GEO ENeRGY

Shale Gas Resources in Europe

Shale gas deposits are considered unconventional gas resources that can be found in very low permeability shales. These rocks act at the same time as source rocks and reservoir rocks and are usually located in geological formations deposited from Cambrian to Cretaceous. Shale formations are typically from anoxic basins, influenced by the development of carbonate ramps that lead to continuous reservoirs that consist of an accumulation of sedimentary seams with low permeability and saturated in gas. These formations are rather heterogeneous and present a very complex stratigraphic architecture as a consequence of the numerous physical, chemical and biological processes that take place during sedimentation. This last aspect has to be seriously taken into account during exploration and exploitation of shale gases.

The structure is characterized by very thin lamination, causing very small pores and a low permeability. Therefore, production of gas in commercial quantities requires the use of fracturing techniques. Technological advances related to drilling (horizontal drilling) and well stimulation (hydraulic fracture) permit profitable production, moving considerable resources of unconventional gas reservoirs into the category of reserves.

The process to extract the unconventional natural gas roughly consists in the drilling of a vertical well until the potentially productive formation is reached. In that moment, horizontal drilling is performed along this formation to create the maximum possible surface of contact, achieving maximum lengths of three kilometres. The next step is the hydraulic fracture of the rock (fracking), a technique that injects a mixture of water, sand and chemical products into the rock at a high pressure. This process creates fractures in the rocks, enabling gas to reach the surface. The previously mentioned mixture contains synthetic particles of ceramics (proppants) that are very resistant to pressure, working as a supportive material and also keeping the fractures open, allowing gas to flow. When the mixture has concluded its work, it is extracted out of the well in order to be treated at the surface, as it can be polluting, and it must not be mixed with fresh water. This return water can be re-used in new hydraulic fractures, injected into deep saline aquifers, evaporated to obtain a solid waste or discarded at the surface, providing it satisfies regulations. Technology is advancing in the way to reduce the volume of water necessary for fracking operations by recycling return water, using non drinkable waters and better selecting the required fractures to reduce water demand. Typical composition of the fracturing fluid is between 95 and 98% water (not necessarily fresh), under 5% of sustaining sands and less than 1% chemical products, as bactericidal, friction reducer, thickener, etc. Until recently, companies were not making public the composition of used chemical products, and this was a major reason for concern within the population against the use of this technique.

Other concerns are related to potential pollution of aquifers both from fracking fluid or methane, water consumption (that may lead to potential conflicts of use between sectors), treatment, control and possible radioactivity of return waters, problems of induced seismicity and methane emissions. In this situation, the role of the scientific community is to answer questions and concerns about environmental and social issues leading to the unconventional gas production in case these concerns are overcome.

Following major international projections, gas will play a very relevant role in the future energy mix. The unconventional shale gas resources exploitation in Europe could drastically change the European energy market, as it has in the United States. There is a strong interest in the identification of potential shale gas objectives in Europe. Some systematic approaches that have been carried out in European geological basins are offering, at the moment, perspectives for exploration and production and especially in some countries as Poland and France that hold about half of the estimated resources in Europe, or the United Kingdom, where the government has introduced important support to shale gas exploration (Fig.1). In any case, these estimations have a very wide range of uncertainty and, therefore, it is necessary to conduct studies that provide reliable figures. If the use of these resources becomes a reality, energetic dependence of the European Union on Russia and the Middle East could be reduced, having an impact on economical and political questions.

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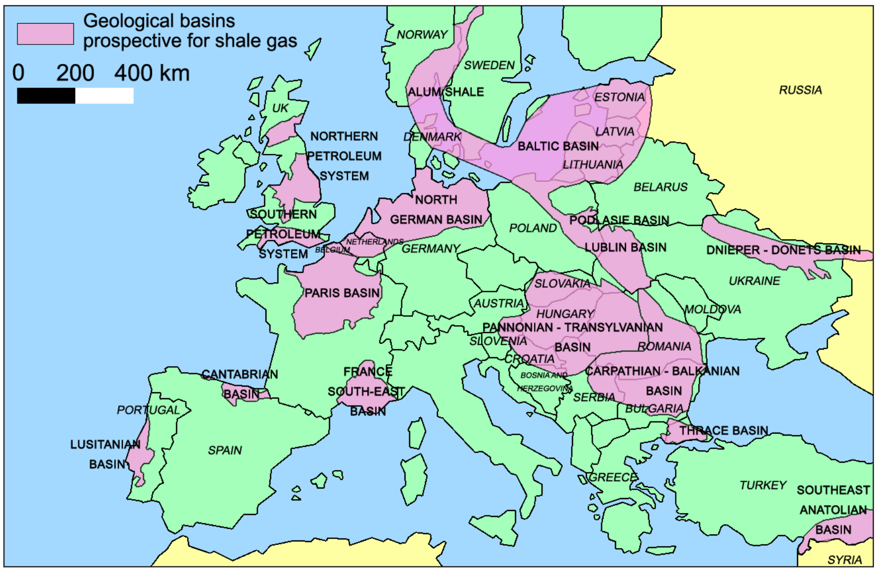

Fig.1 European geological basins prospective for unconventional natural gas exploration and production (modified after IEA Special Report on Unconventional Gas, 2012 and Boyer, C. et al., 2011). Compiled by K. Shogenov (Institute of Geology, Tallinn Univeristy of Technology)

Overview of shale gas activities in Poland

Though Poland is at the forefront of shale gas prospecting activities in Europe, still little is known about the gas proven reserves.

Since 2007 over a hundred (113 by the beginning of 2013) exploration licenses to search for unconventional hydrocarbon deposits have been granted by the Ministry of Environment. First mostly international companies (e.g., Chevron Corporation, Marathon Oil Company, Lane Energy, etc.) applied for and obtained the licenses, then also three domestic operators – Polish Oil and Gas Company, LOTOS and Orlen joined these activities. The mentioned licenses refer to prospecting for shale gas, tight gas, shale oil and sometimes (jointly) conventional hydrocarbon resources.

Regarding shale gas the most prospective area runs through the country, roughly along and east of the Teisseyre-Tornquist zone (Fig.2). It includes mostly the onshore area, but a part of the Baltic economic zone is covered as well. The prospective formations within this „golden belt" range from shales of Upper Cambrian and Lower Ordovician to claystones of Upper Ordovician and Lower Silurian (Lower Palaeozoic basin). The prospective area is determined by total organic content (TOC)>2% and thermal maturity corresponding to the gas window, evaluated on the base of data and cores from old wells.

Since 2010 about 30 wells for shale gas prospecting have been completed, largely in NW part of the belt where it is believed the potential is the highest (Figs.2,3). A dozen wells are being drilled or completed. The Ministry of Environment has obliged the operators (in the signed contracts) to drill, by 2021, at least 128 wells and up to 181 wells depending on prospects of particular license blocks. However, no full production tests have been performed yet. In one well in the NW part (Lane Energy) production of about 20 thousand m^3 per day was achieved for a period of a week, and in one well in NW (POGC) and in another in the SE (Exxon mobile) the presence of shale gas resources was announced. If proven and economically viable reserves are discovered, thousands of production wells might be drilled within the prospective area, especially within the NW part, believed to be the most promising one.

Regarding assessment of reserves a number of estimations has been produced ranging from 5300 (EIA, 2011) to 48 Bm^3 (billion cubic meters) (USGS, 2012). The estimations are based mostly on USGS methodology on assessment of the average EUR (Estimated Ultimate Recovery) adopted for the basin and the acreage of the basin and, to a lesser extent, on the volumetric approach employing directly the recovery coefficient. Assumptions and parameters valid for North American basins are considered, most likely corresponding to the situation in Poland. It brings a large degree of uncertainty and until reliable results from numerous wells are obtained, no one can precisely estimate future shale gas production costs in Poland. Actually proven and economically viable reserves would largely depend on availability and development of drilling and fracking technologies.

The official conservative estimates, based on the USGS methodology, say the most probable range of shale gas reserves is between 346 and 768 Bm^3 (PGI-NRI report, 2012), depending on acreage of the basin considered. Corresponding average EUR of one well is 11.3 Mm^3 (million cubic meters), but this value seems to be meaningless because gas production would be focused in the best regions („sweet spots") within the basin where EUR is of an order of magnitude higher. These estimates make the average recovery coefficient of about 7.4% of shale resources (gas in place) within the basin. In any case these reserves (together with conventional gas) are bigger than needs of Poland till the foreseeable end of fossil fuel era.

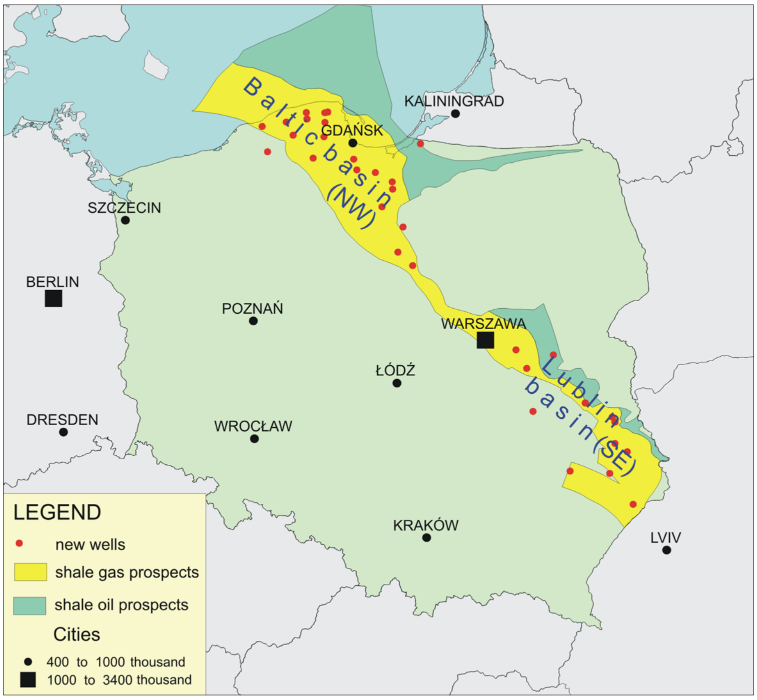

Fig.2 Map of shale gas and oil prospects in Poland with new wells marked (prospective areas after PGI-NRI report, 2012; well locations after website of Polish Ministry of Environment - www.mos.gov.pl)

Adam Wójcicki
PGI-NRI

Fig.3 Poland's first shale gas well in the town of Lebien, 90 kilometres west of Gdansk Copyright (c) 2011. RFE/RL, Inc. Reprinted with the permission of Radio Free Europe/Radio Liberty, 1201 Connecticut Ave., N.W. Washington DC 20036

Shale gas exploration in Denmark

Shale gas is an unconventional energy resource produced directly from the shale source rock itself. Gas productive units are characterised by being regionally extensive and thick, organic rich, and by being buried deep enough to have generated gas. The extraction technique for shale gas (horizontal drilling and hydraulic fracturing) was developed in North America. The new technique unlocked a huge quantity of natural gas which has impacted the Global energy market tremendously.

In Europe shale gas exploration is still in its early phase. In many European countries the industry has primarily focused on thick organic rich Palaeozoic shales which are known as important source rocks for conventional oil and gas fields. In Denmark shale gas research and exploration is currently focused on the Lower Palaeozoic shales, and two licences have been awarded to Total E&P in northern Jutland and northern Zealand. The first exploration well is scheduled to be drilled in northern Jutland autumn 2013 targeting deeply buried gas-mature shale, notably the so-called Alum Shale. Results are expected in mid-2014.

Since 2009 GEUS and the University of Copenhagen have conducted a wide range of shale gas evaluation programmes including shallow coring in areas where the shales are accessible immediately beneath a thin Quaternary cover. Key questions still to be addressed include the gas storage capacity of the shales, their mineralogy and how they respond to hydraulic fracturing.

The shale gas play in Denmark focuses on the rims of the Norwegian-Danish Basin where the Palaeozoic shales are buried between 2-4 km depth (Fig.4). The target formations are the Cambrian-Ordovician Alum Shale which is unusually rich in organic matter, typically 5-10% and locally up to 25%. The formation is up to 180 m thick in offshore areas. Organic rich shales also occur in the slightly younger Ordovician and Silurian successions. These black shale units are thinner than the Alum Shale and show lower contents of organic matter, up to 5%, but they may still be interesting for shale gas exploration.

The Palaeozoic shales in Denmark were buried and matured to gas stage within a Caledonian foreland basin in Late Silurian time (Fig.5). In the Carboniferous and Early Permian the shales were faulted and the fault blocks were tilted and uplifted and locally subjected to intensive erosion. Because of the complicated burial history it is currently uncertain whether significant amounts of gas are still trapped in the shale. The gas may have leaked out through millions of years of uplift and progressive erosion, since the gas formed more than 400 million years ago. A study conducted by Shell on the Alum Shale in southern Sweden indicated that Alum Shale now located at 700-800 m depth did not contain gas in economical quantities and gas retention in the shale poses a major risk factor for the Danish shale gas play.

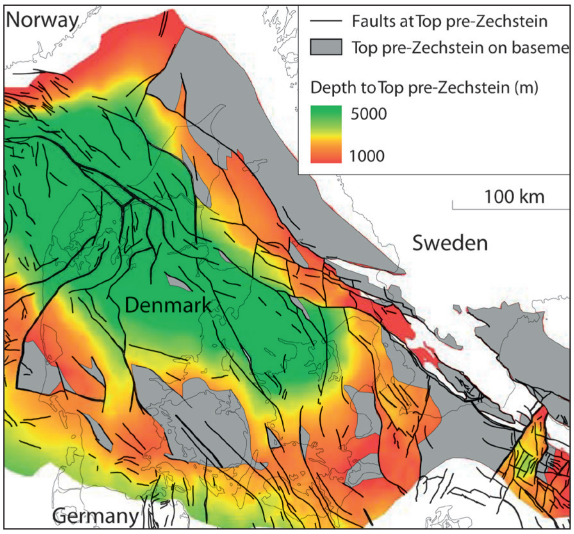

Fig.4 Depth to the top pre-Zechstein surface. Note the deep centre in the Norwegian–Danish Basin exceeds 5000 m and the shallow Ringkøbing–Fyn basement High (<1000 m). Areas where the Top pre-Zechstein surface coincides with basement are shown in grey

Extraction of shale gas in northern America requires high density of wells and hydraulic fracturing of the shale layers, which uses large amounts of water mixed with chemicals. Public concern regarding contamination of groundwater in connection with the fracturing has led to intense debate about the exploitation of shale gas. The Danish government has issued a temporary stop for issuing new exploration and production licences where the exploration target is shale gas. Results from the first shale gas exploration well in Denmark in northern Jutland by Total E&P will be evaluated in 2014.

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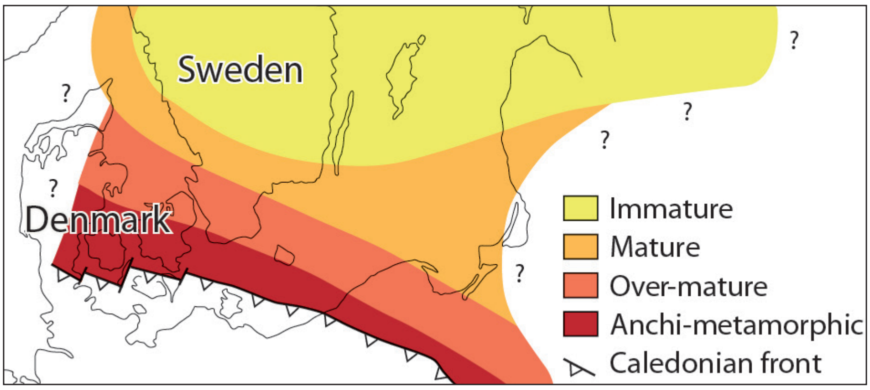

Fig.5 Maturity of the lower part of the Lower Palaeozoic sequence based on reflectance of vitrinite-like particles. The thermal maturity increases towards the Caledonian front, reflecting deep burial in Late Silurian to Early Devonian time

ENeRG – European Network for Research in Geo-Energy

ENeRG – European Network for Research in Geo-Energy is an informal contact network open to all European organisations with a primary mission and objective to conduct basic and applied research and technological activities related to the exploration and production of energy sources derived from the Earth's crust.
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Ex-situ and in-situ shale oil production: cases from Estonia and Israel

Shale oil refers to any synthetic oil obtained by destructive retorting of oil shale. One tonne of commercial grade oil shale may yield from about 100 to 200 litres of oil.

Over 600 hundred oil shale deposits are known in 30 countries on all continents with total resources of shale oil of 4.8 trillion barrels reported by World Energy Council (WEC) in 2010. The largest known deposit is in the western USA (3 trillion barrels). Only Estonia, China and Brazil produce shale oil. According to the WEC the total oil production in 2008 was about 1165 ML (million litres), with Estonia producing 445 ML, China 470 ML and Brazil 250 ML.

Ex-Situ Estonian Case. Estonia was the largest shale oil producer in the world before 2007, when China took the lead. Three Estonian enterprises produce shale oil using the Kiviter-type internal combustion vertical retorts and Galoter or Solid Heat Carrier units. About 500000 tonnes of shale oil is produced annually. From every tonne of Estonian Ordovician oil shale kukersite 125 kg of shale oil, 35 Nm^3 of retort gas, 430 kg of ash and 180 kg of CO_2 are produced.

In 2011, 18.7 million tonnes of oil shale was produced in Estonia. The majority of oil shale is consumed in power plants and as raw material for shale oil. The demand for shale oil in Estonia and in external markets increased the production of shale oil in 2011 by about 7%. Nearly three quarters of the production was exported. More than half (54%) of this amount was exported to the Netherlands, followed by Russia (15%) and the United Kingdom (8%).

Israel In-Situ Project. There are more than 25 deposits of oil shale in Israel. The estimate of resources of the richest Late Cretaceous deposit in Shfela basin is about 150 billion barrels of oil, of which 40 billion barrels are in the license area of the Shfela In-Situ Project. Unique geological conditions of this deposit (size, high quality of oil shale and depth), and the hydrological isolation from the aquifer below and from the surface above make the deposit optimal for in-situ extracting, providing great environmental advantages versus ex-situ shale oil production.

The In-Situ Conversion Process (ICP) enables the extraction of oil from the oil shale rock in place without any mining. The project is led by industry (http://www.iei-energy.com) and academia (http://in.bgu.ac.il/en/natural_science/) and includes geological exploration of 238 km^2 area in the southern Shfela region, and a small scale field production test (pilot). The pilot goals are to demonstrate that the ICP is technologically feasible, economically viable and environmentally responsible.

ICP involves drilling heating wells into the oil shale with a smaller number of production wells. The heater wells gradually heat the subsurface oil shale formation. The elevated temperature converts the kerogen into lighter hydrocarbons fractions, which are then brought to the surface through the production wells as light hydrocarbon fuel, leaving the coke residue in the reservoir. The Shfela In-Situ project includes the drilling of six survey wells (Fig.6), a pilot test (2012-2015), plans for future demonstration (2015-2019) and commercial stage (2020).

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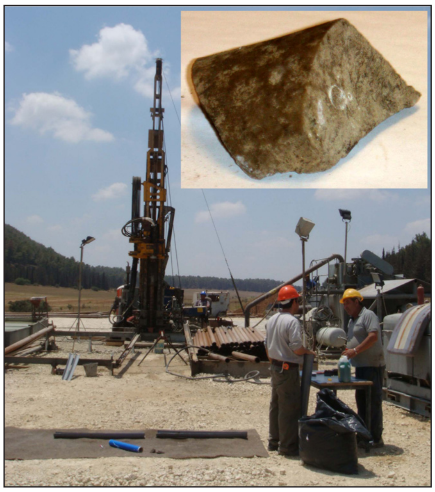

Fig.6 Drilling of Zoharim exploration borehole in Shfela basin, June 2011. The Late Cretaceous oil shale drill core sample is shown

Erratum

Errata for the Newsletter of the ENeRG Network, Issue N° 26, September 2012, Figure 2, Page 2: An erratum in the figured countries participating in the CO2StoP project has come to our attention. Serbia was unluckily figured as not participating.

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