PS The Anisian Carbonates of the Peri-Tethys Basin: From Reservoir Characterization to Subsurface Utilization*

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Abstract

The sustainable subsurface utilization is focus of recent studies on Triassic sedimentary series in northeast Germany, aiming at geothermal energy and gas storage. Based on outcrop analogue studies on Anisian Peri-Tethys carbonate ramp deposits along a palaeogeographic transect from northwest Germany to south Poland (Götz and Lenhardt, 2011), well logs are analyzed with respect to the petrophysical rock properties and sequence interpretation. From outcrops, stratigraphic intervals of low, medium and high permeabilities are recognized, corresponding to transgressive, maximum flooding and highstand deposits in terms of sequence stratigraphy. Within large-scale, third-order depositional sequences, late highstand deposits represent the most permeable sediments.

In northeast Germany, the top of the up to 150 m thick Anisian carbonates is known to be at depths of 100 to 3,300 m (Hoth et al., 1993). This wide range of the tops is due to regional salt tectonics characteristic of the Southern Permian Basin Area, documented in the Petroleum Geological Atlas (Doornenbal and Stevenson, 2010). Here, a research well (Luckenwalde E Lw 1/1980) southwest of Berlin was investigated to demonstrate the high degree of lateral facies and poroperm continuity, contributing to subsurface reservoir characterization. Once the lateral and stratal facies successions and sequence architecture of the sedimentary basin and its distinct ramp system is known, a reliable reservoir prognosis becomes feasible from well logs.

The Anisian Carbonates of the Peri-Tethys Basin: From Reservoir Characterization to Subsurface Utilization

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Introduction

The sustainable subsurface utilization is focus of recent studies on Triassic sedimentary series in northeast Germany, aiming at geothermal energy and gas storage. Outcrop analogue studies serve to gain information on reservoir facies, sequence architecture, and petrophysical rock properties to be integrated into 3D reservoir models. Anisian carbonate ramp deposits of the Peri-Tethys Basin studied in outcrops along a palaeogeographic transect from peritidal environments in the north-western part of the basin (NW Germany) to subtidal sediments in the south-east (E Germany and S Poland) are considered as an outcrop analogue for layer-cake reservoirs (Götz and Lenhardt, 2011). Characteristic lateral facies distribution enables one to distinguish inner, mid, and outer ramp zones. Stratigraphically, distinct facies types build small-scale successions, displaying cyclic patterns of different hierarchies. Poroperm data of the main facies types are compared to published data (Noack and Schroeder, 2003; Borkhataria et al., 2006; Ehrenberg et al. 2007) and displayed within the basin-wide sequence stratigraphic framework.

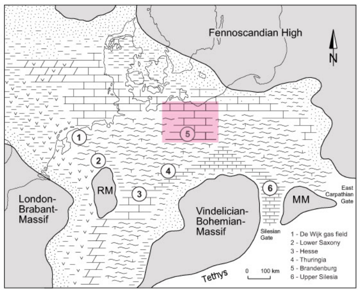
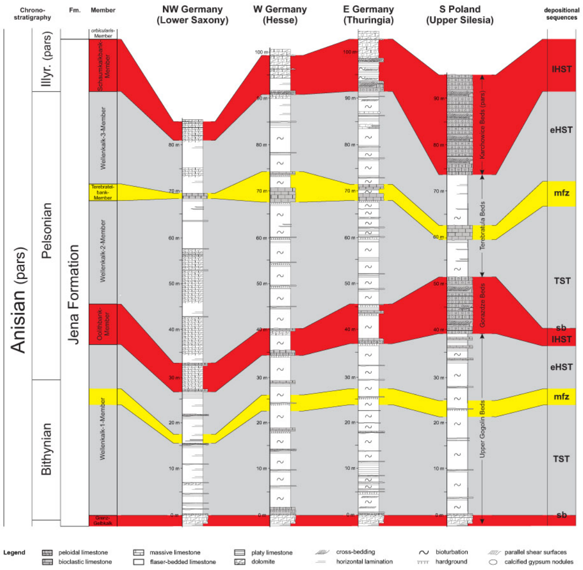


Fig. 1: Palaeogeography of the Germanic (Peri-Tethys) Basin during Pelsonian times and location of outcrops in Germany, Poland and the Netherlands; modified from Götz et al. (2005). Abbreviations used: RM - Rhenish Massif, MM - Małopolska Massif.

Materials and Methods

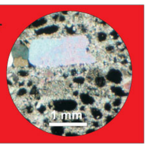
We sampled Muschelkalk carbonates from Lower Saxony, Hesse and Thuringia (Germany), from Upper Silesia (Poland) and used published data from Brandenburg (NE Germany) and the Netherlands (De Wjik gas field) to analyze porosities and permeabilities of the different lithofacies types. A total of 98 dried cubic plug samples was investigated to document the relation between lithology, porosity types, permeability, and the nature and intensity of fractures. Additionally, microfacies analysis was carried out to classify the main facies types (MFT). Separate measurements of skeletal density (helium pycnometer AccuPyc 1330) and envelope density (DryFlo pycnometer GeoPyc 1360) enabled the calculation of porosity. Permeability measurements were carried out using a gas mini-permeameter constructed by the TU Darmstadt.



high permeability

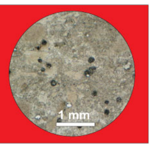
Strat.: Schaumkalkbank Member Lower Schaumkalk Bed

MFT1: Peloid Grainstone
φ = 12.0 %, κ = 7.0 mD
moldic porosity



Strat.: Uppermost Röt Grenzgelbkalk

MFT2: Dolo-Wackestone
φ = 24.0 %, κ = 6.1 mD
vuggy porosity



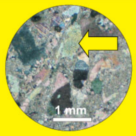
medium permeability

Strat.: Terebratelbank Member Lower Terebratel Bed

MFT3: Bioclastic Grainstone
φ = 8.0 %, κ = 3.1 mD
interparticle porosity

Strat.: Wellenkalk-1-Member Konglomerat Bed f4

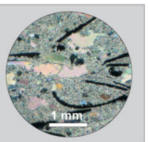
MFT4: Bioclastic Packstone
φ = 0.3 %, κ = 4.9 mD
inter-/intraparticle porosity



low permeability

Strat.: Wellenkalk-3-Member *Spiriferina* Bed

MFT5: Bioclastic Wackestone
φ = 0.5 %, κ = 1.9 mD
moldic porosity



Strat.: Wellenkalk-2-Member Lower Wellenkalk

MFT6: Nodular Mudstone
φ = 0.2 %, κ = 1.2 mD
stylolithic porosity

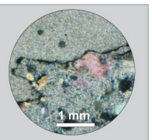


Fig. 2: Lower Muschelkalk facies types characterized by low, medium and high permeabilities, building basin-wide layer-cake reservoir zones. Within large-scale, third-order depositional sequences late highstand deposits represent the most permeable sediments.

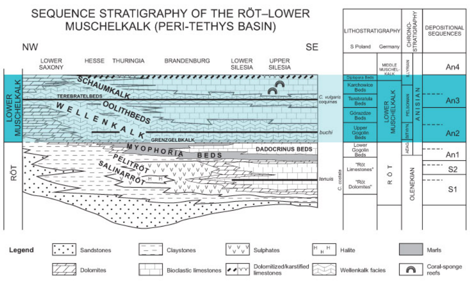


Fig. 3: Palaeogeographic cross-section (NW-SE) of the Middle Triassic (Anisian) Peri-Tethys Basin (Central Europe) and sequence stratigraphic framework of the Lower Muschelkalk depositional series (modified from Szulc, 2000).

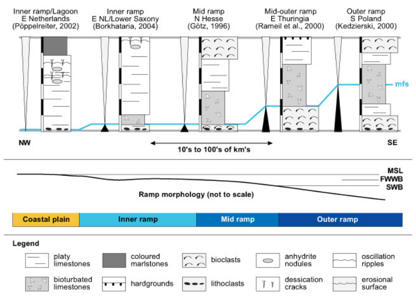


Fig. 4: Conceptual correlation of small-scale sequences of the Lower Muschelkalk ramp system, modified after Pöppelreiter (2002) and Götz and Török (2008). sb - sequence boundary, mfs - maximum flooding surface, MSL - mean sea level, FWWB - fair-weather wave base, SWB - storm wave base.

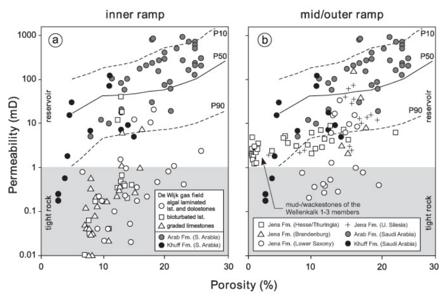


Fig. 5: Porosity/permeability crossplots comparing Lower Muschelkalk values to those of Middle East Arab and Khuff formations: a) Inner-ramp facies from the De Wijk gas field, NE Netherlands (data from Borkhataria et al., 2006); b) Mid- and outer-ramp facies from the Osnabrück, Großenlüder, Steudnitz and Rüdersdorf quarries, Germany (Rüdersdorf data from Noack and Schroeder, 2003), and the Strzelce Opolskie quarry, Poland.

Results

Muschelkalk carbonates from the Netherlands, Germany and Poland were analysed with respect to reservoir characteristics. Dolo-wacke-/packstones and peloid grainstones attain the highest porosities of up to 24%, bioclastic grainstones show porosities of up to 8%. The platy and nodular mud-/wackestones and most of the bioclastic wacke-/packstones of the Wellenkalk members typically show porosities below 2%. Even in the most porous strata (Grenzgelbkalk, Oolithbank and Schaumkalkbank members), permeabilities do not exceed 10 mD, and only a few carbonates (peloid shoals of the Schaumkalkbank Member, E Germany; grainstones of the distal ramp, Gorazdze and Karchowice beds, S Poland) show higher permeabilities up to 90 mD. According to the measured permeabilities, carbonates of the Anisian Peri-Tethys ramp system are grouped into three classes: low permeability rocks (k < 2 mD), medium permeability rocks (k < 7 mD), and high permeability rocks (k < 20 mD; max. 90 mD). The facies architecture consists of layer-shaped large-scale depositional sequences of tens of metres subdivided in small-scale, metre-thick cycles (Götz and Török, 2008). Transgressive and early highstand deposits, build up by nodular mudstones and bioclastic wackestones, have low permeability; bioclastic carbonates of maximum flooding phases, grainstones and packstones, have medium permeability. Late highstand deposits, peloid grainstones and dolo-wackestones, represent the most permeable sediments. In terms of reservoir geometry, the area studied represents a layer-cake structure with laterally continuous fluid-flow units. The here detected high degree of lateral facies and poroperm continuity contributes to subsurface reservoir characterization, where often only limited well and seismic data are available. Once the lateral and stratal facies successions and sequence architecture of the ramp system is known, a reliable reservoir prognosis for subsurface utilization becomes feasible from well logs.

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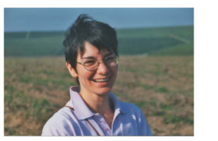

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