Romania Energy Center

Shale Gas – challenges and opportunities

Eugenia Gușilov

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SHALE GAS – challenges and opportunities

This is a rather nontechnical approach of some of the geologic, economic, policy and environmental implications related to shale gas development in Europe. The article does not discuss the influence of shale gas on shale oil E&P, neither the link between shale gas and the global LNG market or its impact on the renewables market, nor any specific legal aspects. It attempts to frame the question in a more holistic manner, in light of such recent developments as the Bulgarian ban on the use of hydrofracking. The discussion of shale gas has been lately dominated by environmental concerns, but it is also about job creation and energy security. Finding a common ground could provide solutions in the medium term to key goals such as the use of more environmentally friendly energy sources, as well as the diversification of energy supplies.

The "revolution" that shale gas prompted in the U.S.A., a couple of years ago is already producing effects on the global energy market. Presently, the United States is the only country in the world with significant commercial production of this type. According to a study published last April by the Energy Information Administration (a U.S. institution specialized in energy analysis and statistics), in 2010 shale gas production accounted for 23% of the total dry gas production in America. Not only did shale gas increase the proven reserves of the United States (by 11% at the end of 2009) and halted the decline, that started in 2000, of the domestic natural gas production, but it reversed this trend altogether. Thus, in 2010, production from unconventional gas – shale gas, coal bed methane (CBM), and tight gas – represented half of the natural gas produced in the United States. Furthermore, due to shale gas, American annual natural gas production surpassed that of Russia (until two years ago, the biggest producer of natural gas in the world) for a second consecutive year. The EIA projections for the American market suggest that shale gas will account for 45% of the total natural gas production in the country by 2035. It is said that recoverable shale gas reserves have the potential to meet the American demand for natural gas for the next 100 years. In Europe, it is thought that unconventional gas resources could in theory cover the demand for gas for the next 60 years. According to a 2011 study by Maximilian Kuhn and Frank Umbach of the European Center for Energy and Resource Security (EUCERS) from King's College, London: "*Estimated total recoverable reserves in Europe amount to between 33-38 Tcm [Trilion cubic meters], of which 12 Tcm are tight gas, 15 Tcm shale gas, and 8 Tcm coal bed methane; whereas total conventional gas reserves in the EU amount just to 2.42 Tcm*".

The resource estimation process currently underway worldwide is more advanced in some countries than in others. However, the first initiative to collect and centralize shale gas data at global level is attributed to Hans-Holger Rogner and dates back to 1997. Recent data confirm that shale gas is abundantly present worldwide. According to the study conducted by Advanced Resources International for EIA, published in April 2011, countries with rich resources of this type include China (36.1 Tcm), USA (24.4 Tcm) and Argentina (21.9 Tcm). The assessment effort of the cited report has focused on areas onshore and outside the USA and did not target the states that already possess rich conventional gas resources such as Russia, Iran, Qatar or the adjacent areas (Middle East and Central Asia). Given the fast dynamic of the data, the numbers discussed here should be treated as indicative, especially in the areas outside the United States where exploration is still in its early stages.

Shale gas consists of natural gas molecules that are trapped in hard rock formations with low permeability and porosity. This is most commonly found at depths over 2 km below ground, below the traditional hydrocarbon deposits. In some cases, shales are the source rock of the conventional natural gas and crude oil. In the United States, among the biggest shale gas formations are: Marcellus, Barnett, Fayetteville, Haynesville, and Eagle Ford. In Canada, the most promising formations are Horn River and Montney. In China, two sedimentary basins – Sichuan (situated in the country's center-south region) and Tarim (Xinjiang Autonomous Uigur Region) – are thought to possess rich shale gas deposits. In **Argentina**, the most prospective region is the Neuquen Basin, followed by Golfo San Jorge, Astral-Magallanes and Chaco Basins. In **Germany**, significant shale gas deposits seem to be present in the lands of Renania, North Rhine-Westphalia, Lower Saxony, Baden-Württemberg and Thuringia.

Stimulated by the global competition for securing positions in the most promising shale gas plays in the USA, the big international companies show an increased interest toward natural gas in general, and shale gas in particular, as the big industry acquisitions seem to indicate (e.g., ExxonMobil's acquisition of XTO and Chevron's acquisition of Atlas Energy in 2010). In the rest of the world, the supermajors – Exxon, Shell, ConocoPhilips – are present alongside NOCs and some recently established companies. Despite this global potential, industry observers believe that commercial production in China is not likely to begin earlier than 5 or 10 years. The same time horizon is quoted for Europe, although the expectation is that Poland may start production earlier (2013-2014). The State Department launched the *Global Shale Gas Initiative* in April 2010. China, India, Poland and Jordan have signed cooperation agreements in the energy sector with the United States, which will assist them through the USGS to evaluate their resources. The first initiative to research European shale gas formations, *Gas Shales in Europe (GASH)* was established in 2009, a project in which Romania is participating through the Geological Institute of Romania (IGR).

In Europe the ARI/EIA study points to the following countries as being endowed with significant resources: Poland (5.3 Tcm), France (5.1 Tcm), Norway (2.35 Tcm), Ukraine (1.19 Tcm), Sweden (1.16 Tcm), Denmark (0.65 Tcm), Great Britain (0.57 Tcm), Netherlands (0.48 Tcm), Turkey (0.42 Tcm), Germany (0.23 Tcm), Lithuania (0.11 Tcm). Although the study does not provide an individual estimate for Romania, it mentions that, together with Hungary and Bulgaria, all three countries possess 0.54 Tcm worth of recoverable reserves. Of the enumerated countries, only Norway, Netherlands and Denmark meet their domestic natural gas consumption and even export gas, while the rest have a high degree of import dependence.

Poland, the most advanced country in Europe in terms of exploration and the strongest supporter of unconventional resource development in the EU, is viewed as the *"European barometer"* on this topic. Poland's resources are located in three basins: Baltic (in the North), Lublin (in the South) and Podlasie (in the East), with the concession and exploratory activity being focused on the first two. Since 2007 until November 1, 2011, the Polish Environment Ministry (the institution responsible with granting the E&P concessions) has awarded 104 concessions for shale gas prospection and exploration. As of November 2011, 10 exploratory wells have been drilled of the 123 mandatory ones planned until 2017 (without factoring in another 100 wells that are optional). No production concessions have been granted yet. Last

September, Ukraine signed another shale gas exploration agreement with Shell, which is to explore in the country's NE region of Kharikov. In Lithuania, Minijos Nafta UAB will most likely be the first company to drill a shale gas well, planned for the fall of 2012, in the Western part of the country.

In Romania, the ARI/EIA study points to two prospective areas: in the West – the Pannonian and the Transylvanian Basins (the first one shared with Hungary and Slovakia), while in the South – the Carpathian-Balkan Basin (the Dobrogea region, which extends into Bulgaria as well). Presently, an official estimate, even a ballpark one, for the Romanian shale gas resources is not known, as the assessment process for Romania's unconventional gas has started later. Furthermore, a perspective on the topic is rendered more difficult due to the confidentiality provision of Romania's Petroleum Law 238/2004 under which data and information included in the national geologic database and/or national oil resources/reserves database are covered by secrecy (Art. 4). Therefore, the public opinion can at best make an educated assumption about Romania's shale gas potential, the expectation being that it should be quite significant in light of Romania's 150 year oil industry tradition and 100 year tradition in gas production. According to Dr. Nicolae Anastasiu, professor at the Bucharest University's Geology and Geophysics Faculty, in Romania "*There is a good understanding of the geological formations located between 0 and 3500 m, which are mainly of a Neogene age"* while *"Less well understood are the geological formations deeper than 3500/4000 m, which are basically pre-Neogene"*.

Mihail Batistatu, associate professor and scientific secretary at the Ploieşti Oil & Gas University (UPG) believes that "*a possible resource of over 150 billion cubic meters [Bcm] of gas can be estimated for the Transylvanian Basin (…), while in the Outer Carpathian arc the resource potential is at least double"*. According to him, in Romania the shale gas formations are found at depths that vary greatly *"from approximately 1000 m up to over 6000 m"*. Based on what is presently known about the properties of these formations, *"geological conditions favor commercial exploitation especially in the Translyvanian Basin and less so for the extra-Carpathian areas",* stated Dr. Batistatu in an interview which can be read entirely at the end of the article.

In June 2011, NAMR's Director for Management, Assessment and Concessions, Dorin Cojocaru, stated that up until then, *"Romania has not defined any category of unconventional gas, accordingly there were no estimations"*. A preliminary statistic regarding the number of licenses awarded for shale gas exploration was not available at the time either, since *"the companies are the ones left to decide whether they want to look for these type of unconventional resources or not"* under the permits they hold. Nevertheless, *"during the X^{th} licensing round several companies expressed their interest for this type of natural gas categories"* said the official last summer.

During the specified licensing round (which took place in July 2010), NAMR's offer included 12 perimeters in the Pannonian basin and 7 in Dobrogea, the rest of them being in the Black Sea. Among the companies that publicly announced their intention to explore for shale gas so far are: MOL and Expert Petroleum; EWP and NIS; Chevron and Sterling Resources. Thus:

In North Western Romania shale gas exploration activities will be carried out by a 70/30 JV between MOL and Expert Petroleum (with MOL as operator) and by the Canadian company East West Resources, which entered into a partnership agreement with Naftna Industrija Srbije (NIS) - *"the sole operator in the Serbian sector of the Pannonian Basin"* according to a recent EWP press release.

- **MOL** together with **Expert Petroleum** have concession agreements for 3 perimeters located in the Pannonian basin: Ex-1 (Voivozi), Ex-5 (Adea), and Ex-6 (Curtici), totaling an area of 3,434 km^2, suspected to contain *shale gas*.
- **East West Petroleum** (former known as Avere Energy, as the company changed its name into EWP in august 2010) holds concession agreements for 4 exploration perimeters in the Pannonian basin: Ex-2 (Tria), Ex-3 (Băile Felix), Ex-7 (Periam) and Ex-8 (Biled), of 1,000 km^2 each. The exploration of these perimeters will be undertaken together with NIS, a subsidiary of Gazprom Neft, with which a farmout agreement was finalized at the beginning of the year. The partner company will be the project operator and will incur all the expenses. The JV will have a 85/15 structure in favor of the Serbian company, while the 15% EWP participation will be on a carried interest basis. After the government ratifies the concessions agreements, the JV will focus on seismic data acquisition and drilling of minimum 12 exploratory wells.

In the Southern part of the country, **Chevron** was granted 3 exploration licenses in Dobrogea, in particular for the: Ex-17 (Costineşti), Ex-18 (Vama Veche) and Ex-19 (Adamclisi) perimeters, which altogether total 2,700 km^2, currently awaiting government approval. In February 2011, Chevron acquired the concession for the 6,257 km^2 E V-2 (Bârlad) perimeter situated in the country's North-East, at the border with Republic of Moldova. The company is planning to drill its first exploratory well at Bârlad, in 2012, followed by another 8 wells in Dobrogea starting with 2013.

In the country's South East (Oltenia region), **Sterling Resources**/Midia Resources holds the E III-7 (South Craiova) perimeter where it intends to evaluate the shale gas potential, the rest of the company's perimeters being offshore and thus irrelevant for the shale gas discussion, since shale gas is not produced offshore anywhere in the world at the moment.

The state owned company **Romgaz** stated in September 2011 that it was studying the shale gas potential of the perimeters which it already has, the majority of which are located in Mureş and Sibiu counties (Transylvanian Basin). According to the company website, "*Romgaz is the co-owner of the Petroleum Agreements for three perimeters in Romania's Moldova region where it has the right to explore-develop-exploit, in consortia with Aurelian Oil & Gas Romania and Europa Oil & Gas*", two companies whose interest in unconventional gas (tight gas) is known.

Europe vs. United States: geology, economics, environment and politics

Economic costs: There is no standard cost for shale gas production, each well being different, but there are factors that influence costs. As with conventional hydrocarbons, they fall into two categories: *above ground* and *below ground* considerations. In the first category belong the legislation (especially, fiscal and environment policies), the existence of a developed gas pipeline infrastructure and service industry as well as the proximity to the market. Within the second category one usually talks about the specifics of the geological structure – the depth of the shale formations, organic content, temperature and other elements which influence the well productivity, and through this, its economic viability.

In the United States, the ensued result (the low spot gas price, which reached \$2.5/MMBtu at Henry Hub in mid February) is attributed to a number of factors: a competitive gas market (price liberalization started in 1980s), private property over mineral resources, favorable geological structure, fiscal stimulants, but also the speed with which the technology was adopted by market participants.

A 2007 NPC study shows that, on average, the transition from concept to widespread commercialization of a new technology in the oil and gas markets (period often called *"technology valley of death"*) is about 16 years. According to Florence Geny of the Oxford Institute of Energy Studies, the technology for shale gas was adopted in less than 10 years. For comparison, the time required for industry wide adoption of horizontal drilling and 3D seismic prospection was 30 years.

On average, the cost associated with shale gas production in America is around $4 million/well. Drilling costs are higher than fracturing costs, thus the depth at which the shale gas formations occur seem to matter a lot in shale gas economics. Preliminary data seems to indicate that exploitation of this resource is more profitable up to a depth of 3.5 km into the ground, while accessing deposits located at depths higher than 5 km is likely to undermine the commercial rationale (this, of course, would depend heavily on the price level for gas in the destination market as well as the overall tax burden).

According to statements by OMV representatives in 2010 for the *FT blog*, one of the main difference in terms of production cost between the USA and Europe resides in the following: shale gas deposits in America are more often situated closer to the surface (3-4 km) as compared to Europe (5-6 km depth which is the case for the Vienna Basin, for instance). In the case of the specified Austrian formation, this aspect alone would translate into a cost differential of 4-5 million USD/well (in USA) vs. 20-50 million USD/well (in Europe). However, despite some common trends which may be observed in the European shale plays (smaller basins and more variety in geological age than in the USA), a general conclusion would not be warranted. According to the Kuhn and Umbach 2011 study, in Europe, as in the U.S., gas shales are found at various depths: "*The Fayetteville produces from 1,200 m and Haynesville at 4,000 m. In Europe, Shell is testing the Alum shale in Sweden at 900 m, while other companies are targeting shales in the Baltic Basin between 2,500 m and 4,000 m"*.

More recent data seems to confirm that shale gas extraction will be more expensive in Europe. At the end of last year, data suggested that expenses for a shale gas well in Poland were triple than in the United States. *"The cost of drilling a 2,000-meter horizontal well in the U.S. averages $3.9 million, compared with $11 million in Poland"* said, according to a Bloomberg report, Peter Richter, global unconventional technology manager at Schlumberger, during a Warsaw conference on November 29 last year.

In addition, a preliminary comparison, based solely on data from the ARI/EIA report, shows that North America's shale gas endowment far exceeds that of Europe (54.7 vs. 17.7 Tmc).

Environmental costs are centered on two aspects: *water pollution* and *atmospheric pollution*. The technology used to extract shale gas combines hydraulic fracturing with horizontal drilling. The first involves injecting large quantities of water (with chemical additives) into the rock, which once fractured, releases the hydrocarbon molecules. This technique was first applied to the Texas oil fields in late 1940s, but research continued into the 1970s to optimize and improve the procedure. At first, the companies seemed more interested in its application in the traditional industry, where *fracking* was initially used as part of the *enhanced oil recovery* (EOR), process which allows the extension of a field's productive period by increasing its *final rate of recovery*. The first commercial scale experiments with shale gas production dates from the 1980s-1990s (Barnett Shale, Texas) with initial modest results. The breakthrough came in 2005, when Devon Energy combined the two techniques, which individually have been known and applied throughout the industry for a long time, for shale gas extraction in Barnett. Lately, the process was improved through the so-called *"multi-stage fracking"*.

Exactly one year ago, the *New York Times* published a series of articles on the risks to human health associated with production of gas that uses this technique. The controversy is linked to the fact that the use of this technology could disrupt subterranean water aquifers and result in contamination of drinking water systems near shale gas drilling areas. The discussion centered on the documented incidents in Pennsylvania, a state where the underground storage capacity for used water is limited. In response, industry specialists state that these problems are unrelated to hydrofracking – a process that has been used in the United States for six decades – but stem from an improper isolation of the well site (in particular, sub-optimal standards in executing the steel casing and cement jobs). The gas industry contends that these were isolated incidents, caused by inadequate financial, enforcement and monitoring capabilities of the early independent companies, which had limited resources. This, however, is not the case for the big IOCs.

In March 2011 three researchers from Cornell University published a paper that generated a lot of controversy last year. The text, which claims that shale gas production has a GHG footprint higher than conventional oil & gas production, raises two questions that have received significant attention since then. The first is the question of methane emissions during the process of well completion (the so-called *"fugitive emissions"*). The second relates to the water injected in the ground, part of which comes back to the surface during the next days or weeks following the frac job (the so called *"flowback"* water).

While it is common knowledge that natural gas when burned has the lowest carbon footprint of the fossil fuels, aspects related to upstream methane emissions seem to be insufficiently documented. Precisely because methane is a gas 25 times more harmful for the atmosphere than CO2, it is usually captured (for sale), or flared. A small quantity inevitably escapes into the air during the well completion process, to which a further 2% methane loss can be added during the flaring process which converts methane into CO2. However, according to an August 2011study by IHS CERA, the estimates of methane emissions used by EPA (and by the controversial Howarth study) are *"dramatically overstated"* adding that *"it would be unwise to use them as a basis for policymaking*". The methodology used has two errors: (1) data for methane "*emitted during well completions"* is based on a set of data which in fact represent "*emissions captured during well completions*"; (2) it makes assumptions that "*do not reflect current industry practice"*. Furthermore, the report indicates that *"cold venting is no longer industry standard practice in oil and gas operations, although it was common as recently as a decade ago"*, while *"open-pit flowback has been losing favor as more and more operators move toward enclosed tanks"*.

The topic of the water with high methane content is also a very disputed one, as it is possible for methane to pre-exist in the *"water acquifers"* or even *"migrate"* from shallow methane strata, and not from the shale gas deposits located deep underground and separated from drinking water aquifers by thick, impermeable layers. A conclusion is rendered more difficult by the absence of relevant historical data on this issue. Daniel Yergin, in his latest book, *The Quest*, enumerates three main methods of water management (referring both to 'flowback water' and 'produced water'): injection 'into deep disposal wells'; treatment; and recycling. According to Yergin, *"New large-scale water treatment facilities are being developed. The industry is now recycling 70 to 80 percent of the flow back. There is also intensive focus on innovation. These include developing new methods to reduce the amount of water going in and to treat the water coming out, and the drilling of more wells from a single 'pad' to reduce the footprint".*

Thus it would seem that, there are currently methods and technologies that can reduce the degree of pollution. Among the new innovative solutions developed recently which could gain significance going forward, two alternative technologies deserve attention. One was developed in Ukraine and is called **"*cavitation hydrovibration"*** and is an entirely chemical free but water based process, as described by Kunh and Umbach in their paper. The other one is a waterless process called **"*propane fracking*"** or **"*liquefied propane gas" (LPG) fracturin***g. Invented by Robert Lestz, a former Chevron engineer, this innovative technology is used by a Canada based company called GasFrac Energy Services, where Lestz is currently working as Chief Technology Officer. The company was awarded the first annual "Technological Innovator" award at the 2nd Annual World Shale Gas Conference, held in November 2011 in Houston, Texas.

Aside from innovative solutions as well as development of industry wide Best practices code (like in Poland), it is up to the governments and specialized agencies to impose and/or ensure the enforcement of regulations that protect the environment. The EU environmental legislation is stricter than in the U.S. and will probably drive up the costs of shale gas development here, reflecting a more responsible approach to environmental concerns. From the European legal environmental framework it is worthwhile referring to the EU Water Framework Directive 2000/60/EC (WFD) or the REACH Regulation on chemical substances, the later in force for five years already. Romanian experts consulted on this matter reckon that Romania is entirely aligned with European environmental legislation, and consequently should not fear the technology as long as the regulations in force are strictly observed. In Romania, the Water Framework Directive was transposed into national legislation by Law no. 310/2004 (which completed and modified the Law on Water no. 107/1996), while the quality of drinkable water is regulated by Law 458/2002 (completed and modified by Law 311/2004). Government Decision (HG) 351/2005 (completed and modified by HG 1038/2010) regulates the disposal of hazardous substances, whereas HG 188/2002 (modified by HG 352/2005) regulates the conditions for discharging wastewater into the aquatic environment, to name just a few.

In 2012 are expected the initial results of a study by the U.S. Environment Protection Agency (EPA) concerning the potential link between hydraulic fracturing and the risk of water contamination, with a full study to be published in 2014. Until then, opinions remain divided, both academically and among the policy-makers. For instance, a 2011 MIT study concluded that the "*environmental impacts of shale gas development are challenging but manageable*". Duke University and University of Maryland joined the debate, as did a second group of researchers from Cornell University who disagree with the findings of the first Horwath paper (who in the meantime issued a rebuttal in December).

New York state imposed a one year moratorium on the use of hydrofracking in August 2010, thereafter extended until July 2012. New Jersey followed suit in August 2011. France adopted a law banning the use of hydrofracking on its territory last July, a measure described at the time by Jean-Marie Chevalier, one of the most respected French energy economists as *"an irrational attitude"* and a *"completely anti-Cartesian"* reaction. Bulgaria adopted recently a similar measure, one with consequences for US major Chevron, which had previously obtained a 5 year exploration license in the country's North East region (Dobrudja, near the town of Novi Pazar), a perimeter thought to contain up to 1 Tcm of resources.

Meanwhile, **Great Britain** and **Poland** are convinced of the economic and political advantages which the new resource can offer. The UK Parliamentary Committee on Energy and Climate Change concluded back in May 2011 that it is not the case to impose a moratorium on this technology, such a measure being not "*justified or necessary at the moment*". According to the chair of this commission, Tim Yeo: "*There appears to be nothing inherently dangerous about the process of 'fracking' itself and as long as the integrity of the well is maintained shale gas extraction should be safe".* The government response to the report confirmed that the current legislation *"already takes specific account of the challenges unique to shale gas exploration and production".* On the other hand, in Poland the chief geologist and Deputy Environment Minsiter, Henryk Jacek Jezierski, was saying last year that: "*We are prepared to control the process and it can be safely implemented in Poland"* (Platts), a pro-shale gas attitude being assumed by the entire political elite and supported by 82% of the population. With respect to shale gas development, Poland seems to be in Europe what France represented for the development of the nuclear energy during the 1970s-1980s, the political commitment to shale gas in Poland today being as strong as was the French one towards atomic energy in the 1980s.

What the future holds

In continental Europe, gas prices are indexed to petroleum products and despite efforts to liberalize the market, it remains dominated by long term contracts. The events on the American gas market have already affected positively the European one, with the most visible effect of re-routing of LNG volumes bound for the U.S. market toward European and Asian markets, which resulted in lower prices on the European spot markets during 2009. The next 3-5 years will focus on confirming the shale gas potential through hard field data, collected through seismic analysis, exploratory drilling and debit monitoring. Therefore, in the near future shale gas will continue to have an indirect impact on the European gas market. In the medium term, if geological data justifies the start of commercial production, it could offset the decline in European domestic gas production. For Central and East European countries shale gas could offer an indigenous source of primary energy supply, that if responsibly developed and in compliance with the best industry practices, could contribute to a diversified mix.

The options to increase energy security can hardly be risk-free: there are always risks involved – the risk to be overdependent on a volatile region (Middle East), or a questionable political regime (Iran), the risk of an oil spill (BP's Gulf of Mexico incident, 2010), the risk of a nuclear accident (Fukushima, 2011), the risk of environment pollution (coal). There is no individual solution which could secure by itself the necessary level of energy supply and be at the same time completely risk-free. In the equation of "economic-political-and climate costs" there will always be tradeoffs to make and each country will have to ultimately decide the optimal structure of its future energy mix.

It has been almost 100 years since Winston Churchill first formulated (although in the context of crude oil supply) the principle of energy supply diversification. It still holds today: *"On no one quality, on no one process, on no one country, on no one route, and on no one field must we be dependent. Safety and certainty (…) lie in variety and variety alone"* (1913). In this light, any opportunity to diversify the energy mix cannot but increase a country's energy security and shale gas offers this possibility. While the environment concerns are legitimate ones, a premature rejection of the technology, without having all the data, is deemed unconstructive, especially if the knowledge, solutions, and according regulations exist to minimize the risks to environment associated with energy supply diversification.

ROMANIA's SHALE GAS POTENTIAL

Interview with Mihail Batistatu, associate professor, Petroleum- Gas University of Ploieşti (UPG)

Romania Energy Center (ROEC): Since putting forward any numbers regarding Romanian shale gas reserves is premature, but taking into account Romania's over 100 year tradition in the gas industry, if you were to offer a diagnostic of the Romanian potential for this resource, but also make a prediction as to the future of shale gas production in Romania, what would it be?

Mihail Batistatu (M.B.): Shale gas formations can theoretically be considered the hydrocarbon generating complexes, i.e. the source rocks for oil. Taking into account that, out of the total generated hydrocarbons approximately 30% have usually migrated, and of these only a part encountered conditions favorable for accumulation, a quantity comparable to the hydrocarbon resources currently found in conventional 'reservoirs' is locked in unconventional pelitic/compact 'reservoirs'. Therefore, a possible resource of over 150 billion cubic meters of gas can be estimated for the Transylvanian Basin (it has to be mentioned that these rocks are somewhat different from the classic "shales"), while in the Outer Carpathian arc the resource potential is at least double. By taking into consideration the

- deposit conditions, especially the very high pressures,
- environmental pollution problems,
- remarkable technological effort,
- operating costs,

one can consider their exploitation as possible, but very difficult. For example, based on published data, the fracturing operation for a well requires cementation aggregates with a cumulated power of 15,000 – 20,000 HP. Once the abovementioned aspects are resolved and depending on the size of the investments, a minimum annual production of 2 - 4 Bcm/year can be secured.

I consider the exploitation of these resources possible within at least 4 – 6 years after the operations begin.

ROEC: It is believed that Romania's geological structure is extremely favorable for shale gas production. Based on what is presently known about the properties of these formations in Romania, do you believe that geology will favor production on a commercial scale? What would be the timeframe in which production might begin?

M.B.: The geological conditions favor commercial exploitation especially in the Transylvanian Basin and less so for the extra-Carpathian areas. I consider that the possibility to start exploiting these resources, depending on the location, requires a timeframe of at least 3 – 6 years from the moment the operations begin.

ROEC: What is the production history (if it exists) for other forms of unconventional gas in Romania, especially coal bed methane (CBM) and tight gas? Do we have presently any such exploitation

projects? If yes, where and what is the percentage represented by CBM and tight gas production (individually or on aggregate) in Romania's total domestic gas production?

M.B.: With respect to CBM, I do not believe that there are such projects. The coal deposits in Romania are generally of lower quality, lignite [brown-coal], the possibly generated gases could have migrated relatively easy towards the surface, for instance in the Sub-Carpathian region. With respect to the Petroşani Basin, the existence of gases generated by superior quality coal, such as bituminous coal [hard coal], is likely, but I do not have knowledge of any ongoing projects which such an objective. Until today tight gas deposits have not been exploited for gas.

ROEC: What is the depth at which shale gas formations can be found in Romania?

M.B.: The depth varies greatly from approximately 1,000 m up to over 6,000 m. I consider as a limitation, determined in fact by costs, the depth of 4,000 – 4,500 m.

ROEC: Are there any environmental impact assessment studies related to the development of the resource in Romania?

M.B.: I have no knowledge of such studies, but I know that they are mandatory in order to obtain an operating license and if Chevron declared that it will begin operations in the Bârlad Depression, it is possible that it did undertake such a study.

ROEC: Which factor do you think will weigh most in the decision to develop or not shale gas resources in Romania: the geology, the water resources, the economic cost, the environmental cost or the political factor?

M.B.: Unfortunately, the technologies presently applied are quite polluting and they also require enormous quantities of water. The amount used for drilling + fraccing/exploitation for one well can be over 2 million cubic meters of water. Romania has a deficient rainfall regime and dwindling water resources. Policies change, technologies can be acquired/optimized, resources are finite while the pollution can become historic. For example, a recent study (2006 – 2008) pointed out the historical effects of the 1943 - 1944 bombardments of the Ploieşti refineries, the resulting groundwater pollution with oil products is present to this day.