AAPG European Region Annual Conference
Paris-Malmaison, France
23-24 November 2009

OVERVIEW of CURRENT EXPLORATION CONCEPTS ONSHORE ROMANIA

Niculai Dedu[1], Csaba Krézsek[1], Stuart Bland[1] and Gabor Tari[2]
1 Petrom, Ploieşti, Romania
2 OMV, Vienna, Austria

Romania is one of the most important hydrocarbon provinces of Eastern Central Europe (Paraschiv, 1979; Popescu, 1995). Oil Production started in 1854 and since than 465 oil pools and 430 gas pools have been discovered (Ştefănescu et al., 2006). The cumulative oil production in 2007 was about 5 bn bbl, whereas the gas production reached 37 TCF (Boroşi and Gherman, 2007).
The Cenozoic geology of Romania is strongly linked to the development of the Carpathian Orogen. This is part of the Alpine system that resulted from the Triassic to Cenozoic evolution of continental blocks derived mostly from the European margin (Săndulescu, 1988; Schmid et al., 2008). The Carpathians is a thrust and fold belt formed by thick-skinned internal nappes assembled during the Aptian-Albian (i.e. Inner Carpathians) and by thin-skinned external nappes of Tertiary age (i.e. External Carpathians) (Fig. 1). This latter is an accretionary wedge that overrides the relatively undeformed Eastern European plate margin.
Hydrocarbon exploration onshore Romania mainly focuses on 1) the outermost External Carpathians and in basins developed coeval with the Carpathains (e.g. Popescu, 1995; Ştefănescu et al., 2006). These include the foredeep/foreland of the External Carpathians, which partly overlaps the Getic Basin (2) and the (3) undeformed part of the East European margin (e.g. Moesian platform, 3a). Other areas of interest are basins formed on top of the Inner Carpathians, such as the (4) Pannonian Basin, the (4a) Maramures Basin, and the (5) Transylvanian Basin (Fig. 1).
Exploration typically consisted in drilling shallow structural closures using 2D seismic data. However, in most basins the shallow plays are densely drilled and only limited exploration potential is left. This is reflected in the relative flat creaming curves for the last 20 years of exploration. Despite this we are going to show that significant exploration potential is left in mostly untested or under explored 1) deep structural closures and 2) stratigraphic traps. Various exploration technologies (e.g. 3D seismic, AVO, long-offset 2D seismic), yet unapplied in many basins, could shed light on the remaining exploration potential.

(1) The outermost External Carpathians are thin-skinned nappes built by Late Cretaceous to Early Miocene foredeep sediments thrusted over the Eastern European margin during the Miocene (Maţenco and Bertotti, 2000). This was a typical soft collision process where deformation was accommodated by thin-skinned in-sequence deformation. Later, in the Pliocene, due to the locked collision boundary, thick skinned inversion of basement structures occurred along with crustal-scale folding and uplift of the entire orogen . The petroleum system consists of Lower Oligocene and Lower Miocene source rocks (menilite and disodile shales), Paleogene to Lower Miocene turbidite sandstone reservoirs, and traps formed by structural closures, mostly faulted anticlines (Ştefănescu et al., 2006). Exploration targeted relatively shallow traps with more than 50 oil and a few gas fields being discovered. Current exploration continues to look for opportunities in the shallow section, but also considers going deeper, where potentially large gas structures exist. The presence of these is suggested by seismic data backed by structural balancing. These deep structures developed in the Early

Burdigalian and were subsequently modified by continued in-sequence deformation on deeper detachments.

(2) The Getic Basin has a complex tectonic evolution. It represents the foredeep of the Cretaceous to Paleogene (?) Southern Carpathians. Later, during the Paleogene (?) to Early Miocene it has been affected by transtension due to the eastward movement of the Inner Carpathians into the Magura embayment (Răbăgia and Mațenco, 1999; Schmid et al., 2008). Finally, the basin has been inverted and thrusted over Moesia during the Mid Miocene collision of the Carpathians. This was manifested by mostly thin-skinned in-sequence deformation of which the magnitude increases from west to east. Thick-skinned inversion of former extensional faults has been observed as well, mainly in the western part of the basin.
The petroleum system consists of Oligocene marine source rocks that produce oil and gas stored in Oligocene to Pontian reservoirs in structural or combined traps (Paraschiv, 1979). Trap formation is Mid Miocene with a minor reactivation during the Late Pliocene event. Exploration focused on relatively shallow depths (2-4 km), where large undiscovered traps are unlikely to exist to date. Thus, new play concepts are developed by OMV/Petrom, which focus on deeper levels (4-6 km, i.e. the Paleogene of the Getic Basin and the Mesozoic of the under thrusted Moesia), where potentially large gas accumulations are present. This is suggested by the current – yet low quality seismic data, backed by new balanced structural models and basin modelling. The most important challenges we face are the poor quality seismic data, understanding structural evolution, hydrocarbon migration, segregation, and cracking. Therefore, the current exploration efforts involve long-offset 2D seismic surveys over designated prospective areas, structural balancing and geochemical studies of source rocks and hydrocarbons.

(3) The Eastern European margin in Romania comprises different tectonic units (locally known as the Moldavian platform, Scythian platform, North Dobrogea Orogen and the Moesian platform, Fig. 1) delimited by crustal-scale fault zones (Săndulescu, 1988). These tectonic units were involved in Paleozoic and Triassic compressional deformations, but not/slightly affected by the Alpine tectogenesis. In general, the sedimentary succession is formed by four major sedimentary megasequences delimited by major unconformities: Paleozoic, Permian – Triassic, Jurassic - Cretaceous and Miocene (Paraschiv, 1979). Reservoirs may be found in all of these sequences, but mostly in the Mid Triassic Carbonates in shallow-marine Mid Jurassic sandstones, Lower Cretaceous Carbonates and Mid Miocene sandstones. Potential source rocks have been considered the Silurian graptolitic, Mid Jurassic and Sarmatian shales. However, the results of a recent (take out in house) geochemical study on a number of Moesian oil and gas samples came out as a surprise, because it suggests a Paleogene (Oligocene?) source. This source may be located on the distal Moesia under thrusted by the Getic Basin during the Mid Miocene.
Exploration in the past has targeted tilted fault blocks and various stratigraphic traps (toplaps, onlaps, reefs, incised channels) and likely several more, but relatively small traps are present, which can be identified with 3D seismic surveys. Two new plays may emerge in these areas: the unconventional gas shale play and subtle, but potentially large and deep traps related to the Cimmerian folds. These latter are low-amplitude fault-bend folds related to the regional-scale Cimmerian deformation at the end of the Triassic (Tari et al., 1997). The unconventional shale gas potential of Silurian to Lower Devonian and Middle Jurassic shales is being investigated. Preliminary results indicate that the Permian to Triassic rift shoulders of the Moesian Platform are the most prospective areas, because the shales appear to be in the gas window and relatively shallow for drilling. Furthermore, far away from the Getic thrust front

to the South thermal gas was discovered, recently typed to a very mature Mesozoic and/or Paleozoic source based on its stable carbon isotopic signature.

(4) The Pannonian Basin is a Miocene extensional back-arc basin system formed on top of the Inner Carpathians and their tectonic equivalents. The petroleum system is represented by Mid Miocene oil-prone syn-rift lacustrine shales that source altered basement rocks, shallow-marine syn-rift reservoirs and Late Miocene post-rift turbidites (Tari and Horváth, 2006). The easternmost shallow margin of the Pannonian Basin extends to Romania, where successful exploration has been conducted for many years (Fig. 1). Most discoveries lie in structural closures such as tilted fault blocks or drape folds over basement highs. Stratigraphic plays drilled in the last few years in the Hungarian part of the basin using AVO attributes have not been tested yet. These are Late Miocene turbidites that onlap basement highs. However, the exploration risks on the Romanian part are considered higher because of the relatively thin and shallow sedimentary section, the late tilt of the basin margins, and the presence of volcanic gases. The "basin-center tight gas" play that is currently explored in the Hungarian part of the basin most likely extends into Romania as well.

(4a) The Maramureş Basin is part of the Miocene back-arc Pannonian Basin System and extends to the north into Ukraine and East Slovakia (Fig. 1). The basin's basement is represented by a stack of thin-skinned nappes (i.e. the Pienides) mostly built by Paleogene deep marine deposits (i.e. Trans-Carpathian flysch). These were thrusted eastwards over the Inner Carpathians during the Early Miocene (Tischler et al., 2008). A working petroleum system, proved by two small oil accumulations in Romania and others in Ukraine, is formed by Lower Oligocene deep-marine shales that provide oil and gas (in Ukraine; so may be just hydrocarbons) for Paleogene turbidites in structural closures related to the Miocene transtension (Popescu, 1995). The sub-salt Miocene play that works in Ukraine has not been proven yet in the Romanian side despite the presence of similar play elements in western Maramures. It is important to note that insufficient modern seismic data exist in the Romanian part of the basin. Therefore, OMV/Petrom is undertaking an extensive seismic campaign coupled with re-processing of a gravity survey. Preliminary interpretations of these data suggest the presence of prospective areas in the Paleogene and at sub-salt levels.

(5) The Transylvanian Basin is a relatively cold back-arc basin known as a biogenic gas province (Fig. 1; Popescu, 1995). The basin is markedly different from the Pannonian Basin in the lack of syn-rift extension, the thick Mid Miocene, and thin Late Miocene succession (Krézsek and Bally, 2006). The biogenic gas is sourced from deep-marine Middle Miocene shales and is stored in multi-storey turbidite reservoirs in structural traps, frequently salt-cored folds. Exploration started 100 years ago and more than 40 TCF biogenic gas has been produced. Today, limited exploration potential is left in structural closures. However, stratigraphic traps, carefully mapped with AVO techniques will likely shed light on more accumulations. Most prospective areas are the slope channels and fans in the northern and eastern part of the basin. Another, however not yet proven, petroleum system may be present, located deeper (sub-salt) in the basin. The only indication of this is the 6042 Deleni deep well that found oil in Jurassic dolomites in the basement of the basin. The source of this oil is not known. The last major pre-salt exploration attempts were conducted by Shell, in the 1990s, which did not result in any commercial discovery.

In conclusion, significant exploration potential is left in Romania. The general trend is going deeper while applying state-of-the-art exploration methods. Among others, these include 3D seismic surveys over traditionally explored regions, regional long-offset 2D lines for structurally complex and deep leads, AVO analysis of shallow targets and 2D/3D structural balancing. The potential reward could be significant discoveries (likely gas) in the coming years.

References

Boroşi, N., Gherman, M. 2007. Development strategies of the Romanian petroleum sector in the light of 150 years of experience. Conference "Sărbătorirea a 150 de ani a petrolului românesc", October 26, 2007, Bucharesti.

Krézsek, C., Bally, A.W., 2006. The Transylvanian Basin (Romania) and its relation to the Carpathian fold and thrust belt: insights in gravitational salt tectonics. Marine and Petroleum Geology 23, 405–442

Matenco, L., Bertotti, G. 2000. Tertiary tectonic evolution of the external East Carpathians (Romania), Tectonophysics, 316, 255 – 286.

Paraschiv, D., 1979. Romanian Oil and Gas Fields, vol. 13. Institutul de Geologie siGeofizică, Studii Tehnice şi Economice Seria A, Bucharest, 382 pp.

Popescu, B.M., 1995. Romania's petroleum systems and their remaining potential. Petroleum Geoscience 1, 337–350.

Răbăgia, T., Maţenco, L., 1999. Tertiary tectonic and sedimentological evolution of the South Carpathians foredeep: tectonic versus eustatic control. Marine and Petroleum Geology 16, 719–740.

Săndulescu, M., 1988. Cenozoic tectonic history of the Carpathians. In: Royden, L., Horváth, F. (Eds.), The Pannonian Basin: a Study in Basin Evolution, AAPG Memoir 45., pp. 17–25.

Schmid, S.M., Bernoulli, D., Fügenschuh, B., Maţenco, L., Schefer, S., Schuster, R., Tischler, M., Ustaszewski, K., 2008. The Alpine–Carpathian–Dinaridic orogenic system: correlation and evolution of tectonic units. Swiss Journal of Geosciences 101 (1), 139–183.

Ştefănescu, M., Dicea, O., Butac, A., Ciulavu, D. 2006. Hydrocarbon Geology of the Romanian Carpathians, their foreland and the Transylvanian Basin. AAPG Memoir 84, 521-567.

Tari, G., Dicea, O., Faulkerson, J., Georgiev, G., Popov, S., Ştefănescu, M.,Weir, G., 1997. Cimmerian and Alpine stratigraphy and structural evolution of the Moesian platform (Romania/Bulgaria). In: Robinson, A.G. (Ed.) Regional and Petroleum Geology of the Black Sea and Surrounding Regions. American Association of Petroleum Geologists, Memoirs, vol. 68, pp. 63–90.

Tari, G.C., Horváth, F., 2006. Alpine evolution and hydrocarbon geology of the Pannonian Basin: an overview. In: Golonka, J., Picha, F. (Eds.), The Carpathians and their Foreland: Geology and Hydrocarbon Resources, Memoir 84. AAPG, pp. 605–618.

Tischler, M., Maţenco, L., Filipescu, S., Gröger, H.R., Wetzel, A., Fügenschuh, B. 2008. Tectonics and sedimentation during convergence of the ALCAPA and Tisza–Dacia continental blocks: the Pienide nappe emplacement and its foredeep (N. Romania). In S. Siegesmund, B. Fügenschuh, N. Frotzheim (eds.) Tectonic Aspects of the Alpine-Dinaride-Carpathian System. Geological Society, London, Special Publications, 298, 317–334.

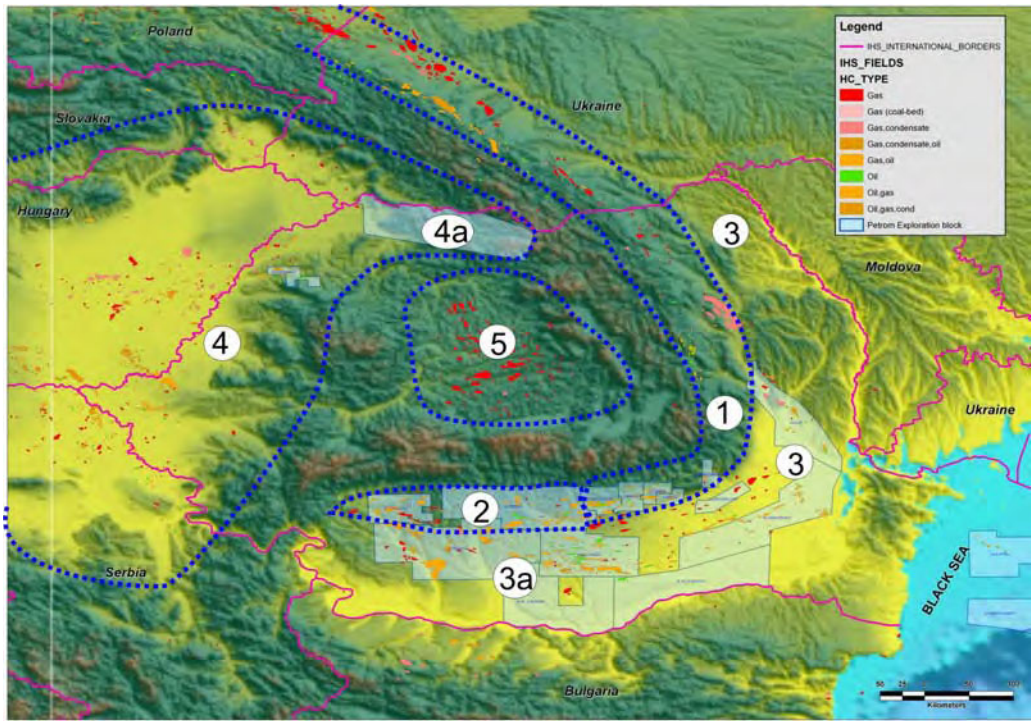

Fig. 1 Map of Romania with the main exploration areas and hydrocarbon accumulations. (1) External Carpathians, (2) Getic Basin, (3) undeformed part of the East European margin, (3a) Moesian platform, (4) Pannonian Basin, (4a) Maramures Basin, (5) Transylvanian Basin.