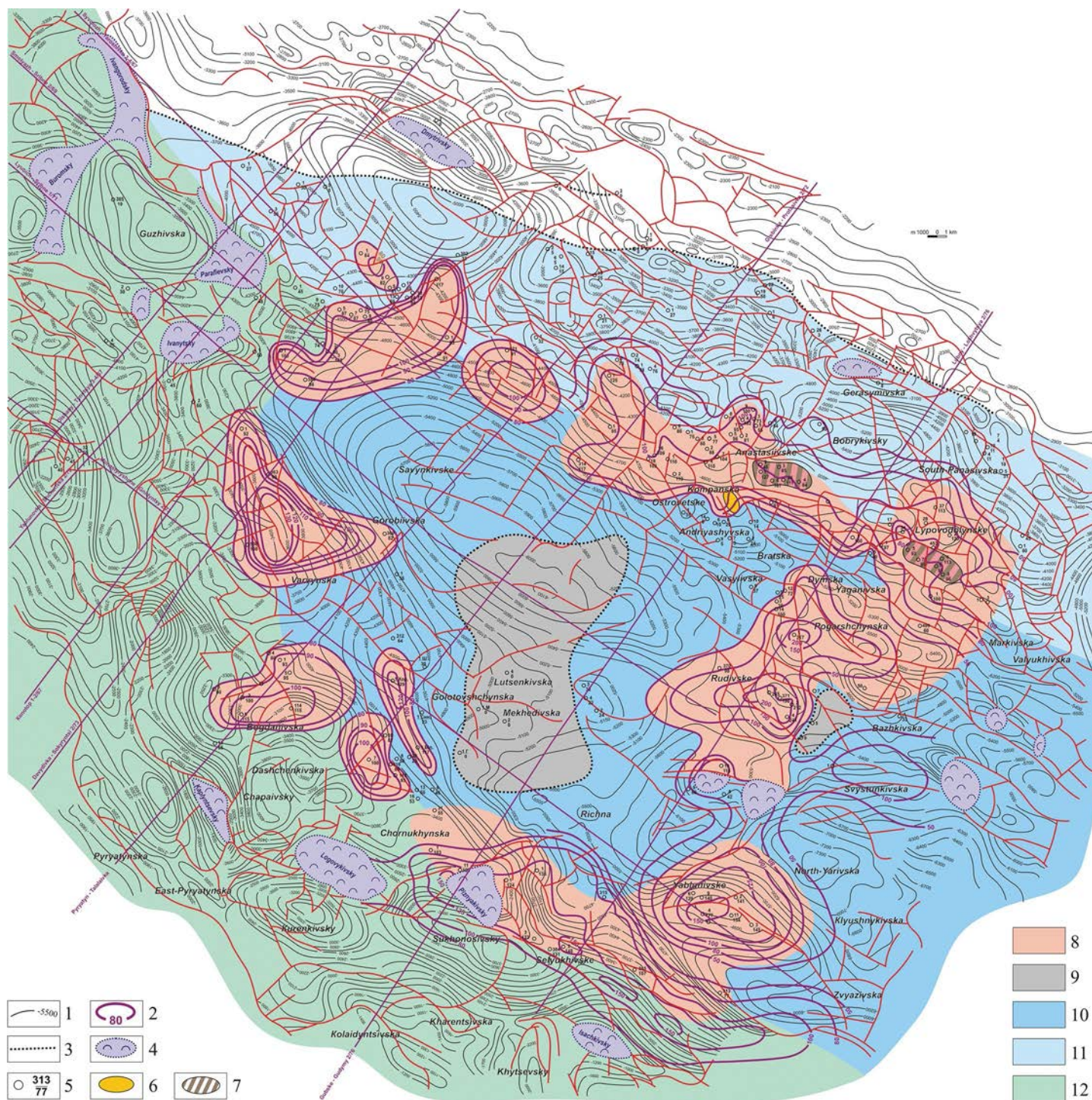


Fig. 5. Sribnensky Lower Visean reef megatoll

1 – isohypses of the reflecting horizons of the Lower Carboniferous; 2 – carbonate thickness of the Lower Visean plate; 3 – wedging line carbonate lower visa; 4 – salt stock; 5 – well number / thickness of carbonate lower visa; HC-deposits in carbonate reservoirs C_1v_1 ; 6 – Gas-Condensate, 7 – Oil (probable); 8 – sites for the development of carbonate organogenic structures and accumulative bodies (bioherm, banks, etc.); 9 – marine depressed terrigenous-siliceous-clay-domanicoid deposits; 10 – marine depressive carbonate-siliceous-domanicoid-clay deposits; 11 – offshore carbonate deposits; 12 – lagoon-shelf terrigenous-carbonate deposits

others) had testified the number of such traps are measured by many hundreds and thousands. Such pools are mainly of small sizes. But they have been clustered by extended zones with considerable proved reserves. The stock of such traps is very considerable. For example, this is sedimentary-paleogeological cross-section Lower-Visean black-shale suit with great number of petroliferous sandstone bodies in Dnieper-Donets basin (fig. 12).

And this cross-section (fig. 13) demonstrates clustering of bars that controlled the zone of intensive gas accumulation (great Abazovo-Sementsovka gas condensate and other fields in Serpukhovian (C_1) facial-cyclic deposits (Dnieper-Donets depression). There are many other examples of HC pools in sand bodies of various types in wide sedimentary-facies range.

Together with elementary sandstone bodies complicated terrigenous bodies of more large size are of wide spreading.

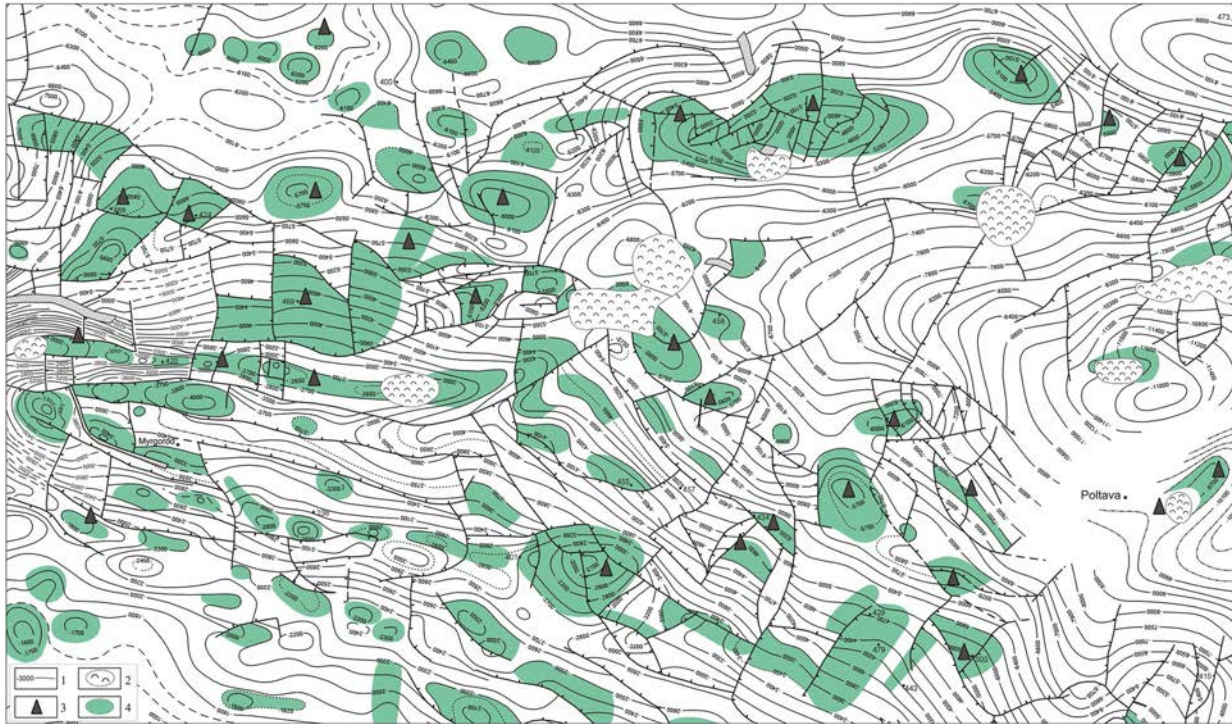
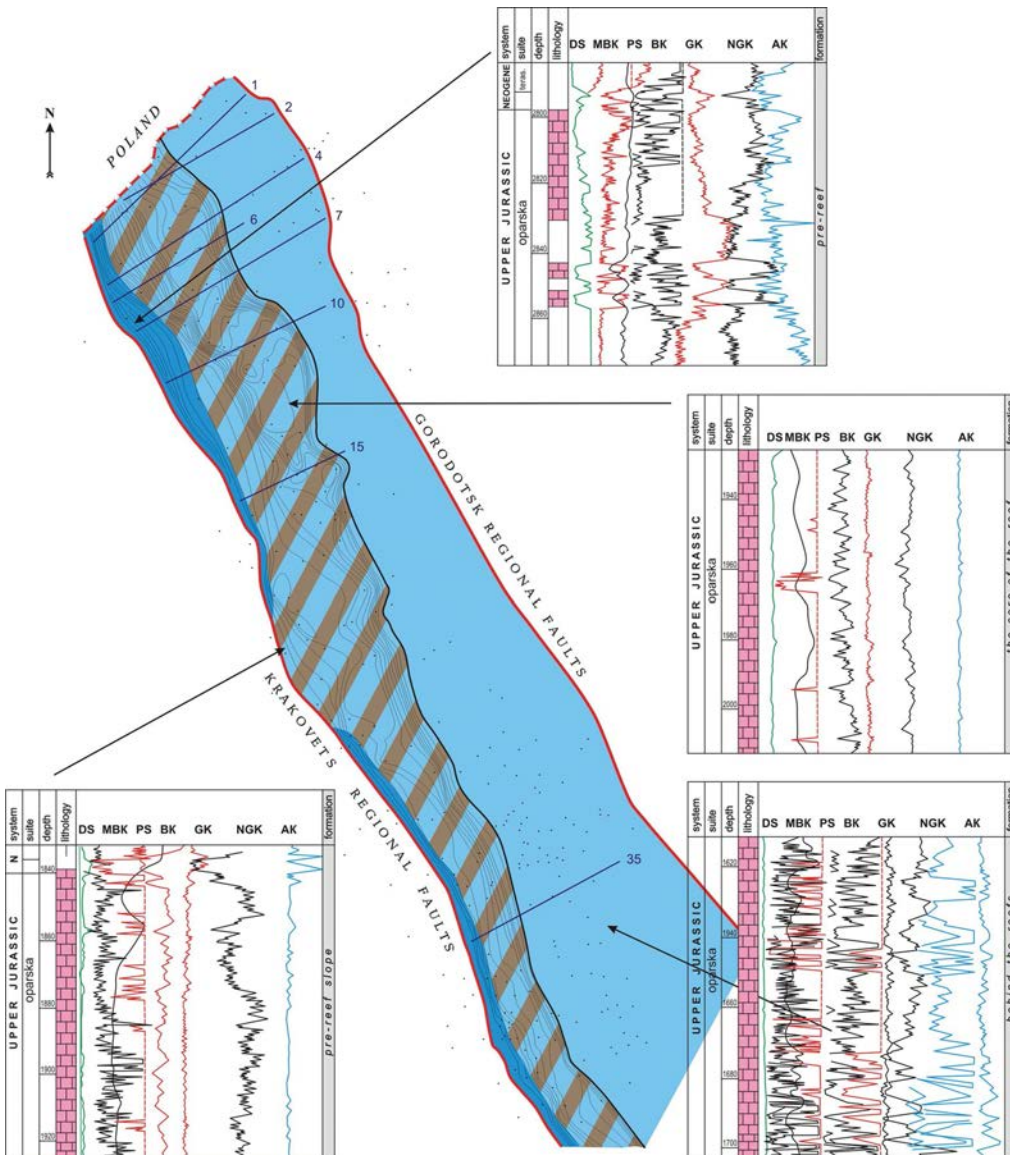


Fig. 6. Prospects for the Oil and Gas potential of the Walsort domes of the central part of the DDD at the depths of more than 5 km

1 – isohypses of the reflecting horizon Vv_{2m} (by to the CDPM seismic data); 2 – salt stocks; 3 – fields with gas-condensate deposits at depths of more than 5 km; 4 – localization sites Walsort domes



Minimal assessment of total HC resources connected with non-anticline traps in terrigenous reservoirs is about 0,5 billion units of conv. fuels (half trillions m^3 of gas or half billions tons of oil).

All above-mentioned types of petroliferous traps are quite traditional in the World, but not completely traditional for Ukraine. So, we have great reserves connected with such pools.

Deep-seated petroliferous complexes. In due time just the great depths had been saved Ukrainian oil-gas exploration branch, oil and gas industry. Moreover, just owing to this line of prospecting and drilling, extraction of natural gas in Ukraine ranges up to about 68–70 billions m^3 per ear (in seventies years of XX century (fig. 14). Tremendous (without any overestimation) ukrainian achievements in development of deep-seated HC pools (particularly discovery of 46 fields – with ~110 gascondensate, gas and also

Fig. 7. Petroliferous Upper Jurassic barrier reef within the North-Western part of the external Pre-Carpathian depression zones. Typical Geophysical Section Characteristics Facial Areas by Data Well Logging

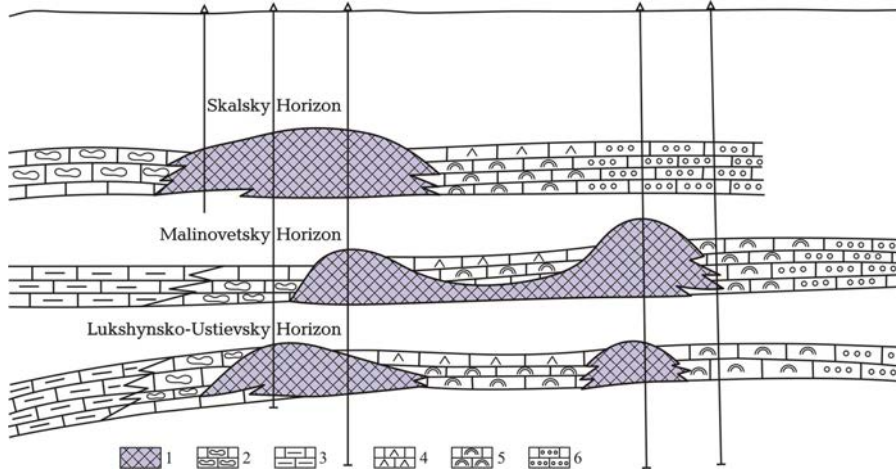


Fig. 8. Silurian Barrier-Reef zones (paleogeomorphological section of the Lokachinsky area)
 1 – reef carbonates; 2 – pre-reef clastic-carbonate deposits; 3 – clay limestones; 4 – sulphate-carbonate deposits; 5 – marine limestones and dolomites; 6 – oolitic limestones and calcarenites

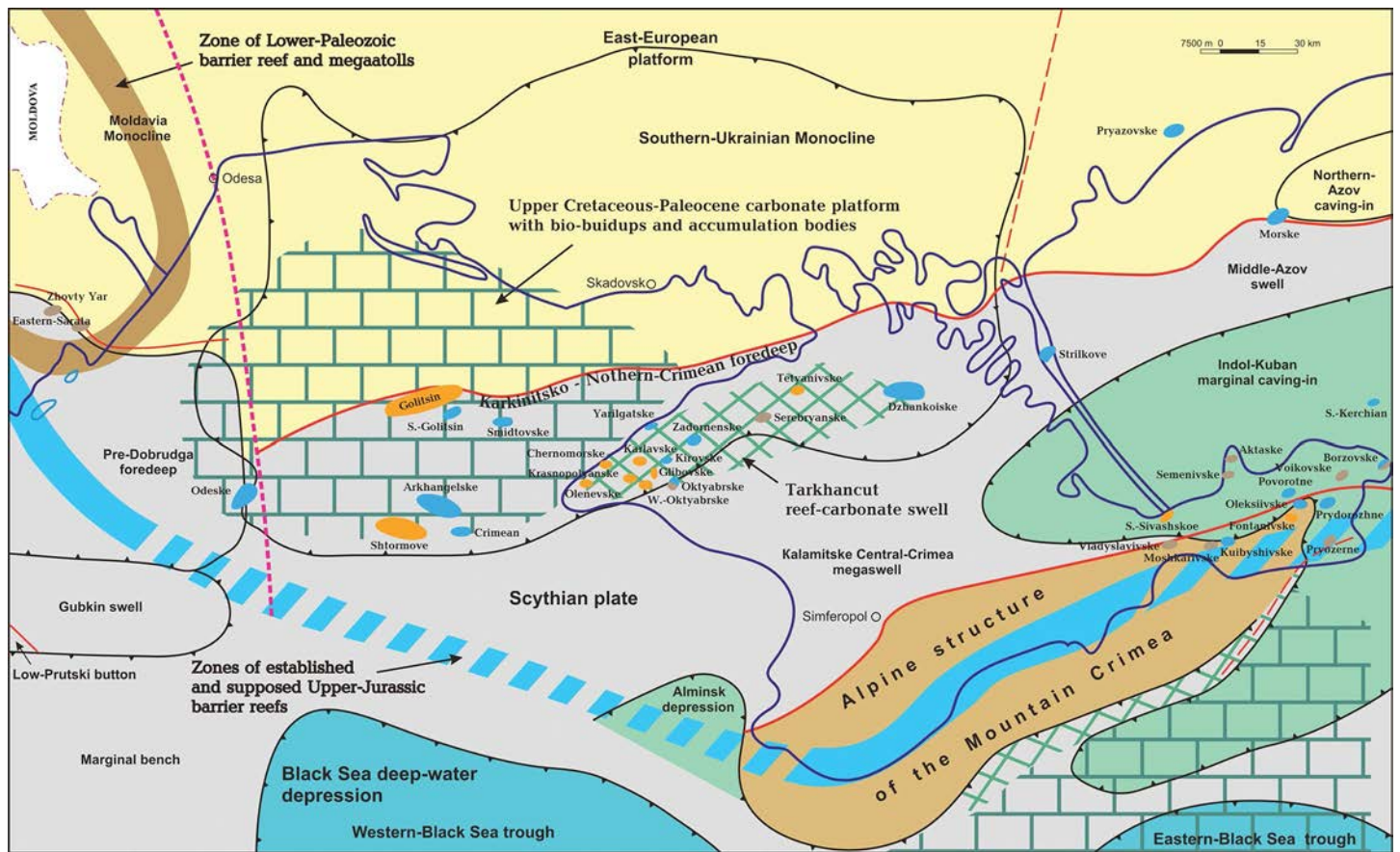


Fig. 9. Reef zones of Southern petroleumiferous region of Ukraine

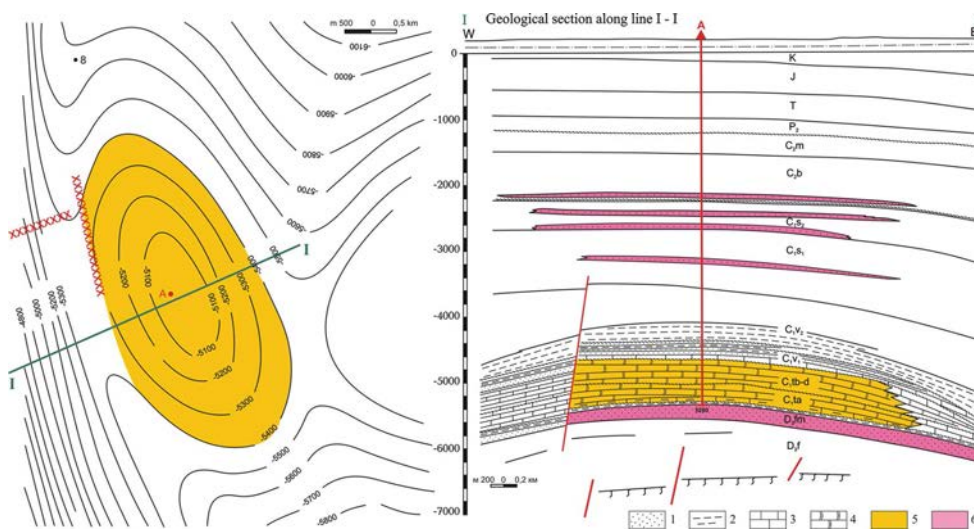


Fig. 10. Great forecast Gas-Condensate field in one of the deep-lying Tournaisian reefs of the DDD
 1 – sandstones; 2 – mudstones; 3 – depressive limestones; 4 – reef-carbonate; 5 – forecast gas condensate reservoir; 6 – forecast hydrocarbon deposits

oil-gas pools at the depth more than 5 km) are of great practical and theoretical significance for the present-day mastering of deep and superdeep depths in the World. Just in Ukraine, especially in central part of DDD secondary reservoirs with various manifestations of dilatancy and other types of deconsolidation (fig. 15) were

investigated the most completely just from such deep-seated reservoirs great stable gas debits were obtained.

Presence of superreservoirs – intervals of intensive open fracturing and cavernosity is established within zones of current tectonic stress. Recently, such productive superreservoirs were

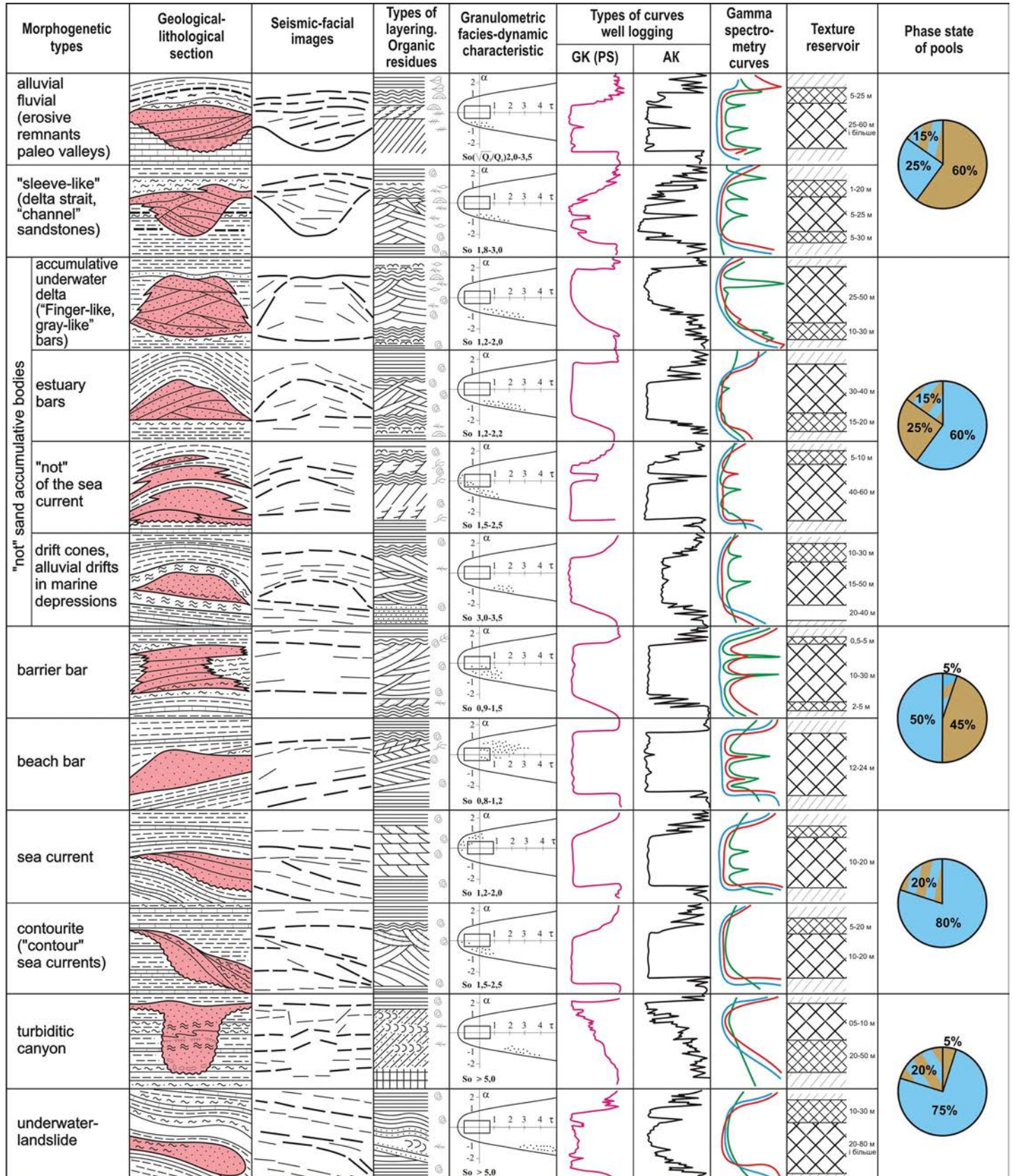


Fig. 11. Main morphogenetic types of terrigenous bodies – hydrocarbons traps

established at the depth more than 6 km in Semirenkivske gas-condensate field (Poltava region, central segment of DDD). Their evidence is self-decomposition of cores into thin discs with condensate and light oil films. According to a set of data such intervals are typical at the depths 5–7 and more kilometers. Deep-seated gas-condensate fields are at the stage of pool accumulation process according thermobaric, hydrogeologic, isotope-geochemical data (fig. 16) with the pace that comparative with velocities of HC-fluid intensive extraction.

Within Poltava-Kharkov segment of the DDD that situated above Dnieper-Donets mantle plume there are localized the bulk part of prospected HC reserves and the most of potential resources of Lower Carboniferous – the main petroleum floor of the Eastern region. There are many very promising targets objects connected with deep-seated terrigenous and carbonate reservoirs in this segment of DDD (fig. 17).

Crystalline basement of different age (particularly pre-Cambrian) shows considerable promise of HC potential. This problem needs in special consideration in Ukraine. Now one can only to mention that just in Ukraine commercial HC potential AR-PR crystalline basement. The question is about intensive oil-gas accumulation in Eastern segment of joint zone between Voronezh anteclysa and DDD – Donets basin. Seven fields including great Yuliivka oil-gascondensate field have been discovered here.

A number of such zones are predicted within dilatation zone within crystalline basement of Eastern, Western and Southern petroliferous regions.

Among indicators of such objects one ought to mention pools of gas in traps, connected with basal strata of sedimentary cover.

An additional point to emphasize is that we predicted big and gigantic oil gascondensate and gas fields connected with massive reservoirs of deconsolidated Paleozoic – Early Mesozoic granites on the North-Western

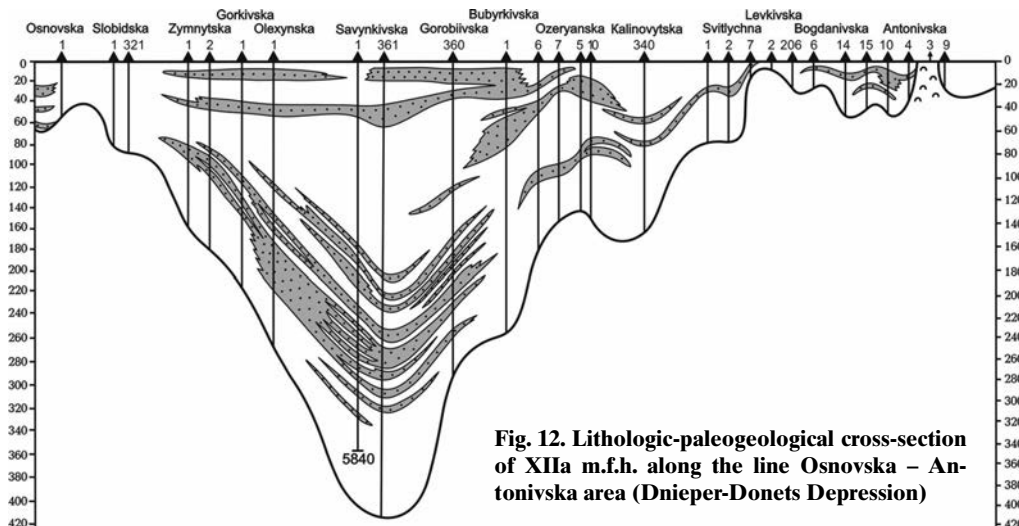


Fig. 12. Lithologic-paleogeological cross-section of XIIa m.f.h. along the line Osnovska – Antonivska area (Dnieper-Donets Depression)

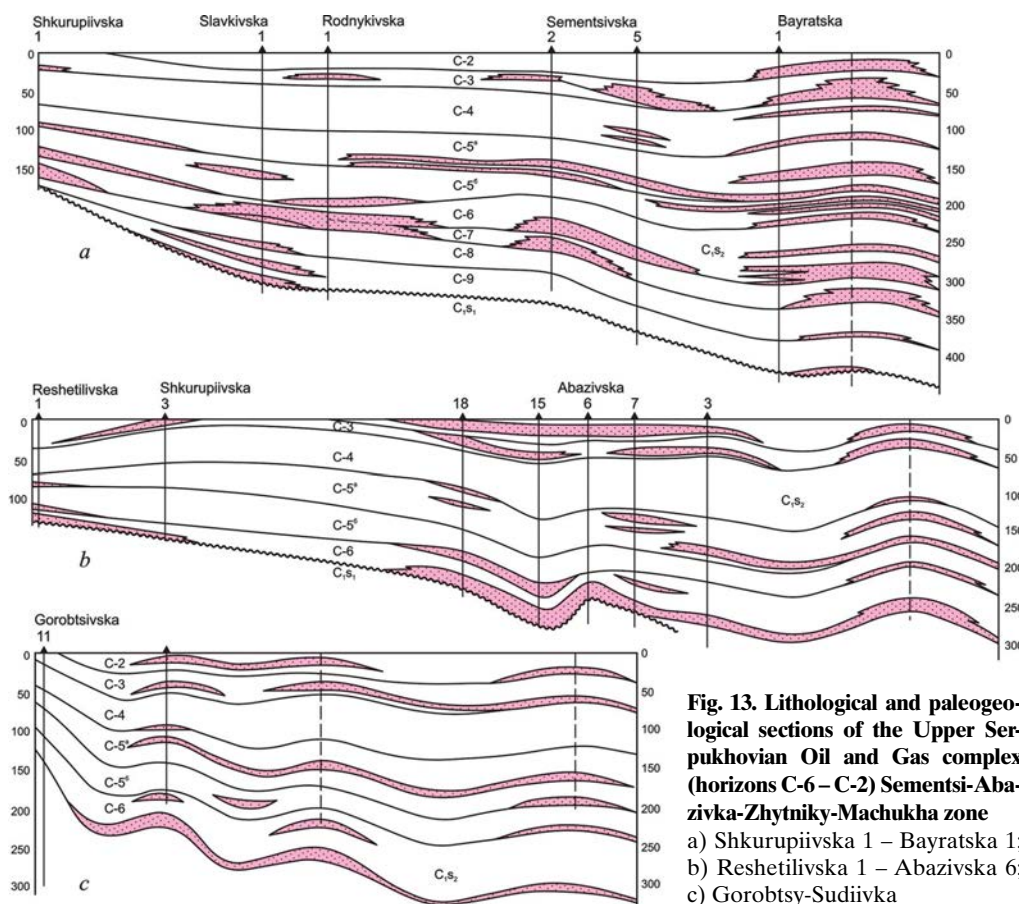


Fig. 13. Lithological and paleogeological sections of the Upper Serpukhovian Oil and Gas complex (horizons C-6 – C-2) Sementsi-Abazivka-Zhytniky-Machukha zone

a) Shkurupiivska 1 – Bayratska 1; b) Reshetilivska 1 – Abazivska 6; c) Gorobtsy-Sudiivka

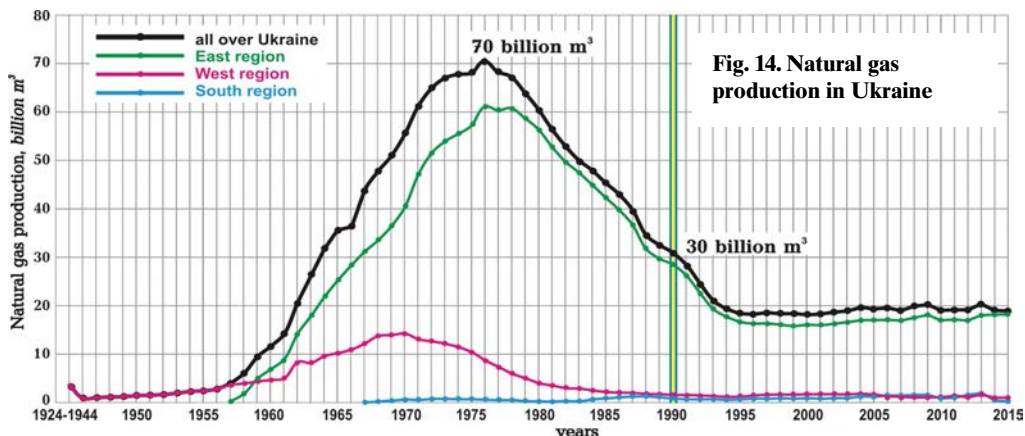


Fig. 14. Natural gas production in Ukraine

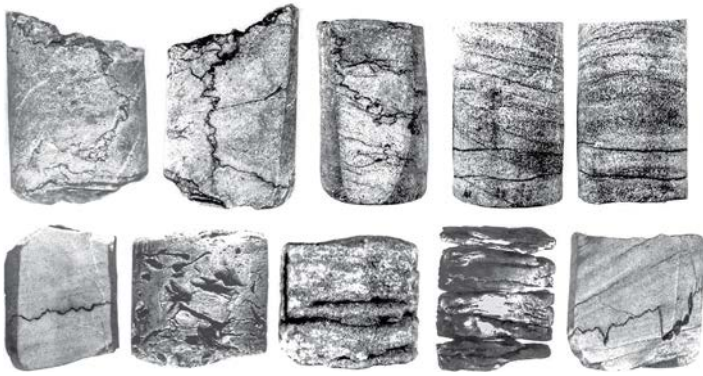


Fig. 15. Secondary fracture-cavernous-porous reservoirs in metasomatic-transformed quartzitic sandstones of Lower Carboniferous (central part of Dnieper-Donets Depression, at the depth of 5–6,5 km)

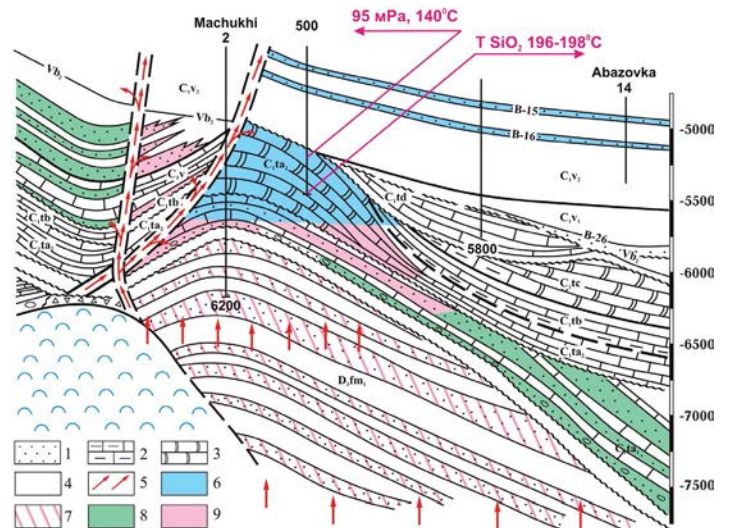


Fig. 16. Deep hydrogeologic anomaly in Machukhi field (Dnieper-Donets Depression)

1 – sandstones; 2 – clay limestones; 3 – reef carbonate; 4 – silt-clay deposits; 5 – movement of deep supercritical HCl-fluids; 6 – gascondensate pools; 7 – supposed pools of critical state; 8 – brines of Cl-Ca type; 9 – low-mineralized condensed waters of hydrocarbonate-sodium type

Hydrochemistry of deep low-mineralized water

cations	mg/l	mg-ekv.	%mg-ekv.
Na ⁺	664,14	28,88	39,69
Ca ²⁺	100,20	5,00	6,87
Mg ²⁺	30,40	2,50	3,44
Fe ²⁺	452,30	2,50	3,44
Fe ³⁺	99,12		
NH ⁴⁺	29,19		

anions	mg/l	mg-ekv.	%mg-ekv.
HCO ₃ ⁻	1012,60	16,60	72,82
SO ₄ ²⁻	22,22	0,46	0,63
Cl ⁻	685,22	19,32	26,55
I ⁻	—		
Br ⁻	0,1		
B	6,69		

Coefficients by Sulin:

Na/Cl = 1,49 Na-Cl/SO₄ = 20,86 SO₄/Cl = 0,0237 Ca/Mg = 2,00

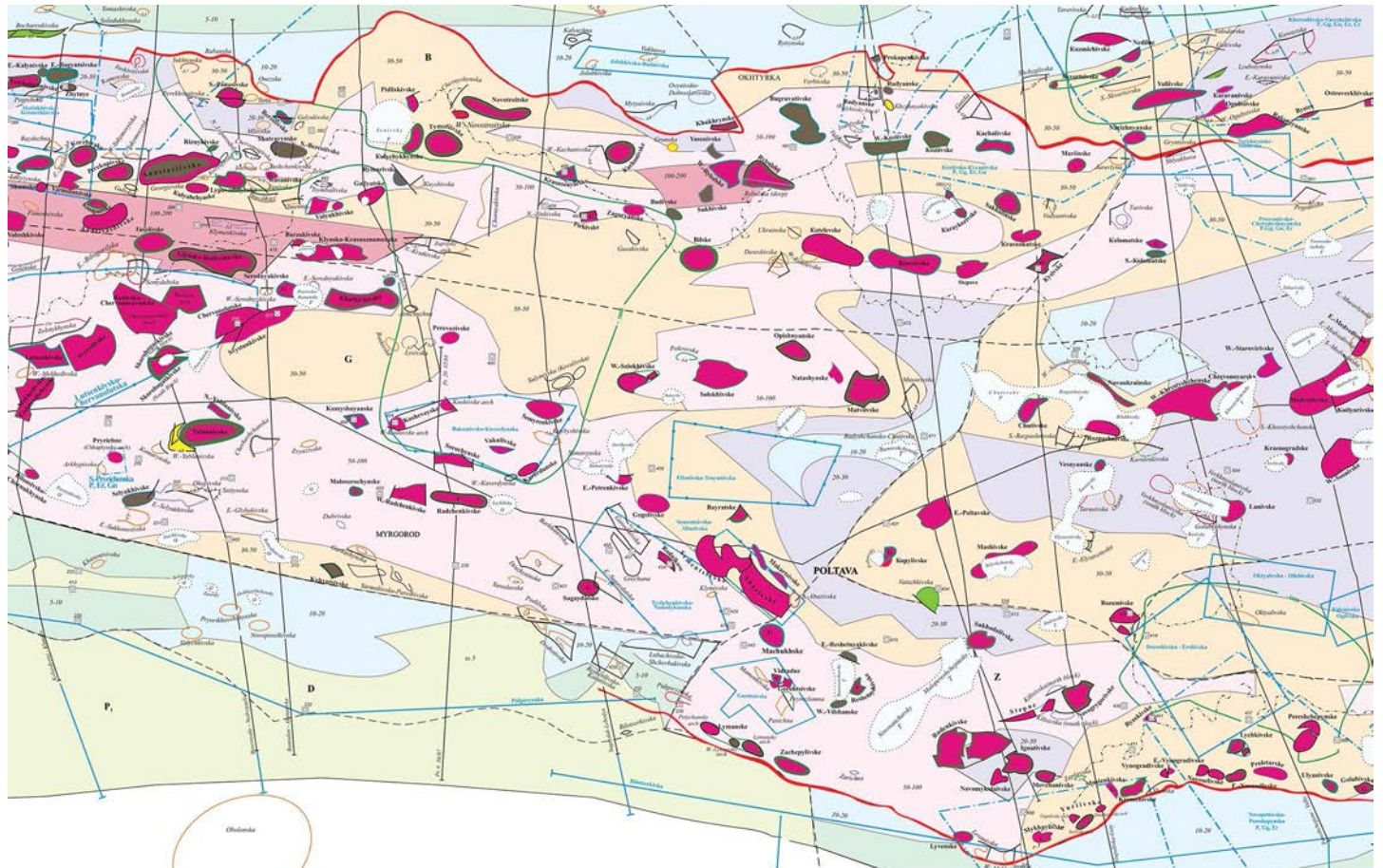
Content of mezo- and microelements, %

Si	1,550	Ti	0,065	Cu	0,025	Sn	traces	Yb	traces
Zn	1,210	Sr	0,050	Ni	0,008	Ag	traces	Hg	traces
Al	0,550	Mn	0,036	V	0,005	Ce	traces	Cd	traces
Ba	0,550	Cr	0,035	Mo	0,001				
Pb	0,520	La	0,030						

Geochemical association of dry residue of thermal water

[Cr, Ti, V, Ni] – [Sr, Ba, Mn] – [Pb, Zn, Cu, Mo, Ag, Hg, Ce, Cd] – [Si, Al, La, Sn, Yb]

Fig. 17. The central segment of the Dnieper-Donets depression. 45 fields (~ 110 pools) at the depths of > 5 km



and pre-Kerchian shelves of the Black Sea. The question is about fields of White Tiger, Dragon and other (fig. 18).

Non-traditional HC sources. This trend has been seemingly very promising ten or even 5 years ago. Then the objects of shale gas were determined and prospecting works have been begun on Olesskaya (Lviv and Ivano-Frankivsk regions) and Yuzivskaya (Kharkive and Donetsk regions) areas. One ought to mention those objects were not the best. All efforts to develop this promising trend proved to be in vein by virtue of ecological and geopolitical reasons. Nevertheless, we argue with full responsibility argue that Ukrainian regions and Dnieper-Donets region first these are inexhaustible nontraditional source of gas during which shale, central-basin and free gas are deeply intertwined. This figure (fig. 19) demonstrates powerful Srebnian areal of gas-saturated Visean black shales. Their as evidenced by results of laboratory investigations and field tests. They are characterized with great content of kerogen and anomaly radioactivity. Bodies of good sandstone reservoirs with gascondensate pools occur within this black shale formation (particularly of large Rudovka field) (fig. 20). The development of such fields must be realized so in order together with free gas from sandstones with effective porosity, to extract shale gas.

Another good case in point – Rudenkovske gas field (fig. 21). Here together with considerable proved reserves of gas in terrigenous and carbonate reservoirs (blue colors), tremendous resources of shale and gas (Lower Visean black-shale suite) and central-basin gas (Upper Visean thickness of blackshale-sandstones thin intercalation).

We believe that the development of such hybride predominantly gas fields will be the very important trend of development to commercial level of the fields production capacity. Numerous oil zone of Carpathian region may be among them in sight. Here traditional oil pools in sandstones are combined with gas-saturated of Menilite black shales with intensive-fracturing caused by disjunctive-plikative tectonics.

It is pertinent to bring in mind that Ukraine has great reserves of coalbed gas and non-exhausted resources of methane dissolved in underground waters of abovementioned regions and connected with gas-hydrates of the ukrainian segment of the Black Sea.

From the aforesaid, it may be seen that collapse of Ukrainian fuel-energetic complexe is caused not by mythical exhaustion of natural HC resources but by collapse of the bulk of geophysics exploration and deep drilling (fig. 22).

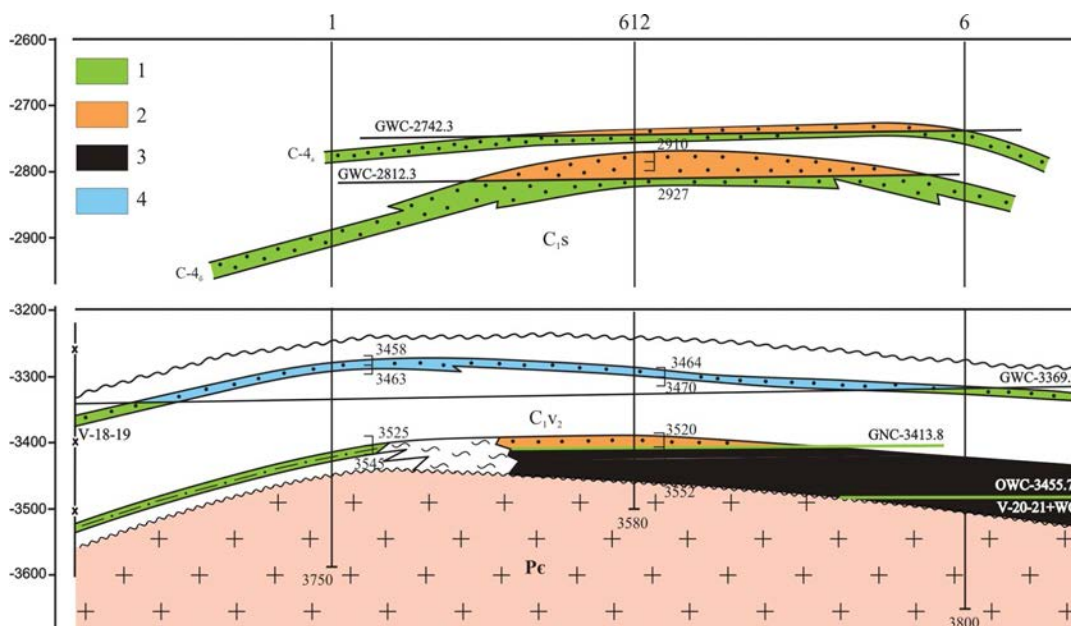


Fig. 18. Dnieper-Donets aulacogen. Northern shoulder (Southern slope of Voronezh anticline). Kharkov gasiferous district, Bezlyudovka gas-condensate field. Geologic profile of hydrocarbons-producing part of section along the line of wells 1 – 612 – 6
Productive horizons: 1 – aquiferous; 2 – gas-condensate; 3 – oil; 4 – gas

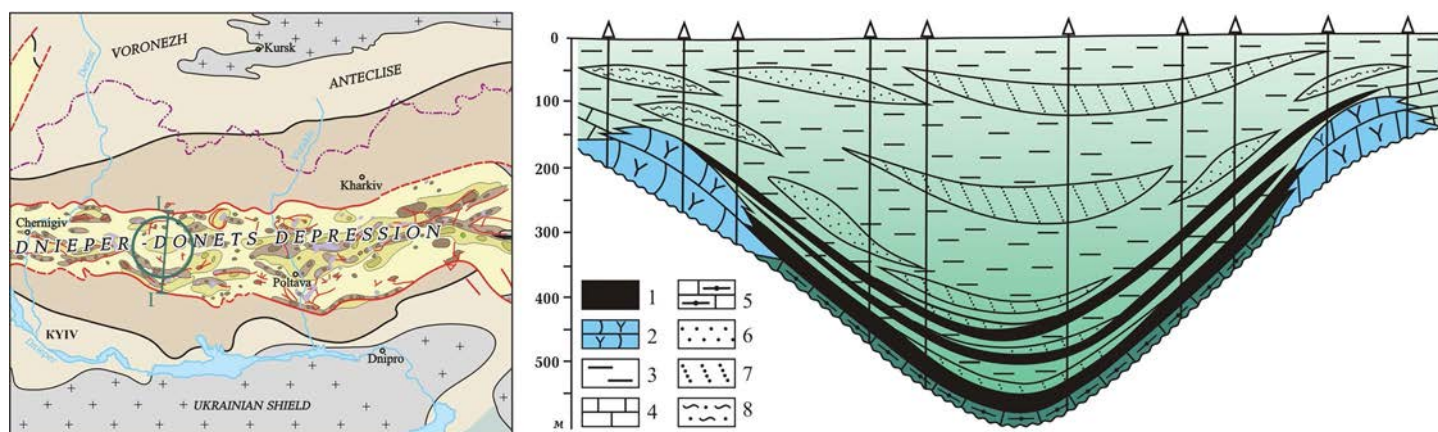


Fig. 19. Sribnean area of gas accumulation in black shales of XIIa m.f. horizon (C_{1v}) of Dnieper-Donets Depression. Cross-section along paleotectonic profile I – I
1 – former combustible shales at the stage of mezocatagenesis (Corg. 4–10 %); 2 – reef limestones; 3 – dark-coloured mudstones (Corg. 1,5–3 %); 4 – shelf detrital limestones; 5 – silicified bitumenous black limestones; terrigenous deposits connected with: 6 – counturites, 7 – turbidites, 8 – river-mouth bars

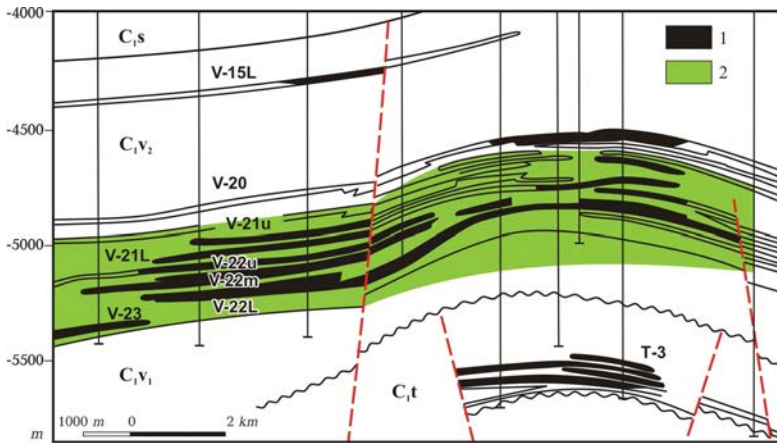


Fig. 20. Rudivsko-Chervonozavodske oil-gas-condensate fields (central part of DDB) as an example of hybrid object of development
1 – oil-gas-condensate pools; 2 – gas-bearing black shales (black shales XIIa m.f.h.)

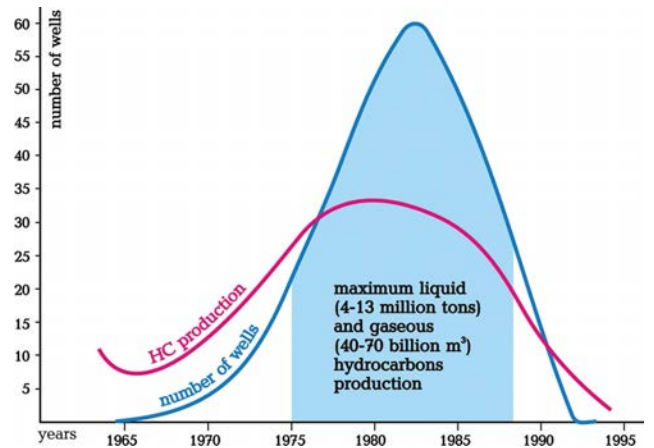


Fig. 22. Dependence between the number of deep (i 5 km) wells and yearly HC-production in Ukraine

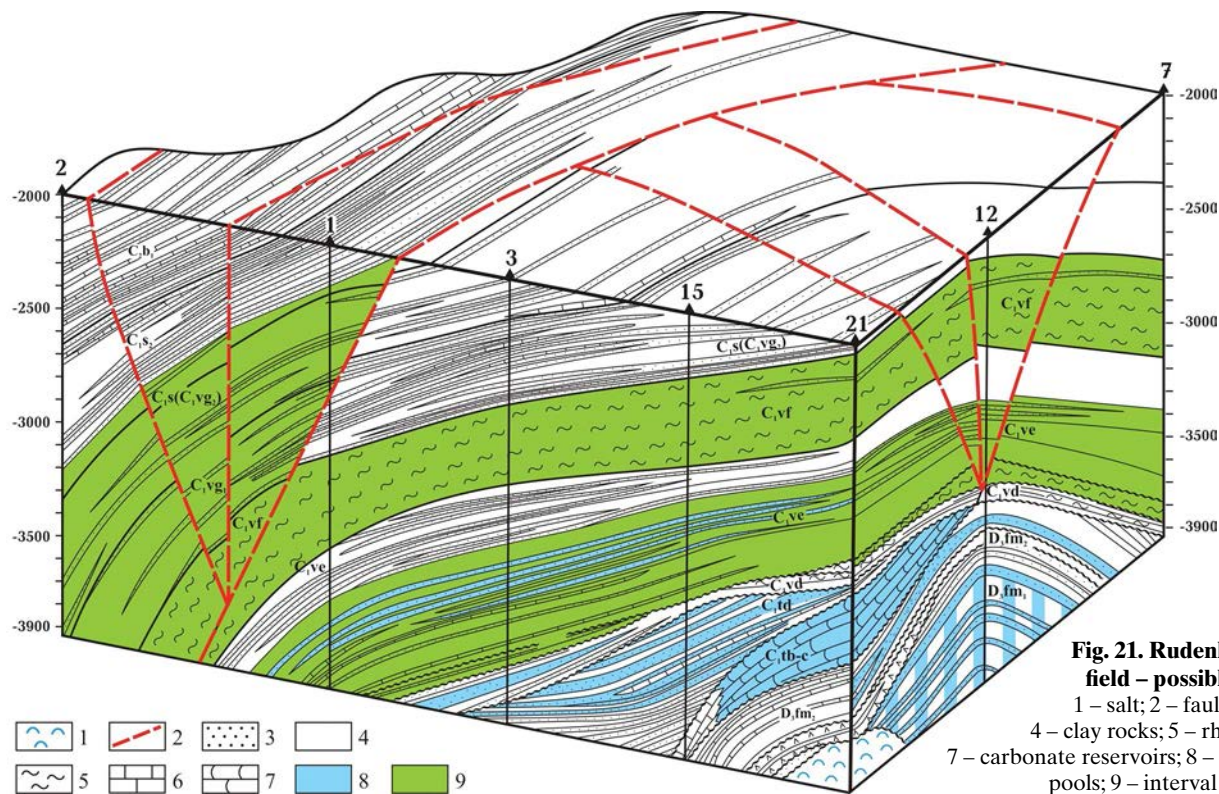


Fig. 21. Rudenivske gas-condensate field – possible gigantic hybrid field
1 – salt; 2 – faults; 3 – silty-sand rocks; 4 – clay rocks; 5 – rhytmities; 6 – limestones; 7 – carbonate reservoirs; 8 – gas and gas-condensate pools; 9 – interval promising for shale gas

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