COAL-BEARING BASINS IN GERMANY: DEPOSITION, TEMPERATURE HISTORY AND NATURAL GAS GENERATION

Ralf LITTKE[1] and Laura ZIEGER[1]

[1]*EMR, RWTH Aachen University, Lochnerstr. 4-20, 52056 Aachen, Germany; ralf.littke@emr.rwth-aachen.de*

Introduction

Major coal-bearing strata in northwestern Europe exist in í) Pennsylvanian deposits, extending from Britain towards Belgium, The Netherlands and Germany and further towards Poland and Ukraine, and ii) Tertiary deposits of different stratigraphic age, e.g. in the Lower Rhine Basin and Lusatia Basin (see Schneider, 1995, Stock et al., 2018).

New research conducted over the past years revealed information on deposition, temperature history, maturation and natural gas generation of Pennsylvanian coal-bearing strata. Deposition took place in a tropical climate. During the Mississippian, most of present-day northern and western Germany was covered permanently by the sea. High nutrient supply from nearby, vegetation-covered land triggered black shale deposition (Ghazwani et al., 2018). During the Early Pennsylvanian, transitional, continental-marine sedimentation set in.

Results and Discussion

Depositional environment of the oldest coals is difficult to decipher due to their high thermal maturity, but the younger Westphalian B and C coals are mostly within the oil window (high volatile bituminous coals) and well-suitable for organic geochemical and organic petrological studies. Coals thicker than 70 cm (representing peat thicknesses of > 5 m) are characterized by either topogenic, vitrinite- and ash-rich or ombrogenic, inertinite-rich, ash-poor peat facies. In many coal seams, changes from topogenic towards ombrogenic and back occur, sometimes several times. Marine ingressions occurred less and less often during the later Pennsylvanian, leading to (strongly) enhanced sulphur contents in the coals.

Organic matter quantity and quality as well as the general maturity pattern of the Pennsylvanian is of great importance for petroleum generation, in particular for natural gas generation. About 2/3 of all organic matter is stored in coals, 1/3 in dispersed organic matter, with highest organic matter contents being present in the west (e.g. Ruhr Basin), and much lower contents in the northeast of Germany. The maturity pattern is strongly influenced by burial history and only locally (to a very limited extent) by igneous activity. Deepest burial during the Pennsylvanian occurred in the south of the Ruhr Basin, leading to high maturities there (low volatile bituminous coal stage; Uffmann and Littke, 2013). Further to the north, in the North German Basin, deepest burial occurred either in the Cretaceous, before basin inversion, or in the Neogene. This complex burial history in combination with organic matter quantity led to a complex natural gas generation pattern, most favorable conditions being present in the northwest, where a thick coal-bearing sequence exists in combination with late, Paleogene and Neogene gas generation and trapping. One example for natural gas fed predominantly by Pennsylvanian coal-bearing source rocks is the giant Groningen field. This field has a relatively high nitrogen content; such high nitrogen contents are typical of Paleozoic gas fields in northern Germany, in particular in eastern Germany and the German North Sea, where partly more than 90 % nitrogen have been detected. Reasons for very high nitrogen contents are related to i) late nitrogen generation from coal/organic matter at the stage of very late diagenesis/early metamorphism, when methane generation potential is exhausted, ii) transformation of nitrogen from organic matter in clay minerals/silicates leading also to late diagenetic/early metamorphic release of nitrogen as well as iii) the absence of a strong methane source (Krooss et al., 1995; Littke et al., 1995).

Organic matter quality is mainly determined in the petroleum industry by Rock-Eval pyrolysis, although the method has severe shortcomings such as the missing detection of generated hydrogen (Li et al., 2015). Within the Pennsylvanian, severe differences exist between coals on the one hand and dispersed organic

matter from silt- and sandstones on the other taking severe influence on petroleum generation potential (Fig. 1; Jasper et al., 2009).

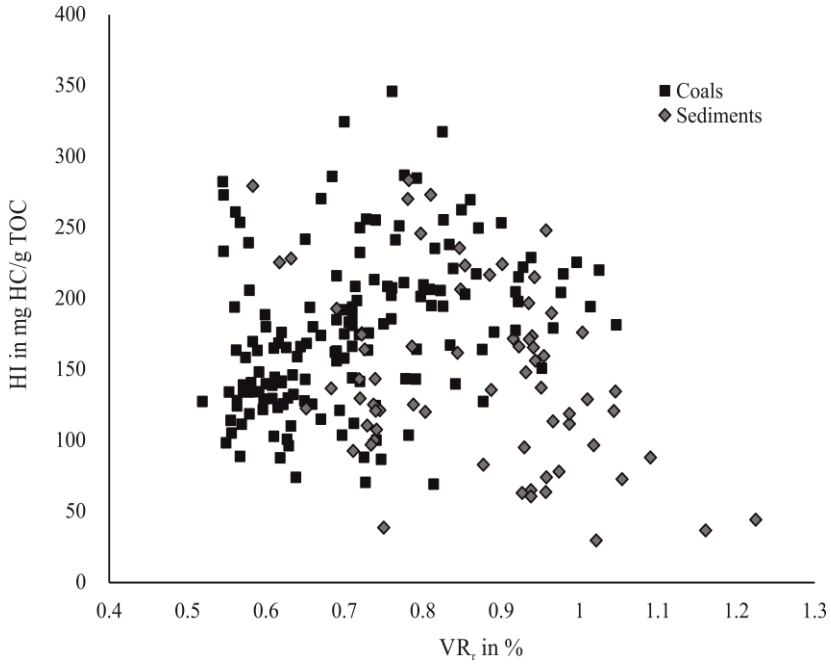

Figure 1. *HI versus vitrinite reflectance values of Pennsylvanian coals from the Ruhr Basin.*

References

Ghazwani, A., Littke, R., Gaus, G., Hartkopf-Fröder, C., 2018. Assessment of unconventional shale gas potential of organic-rich Mississippian and lower Pennsylvanian sediments in western Germany. International Journal of Coal Geology, 198, 29-47.

Jasper, K., Krooss, B. M., Flajs, G., Hartkopf-Fröder, Chr. Littke, R., 2009. Characteristics of type III kerogen in coal-bearing strata from the Pennsylvanian (Upper Carboniferous) in the Ruhr Basin, Western Germany: Comparison of coals, dispersed organic matter, kerogen concentrates and coal-mineral mixtures. International Journal of Coal Geology, 80, 1-19.

Krooss, B.M., Littke, R., Müller, B., Frielingsdorf, J., Schwochau, K., 1995. Generation of nitrogen and methane from sedimentary organic matter: Implications on the dynamics of natural gas accumulations. Chem. Geol., 126, 291-318.

Li, X., Krooss, B.M., Weniger, P., Littke, R., 2015. Liberation of molecular hydrogen (H2) and methane (CH4) during non-isothermal pyrolysis of shales and coals: Systematics and quantification. International Journal of Coal Geology, 137, 152-164.

Littke, R., Krooss, B., Idiz, E.F. Frielingsdorf, J., 1995. Molecular nitrogen in natural gas accumulations: generation from sedimentary organic matter at high temperatures. Amer. Assoc. Petr. Geol. Bull., 79(3), 410-430.

Schneider, W., 1995. Palaeohistological studies on Miocene brown coals of Central Europe. Int. J. Coal Geol., 28(2-4), 229-248.

Stock, A.T., Littke, R., Lücke, A., Zieger, L., Thielemann, T., 2016. Miocene depositional environment and climate in western Europe: The lignite deposits of the Lower Rhine Basin, Germany. International Journal of Coal Geology, 157, 2-18.

Uffmann, A.K., Littke, R. (2013). Paleozoic Petroleum Systems of the Münsterland Basin, Western Germany: a 3D Basin Modeling Study (Part 1: Model Input, Calibration and Maturation). OIL GAS European Magazine, 39, 140-146.