Joannea Geol. Paläont. 9: 39-43 (2007)

Shallow Gas of the Ukrainian Transcarpathian: Still Promising Exploration Frontier?

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The Transcarpathian Sub-basin (Fig. 1) belongs to internal depressions formed during orogenic stage of the Carpathian belt evolution and stretches along its ranges (KRUPSKY 2001). It borders on the Pannonian Basin (Alföld) in the south. The Beregovo fault zones separate it from the Pannonian Basin, which enters into Ukrainian territory with small patches. The sub-basin consists of pre-Neogene basement and Neogene sedimentary fill. The basement (Paleozoic, Mesozoic and Paleogene) is poorly studied. However, it is possible to speak of its heterogeneous fault-and-fold structure inherited from the Tatra-Veporides. In the NE it is overlain with angle and stratigraphic unconformity by wide stripe (15–18 km) of the Central Carpathian Paleogene flysch. Neogene molasses covering the basement rocks build the upper structural stage. Less deformed Neogene rocks, from Karpatian sandstones to sandy-clayey series of Pleistocene fill deep troughs and form anticline crest lines, dissected by the system of along-terrain and transversal faults.

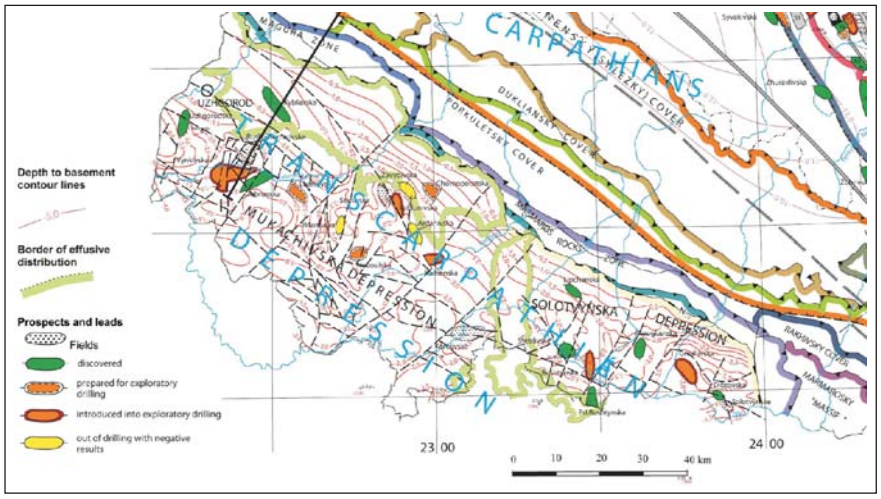

Fig 1: Tectonic map of the Transcarpathian Sub-basin (cf. KOLODIY 2004).

Faults in the Neogene cover mimic the strike and sense of main tectonic surfaces in the pre-Neogene bedrock. These faults have amplitudes of 500–700 m in the central part of the sub-basin and up to 1000–1400 m in the Beregovo zone.

The Transcarpathian gas-prone Sub-basin includes the Mukachevo, Solotvino, and East Slovak depressions, and Maramures Sub-basin. The former two ones are located in Ukraine. Sedimentary section is mainly represented by Badenian stage with thick evaporites and manifestation of halokinesis in the Solotvino depression. As to the Mukachevo one the most typical are younger sediments of Sarmatian, Pannonian and Levantian age accompanied with rather powerful magmatism (Kolodiy 2004). Hydrocarbon production comes from Badenian, Sarmatian and Pannonian. In the Ukrainian part, gas pools are found in the depths from 300 to 1750 m. Productive intervals are mainly composed by rhythmic alternation of sandstones, sands, shales, clays, siltstones and tuffaceous rocks with salt rocks at the level of Middle Badenian. The reservoirs in the Solotvino depression are represented by Lower Badenian rocks with porosity of 5–12 %, and permeability up to 0.27×10^{-3} mkm^2. Reservoirs in the Mukachevo depression are Upper Badenian, Sarmatian and Pannonian sandstones of 10–22 % porosity and permeability varying from 0.12 to 125–174, sometimes up to 500×10^{-3} mkm^2. Reservoir properties are very variable in space and often have a lenticular nature. Seal rocks are evaporites of Tereblia suite (above Novoselitsia tuffs in the Solotvino depression) and clayey units of Upper Badenian, Sarmatian and Pannonian in the Mukachevo depression).

Discovered gas fields are usually attributed to faulted brachianticlines. Productivity contours are controlled by structural, sedimentological and tectonic factors. The depth to GWC can vary by hundred metres within the same field. Typically, here is anticlininal, combination, at tectonically screened pools. A particular feature of gas fields in the Mukachevo depression (like for Slovak ones) is their high hydrocarbon column along with minor reserves. Transcarpathian natural gases consist of methane and nitrogen. Generation capabilities for hydrocarbons in the Transcarpathian Basin are primarily linked to the Miocene, especially to clay series of the middle (Lower Tereblia sub-suite) and the lower part of Upper Badenian rocks (Solotvino suite). One cannot exclude the Karpatian rocks as source rocks as well. The source of hydrocarbons could also be located in the folded bedrock (e. g.,, Triassic dark-grey limestones and marls, Jurassic, Cretaceous and Paleogene dark shales) with high organic matter content.

The formation pressure in the Mukachevo and Solotvino depressions is close to the hydrostatic one and sometimes exceeds it by 5–20 %. The Transcarpathian region is characterized by anomalous thermal regime. The average geothermal gradient is 4.4 °C/100 m, however, in some location it is even higher. For example, the well Mukachevo-1 revealed 200 °C in the depth of 4200 m, and in the well Komarivtsi-1 195 °C in 4000 m depth. Here the geothermal gradient varies from 5 to 6 °C/100 m up to the depth of 2000 m. A lower gradient is fixed for the Solotvino depression – 3.7–4.2 °C/100 m.

There are 12 commercial discoveries taken into consideration both Ukrainian and East Slovak parts of the Transcarpathian Sub-basin: one oil-and-gas (Pozdisovce), four gas condensate (Banovce, Lastomir, Stretava, Ptruksa) and seven gas (Trgoviste, Pavlovice, Terebisov in Slovak Republic; Rusko-Komarivske, Stanivske, Korolivske and Solotvinske in Ukraine) fields. Eight of them are located in the East Slovak depression, three in Mukachevo and one in Solotvino depressions. The first Ukrainian discovery – Solotvinske – was made in 1982. Gas is trapped in the salt plug anticline. The pay zone in Badenian of the well no. 1 at 1440–1530 m produced 137 MMcm/d of gas. Main reservoir varieties are represented by fractured tuffs and tuffites with porosity of 6–13 %. Production contains 95.6 % of methane and 3.4 % of its higher homologues. Formation pressure is 14.73 MPa at 1485 m. Rusko-Komarivske field was discovered in 1985 and controlled by drape fold over gabbro-diabase-basalt intrusion into Badenian sequence. The field consists of 7 individual pools in the Sarmatian sandstones of 14–18 % porosity. Initial flow rates varied from 17–75 MMcm/d in the depth of 900–1650 m. Gas is mainly methane (60–73 %) and nitrogen (25–33 %). Korolivske gas field was discovered in 1988 and its exploration has not been finished yet. Well no. 2 produced 150 MMcm/d flow rate of gas (interval 710–740 m) from Pannonian sandstones of 12–14 % porosity. The field is the anticline structure of 10×4 km in size consisting of two domal crests separated by the saddle. The western cupola is not explored. Gas contains 60.2 % of methane, 3.1 % of its higher homologues, nitrogen (26.6 %), and of carbon dioxide (10.6 %). The latest discovery of Stanivske field was made in 1990. The trap is formed by faulted brachianticline with unconformable relationship between Badenian and Sarmatian bedding planes. The field is under exploration. Yablunivka-2 well produced 115 and 15.3 MMcm/d flow rates of gas from two pay zones, from 310–390 m and 192–238 m respectively. Reservoirs are sandstones of 10–18 % porosity containing mainly 95 % of methane (Hafych & Kurovets 2004). During all history of hydrocarbon exploration in Ukraine the Transcarpathian gas-prone sub-basin was a second order priority. Therefore its resource potential estimated at 140 MMtoe is speaks of under-explored and immature province. The analysis (Tab. 1) of the Ukrainian part of the Transcarpathian Sub-basin testifies that probable reserves (over 130 MMtoe) take the lion share of the resource potential.

Proven reserves of 4 discovered gas fields in the Ukrainian part (2.7 Bcm) are only 3 % from the whole resource potential of the region. Plus, it is known that exploratory drilling in the Transcarpathian Sub-basin has revealed several prospective leads requiring further analysis, exploration and development.

From the figures follow that rather equal shares 70.3 and 62.2 MMtoe is distributed between Neogene fill and pre-Neogene structural stage, respectively. As to the Neogene plays proper around 30 MMtoe are referred to Sarmatian and Pannonian sediments in depths of 0.5–1.5 km.

Main exploration activity in the Ukrainian Transcarpathian region took place during the 80's of the last century. In this time the primary attention was paid to search for big hydrocarbon accumulations and deep drilling into the folded basement.

Productive complexes	Probable reserves, Category D_1	Probable reserves, Category D_2	Probable reserves, recoverable	Prospective area, 1000 sq.km	Density of reserves, Mtoe/sq.km^2
T (Triassic)		15.6	13.3	2.9	5.4
K (Cretaceous)		12.4	10.5	1.0	12.4
P (Paleogene)		18.6	15.8	1.4	13.3
N_1krp (Karpatian)		15.5	13.2	1.6	9.7
N_1b (Badenian)	36.1		31.0	4.9	7.6
N_1s (Sarmatian)	28.6		24.2	4.0	8.5
N_{1-2}pn (Pannonian)	5.6		4.7	0.8	7.7
TOTAL	70.3	62.1	112.7		

Tab. 1: Distribution of initial gas reserves in the Transcarpathian petroleum-prone province (remaining potential), Bcm.

Seismic works were targeted to map large structural traps. During the break-up of the USSR and the pioneering years of Ukraine's independence the exploration works were conducted only episodically and seismic surveying was almost stopped.

Thus, the present-day seismic and geological database for the region is still inadequate to conduct successful exploration. Consequently, we face the following problems:

— Insufficient knowledge on detailed structure of pre-Neogene basement;
— Lack of firm and continuous reflectors in the Neogene sequence;
— Poor quality of the prospects and leads bear high exploration risk;
— Potential traps of stratigraphic type did not studied or studied unsatisfactory;
— The resource potential of shallow gas (up to the depths of 0.5–1.0 km) is poorly recognized due to the orientation on deep horizons and well design.

As a consequence, further exploration strategy should take into account the peculiarities of the known geological structure and hydrocarbon potential of the basin following from the experience gained during previous period and get concentrated onto such trends as:

— Shallow gas prospects in the Neogene sedimentary cover;
— Gas prospecting in the anticline traps of the folded pre-Neogene basement;
— Exploration in the fractured volcanic and volcaniclastic rocks.

Serious economic advantage of the area is a possibility to use abandoned wells drilled to the pre-Neogene basement as hot water producers to utilize hydrothermal energy and conversion of depleted fields into gas storages on the way of Russian gas to the West.

Abovementioned testifies that hydrocarbon potential of the Transcarpathian Basin is far from exhausting and here there chances to discover new fields. Shallow depths of productive complexes and existence of pipeline infrastructure make the development of hydrocarbon potential of the Ukrainian Transcarpathian economically viable despite of minor proven reserves.

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