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UNCONVENTIONAL PALEOZOIC GAS RESOURCES in the GERMAN PART of the CENTRAL EUROPEAN BASIN

Ralf Littke and Bernhard M. Krooss

Institute of Geology and Geochemistry of Petroleum and Coal, RWTH Aachen University, Germany (littke@lek.rwth-aachen.de)

The Paleozoic formations of the Central European basin system, extending from the North Sea into northern Germany and Poland, contain considerable unconventional gas resources. These comprise *coalbed methane* (CBM), occurring in the coal-bearing Upper Carboniferous sequences, *shale gas*, residing in organic-rich shales (gas shales) of the Upper Devonian and Lower Carboniferous, and *tight gas*, in the Upper Carboniferous and Permian (Rotliegend) sandstones.
The overview map in Figure 1 shows the regional distribution of Paleozoic formations in Central Europe. Also indicated are the main coal mining areas.

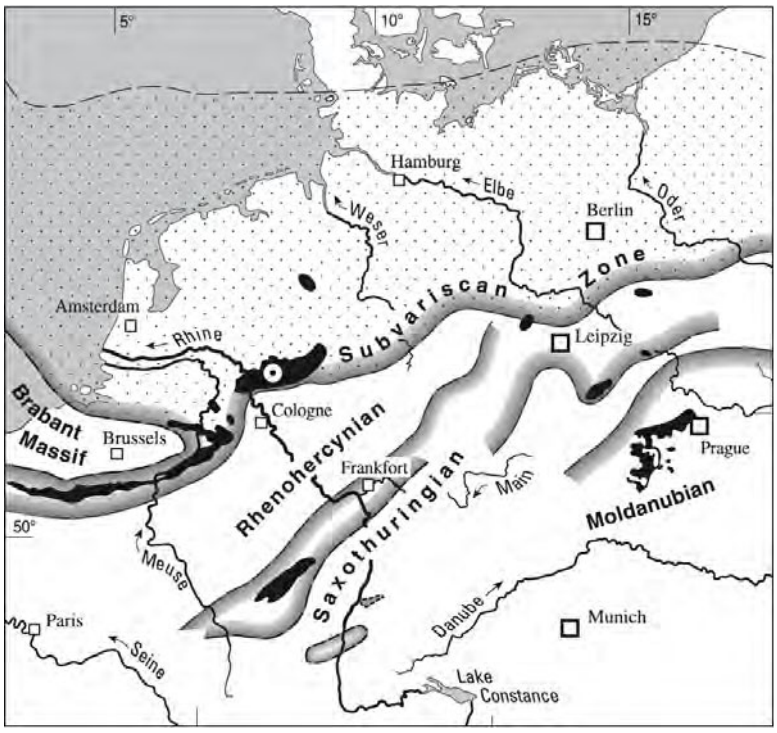

Figure 1 : Distribution of Paleozoic sediments in Central Europe with coal mining areas shown in black.

In the Rhenoherzynian Zone, Paleozoic rocks crop out at the surface whereas further to the north, in the Subvariscan zone, the Paleozoic sequence is overlain by Mesozoic sediments. The latter have a total thickness of almost 10 km north of the city of Hamburg. It should be noted that present-day depth does not correspond to maximum burial depth in the southern part of the Central European Basin system. Thus, the occurrence of thermally highly mature, gas-bearing intervals at shallow depth in the Osnabrück area is due to uplift and erosion of up

to 6 kilometres of sediments (Figure 2). These intervals comprise the anthracite coals of the Ibbenbüren mining district, which are known to be notoriously gas rich, as well as highly mature Mesozoic (Liassic and Early Cretaceous) black shales (Toarcian Posidonia Shale and Wealden Shales).

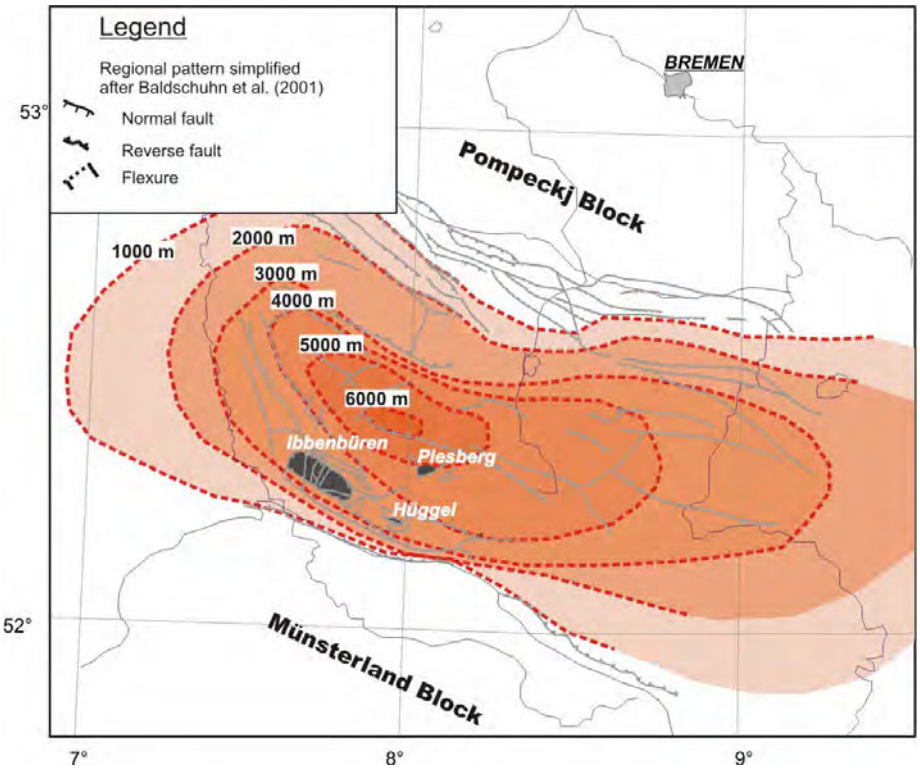

Figure 2: Eroded thickness (corresponding to maximum burial depth) of Paleozoic sediments in the Southern Part of the Central European Basin.

Tight gas-filled sandstones with permeabilities below 0.1 mDarcy (10^{-16} m²) are encountered in northern Germany and the Netherlands, where numerous conventional and unconventional reservoirs have been found. These reservoirs contain mainly thermally generated gas derived from Carboniferous coals and type III kerogen (Gaupp et al., 2008). Gases in this area contain variable, and regionally high, percentages of molecular nitrogen (N_2), carbon dioxide (CO_2), and hydrogen sulphide (H_2S; Krooss et al., 2008). The low permeabilities of these Carboniferous and Permian (Rotliegend) sandstones are due to the great burial depth and a complex cementation history (Hoppe et al., 2005). With new production techniques, in particular horizontal drilling and hydraulic fracking, these unconventional reservoirs are presently on the verge of becoming commercial. A current interdisciplinary research project at RWTH Aachen University aims at an improved understanding of tight gas systems. It combines studies on burial history and diagenetic evolution of tight-gas sandstones with petrophysical measurements and experiments on capillary displacement ("gas breakthrough") and relative permeability in low-permeable rocks.

Gas Shales are present in the Lower Carboniferous and Upper Devonian of the Central European Basin system. These shales were deposited under consistently marine conditions and have partly high Total Organic Carbon (TOC) contents. Virtually all of these rocks are in the gas generation stage and some of them have reached a level of maturation close to the anchimetamorphic stage. This is clearly the case in the Rhenohercynian zone south of the Central European Basin system, where many outcrops exist. Bituminous impregnations in

Devonian reef carbonates indicate that these formed part of a paleo-petroleum system (Schulz and Horsfield, 2009). In the Central European Basin itself, these rocks are usually at depths of more than 5 kilometres (with a few exceptions, especially in the uplifted area close to Osnabrück). Therefore, they were accessed by only a few deep wells, and little knowledge exists regarding their gas generation potential. In the uplifted areas of the basin the Mesozoic shales mentioned above have entered the gas-generation stage. This holds especially for the Wealden shales which reach a great thickness. These Mesozoic shales certainly possess a gas shale potential. In almost all other areas of Germany, the Mesozoic sequence is too immature and has not reached the gas generation stage.

Coalbed Methane is a resource associated with the coal-bearing Upper Carboniferous sequences. The outcrops of these coal seams in the Ruhr Basin, the Ibbenbüren area, the Aachen area, and the Saar-Nahe Basin further to the southwest have been the starting points of coal mining in these areas. Especially the anthracitic coals of the Ibbenbüren and the Saar-Nahe coal seams are known to be gas-rich, whereas gas content of the hard coals in the Ruhr basin is highly variable (Gaschnitz 2000).
Gas drained before or liberated during mining operations (mine gas; coal mine methane, CMM) is nowadays largely collected and combusted for power generation and mitigation of environmental impact.
As industrial coal mining in Germany is declining and will eventually phase out, the utilization of methane emitted from abandoned mines (Abandoned Mine Methane; AMM) has become an important option during the past decade. The AMM production is, however, decreasing now as the abandoned mines are gradually depleted and flooded.
The feasibility of coalbed methane production from unmined deep coal seams has been tested in the Münsterland area in the mid 1990ies by a consortium led by Conoco. Two exploration wells (Rieth and Natarp) reaching a depth of nearly 2 km were drilled in the Sigillaria concession area SE of the city of Münster. CBM activities were abandoned due to low producibility of the gas. Exploration activities in this area restarted, however, in 2008/2009. Concessions were issued to ExxonMobil and Queensland Gas Company in the northern part of North Rhine-Westphalia and adjacent areas in Lower Saxony (Fig. 3). The success of these activities will largely rely on an improved understanding of the geological evolution of the CBM systems and the availability and application of modern in-seam drilling technology.

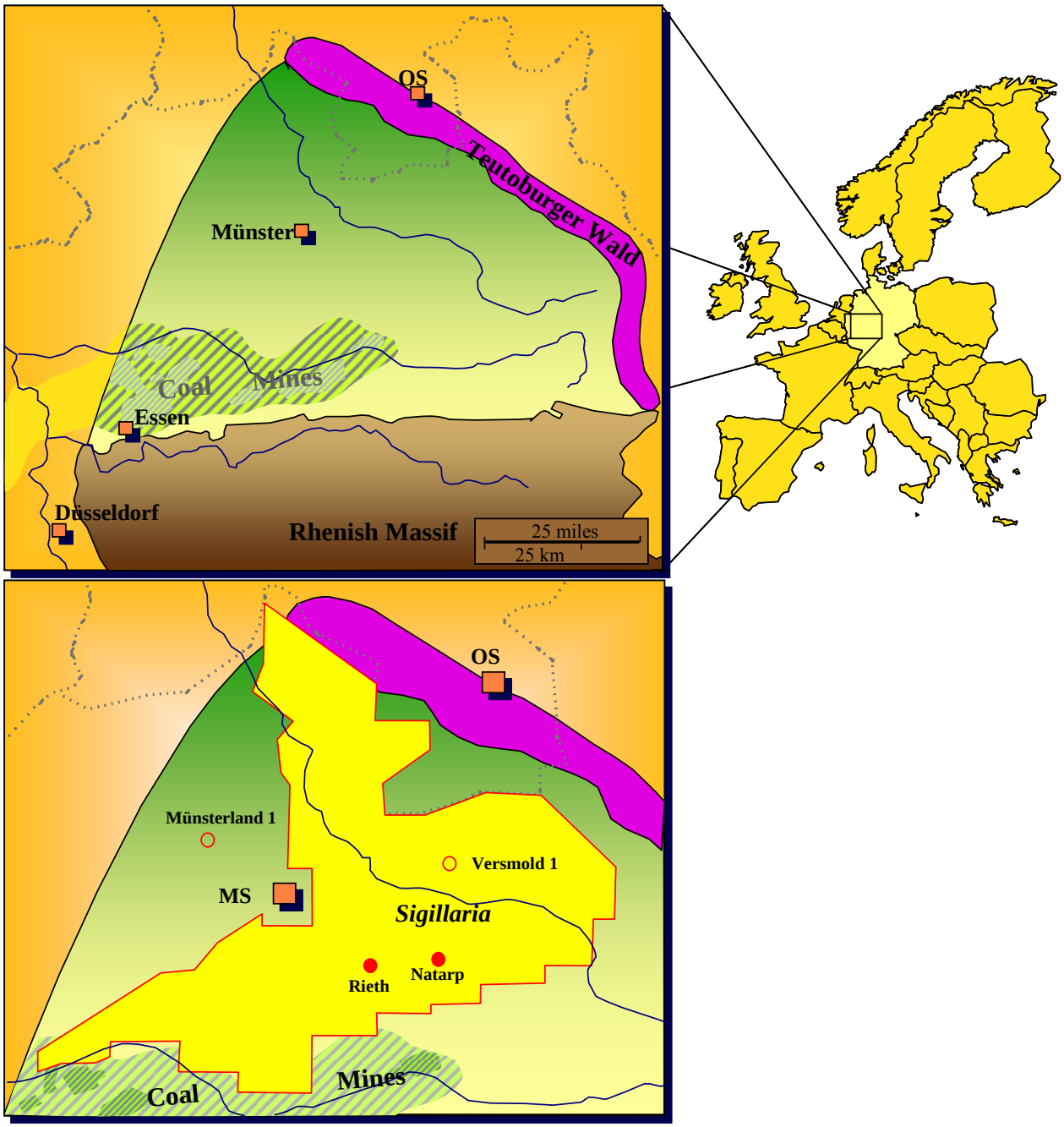

Figure 3: Location of the Sigillaria CBM concession and the Rieth and Natarp exploration wells drilled by Conoco in 1995.

Figure 4: CBM concessions in the northern part of North Rhine-Wesphalia held by ExxonMobil and Queensland Gas.

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