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 Tertiary 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 paleogeographic transect from pelitidal environments in the north-western part of the basin (NW Germany and the Dutch E-W gas field) to alpine settings in the south-eastern part of Poland and the Carpathians (S Poland) are considered as an outcrop analogue for layer-cake reservoirs (Götz and Lachnit, 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. Provenance data of the main facies types are compared to published data (Nooij and Schroeder, 2003; Borkhaila et al., 2006; Ehrmann et al., 2007) and displayed within the basin-wide sequence stratigraphic framework.

Materials and Methods

We sampled Muschelkalk carbonates from Lower Saxony, Hesse and Thuringia (Germany), from Upper Silurian (Poland) and used published data from Brandenburg (NE Germany) and the Netherlands (De Wijk 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, microporosity analysis was carried out to classify the main facies types (MFT). Separate measurements of skeletal density (helium pycnometer Accufy 1330) and enveolopy porosity (Götz GeoPyC 1360) enabled the calculation of porosity. Permeability measurements were carried out using a gas mini-permeameter constructed by the TU Darmstadt.

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 mudstones/stonkstones and most of the bioclastic wacke-packstones of the Wetteren members typically show porosities below 2%. Even in the most porous strata (Grenzgebirge, Oeddbath and Schubreinkalk members), permeabilities do not exceed 10 mD, and only a few carbonates (peloid shales of the Schubreinkalk Member, E Germany; grainstones of the distal ramp, Gonschitz and Karchowice beds, S Poland) show higher permeabilities up to 80 mD. According to the measured permeabilities, carbonates of the Anisian Peri-Tethys basin 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. 80 mD). The facies architecture consists of layer-shaped large-scale depositional sequences of tens of metres subdivided in small-scale, meter-thick cycles (Götz and Türk, 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-packstones, 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 described high degree of lateral facies and programpm continuity contributes to subsurface reservoir characterization, where often only limited wall and seismic data are available. Once the lateral and stratigraphic facies successions and sequence architecture of the ramp system is known, a reliable reservoir prognosis for subsurface utilization becomes feasible from well logs.

Fig. 1: Paleogeography of the Germanic (Peri-Tethys) Basin during Palaearktic times showing location of outcrops in Germany, Poland and the Netherlands. Modified from Götz et al., (2005). Abbreviations used: RM - Rothneus Member; MMT - Mariensiel Member.

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 lateral highstand deposits represent the most permeable sediments.

Fig. 3: Paleogeographic cross-section (NM-GE) of the Middle Triassic (Anisian) Peri-Tethys Basin (Central Europe) and sequence stratigraphic framework of the Lower Muschelkalk depositional series (modified from Schott, 2000).

Fig. 4: Conceptual correlation of small-scale sequences of the Lower Muschelkalk ramp system, modified after Poppetweiler (2002) and Götz and Türk (2008). 3D - sequence boundary, mFB - maximum flooding surface, MSL - mean sea level, FWWB - far-weather wave base, SWWB - storm wave base.

Fig. 5: Porosity (permeability) crossplot comparing Lower Muschelkalk values to those of Middle East Arab and Kufra formations: a) Inner-ramp facies from the De Wijk gas field, NE Netherlands (data from Borkhaila et al., 2006). b) Mid- and outer-ramp facies from the Onschrink, Großenbütter, Steinhilde and Rüdersdorfer quarries, Germany (Rüdersdorfer data from Nooij and Schroeder, 2003) , and the Strelitzke Oktische quarry, Poland.

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