Petroleum Systems Modeling of the Muensterland/Ruhr Basin, Western Germany with Special Emphasis on Unconventional Gas Resources*

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Abstract

Exploration of unconventional gas resources from Paleozoic formations in Western Europe is just getting started. Large, potential gas reservoirs are presumed north of the Rhenish Massif, where marine black shales of the Mississippian, the Pennsylvanian, and Pre-Carboniferous occur, as well as numerous Pennsylvanian coal seams (Figure 1). Little is known about the black shales occurring in the Carboniferous, which have not been considered economically interesting targets due to their high thermal maturity in the past. The high maturity has exhausted all oil potential, but some of these shales are still within the gas window.

In general, all Paleozoic black shales are at present highly mature, between about 1.5 and >3% vitrinite reflectance. Especially the shales of the uppermost Mississippian (Upper Alum Shale; "Hangende Alaunschiefer") have high contents of organic carbon, are tens of meters thick and can be regarded as potential gas shale targets. These shales dip northward, cropping out in the south of the study area.

The Muensterland/Ruhr Basin is characterized by an Upper Cretaceous basin fill which is separated by an unconformity from Upper Carboniferous sedimentary rocks, which were deposited in the Variscan foreland basin and contain the most important anthracite and hard coal reserves in Germany. The depth of the top Carboniferous ranges from about 1.5 km close to the city of Muenster in the north, to 0 km at the southern rim where Carboniferous rocks crop out at the surface.

This study deals with the geological evolution of the Muensterland Basin/Ruhr Basin with special emphasis on the Paleozoic petroleum systems, including its unconventional gas resources. Various data bases were used to construct a 3D model (PetroMod® suite software) for this region, reaching from the Lower Saxony Basin in the north to the Rhenish Massif in the south, and from westernmost Germany to the Egge

Fault south of the city of Minden. The model represents an area of 110 km (length) by 152 km (width) with a horizontal resolution of 500*500 m (220*304 cells). It covers the whole Muensterland Basin and comprises important tectonic elements including the Variscan front with important faults in the Carboniferous as well as the Osning Fault in the northwest.

In this area, a few basin modeling studies were performed in the past (e.g. Littke et al., 1994; Büker et al. 1995), but focused on the southern margin of the basin and no 3D petroleum systems model has been published so far. It is known from these studies that maximum burial and hence thermal maturation occurred at the end of Carboniferous. Numerous vitrinite reflectance profiles from wells were used to calibrate Late Carboniferous heat flow. The temperature history for the Mesozoic and Cenozoic periods is based on apatite fission track data adopted from Büker et al. (1995) and Karg et al. (2005).

Physical parameters, such as porosity and permeability, which characterize the individual lithologies present in the basin, have been assigned to the strata in the model, partly based on new measurements. This also includes sorption capacities measured on Namurian black shales and Pennsylvanian coals. Also, chemical properties of several source rocks have been summarized for this model.

The goal of this study is to focus on the geodynamic evolution of the Muensterland region and use these results to calculate maturity levels and petroleum generation stages, and also sorbed gas and free gas in unconventional reservoirs in a fully integrated numerical petroleum systems model.

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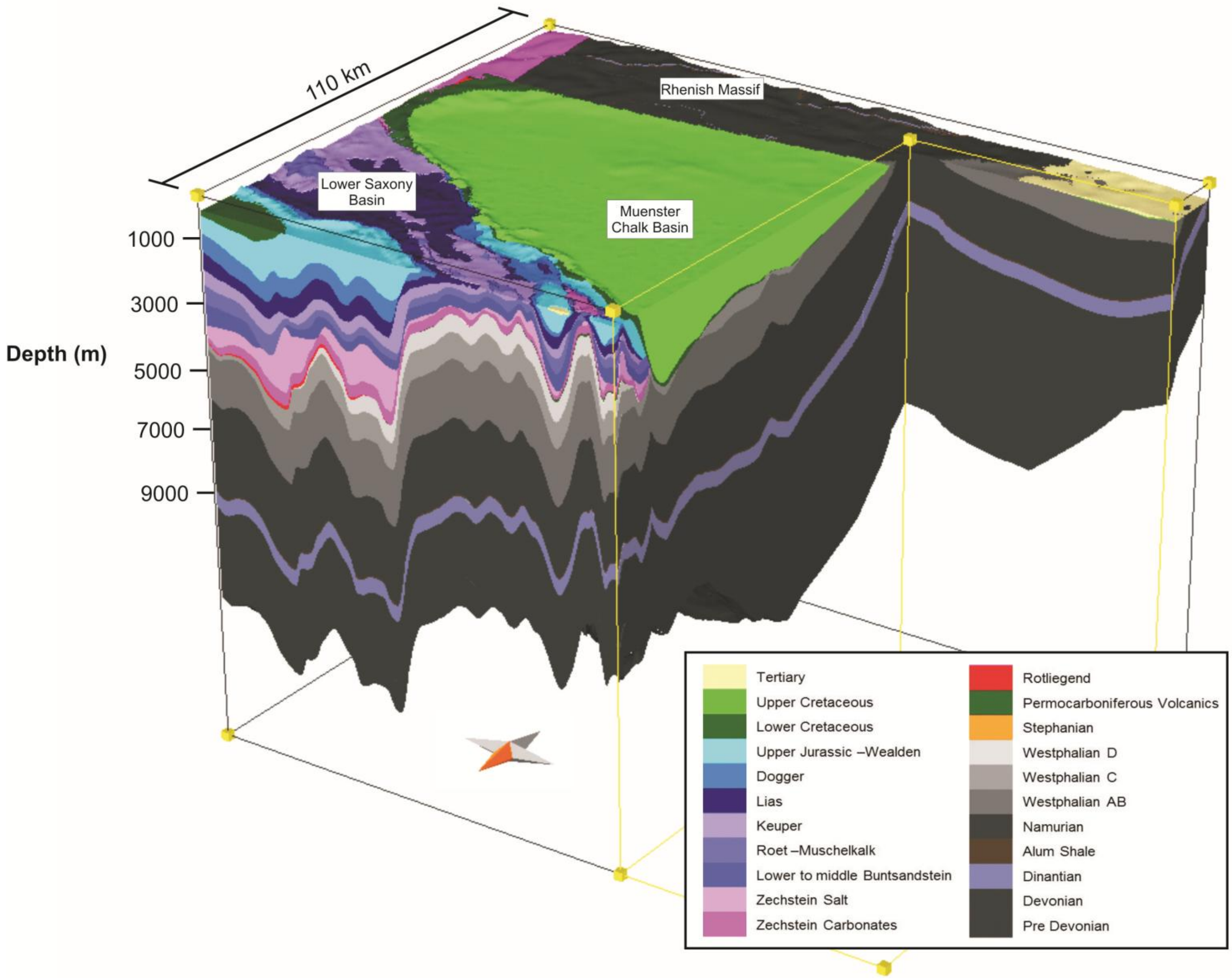

Figure 1. 3D model of the Muensterland/Ruhr basin and adjacent areas (yellow arrow points to the north).