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TNO Report | Public summary of the final report

Conceptual diagenetic models for cementation in Rotliegend sandstones

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1 Public summary

A full colour, over 100 pages, report with many colourful graphs and illustrations is available. This document only represents a brief public summary of that report. For more information on this topic, please turn to TNO or one of the sponsors for additional information.

1.1 Background and aim of the project

Porosity and permeability determine to a large extent the reservoir quality and the success of gas production. The growth of cements (= diagenetic minerals) can lead to severe reservoir quality reduction locally. This study is aimed at the understanding of processes that influence cement diagenesis in relation to porosity and permeability loss in the Upper Rotliegend sandstones.

1.2 Approach

A detailed, quality controlled petrographic database was compiled. This database was the foundation for the study. The data was sourced from publicly available reports from the Geological Survey of the Netherlands, literature and confidential reports supplied by Total E&P Netherlands. The database contains thin section petrography data, X-ray Diffraction and Mineralog data, and sedimentological and conventional core analysis data. Cements and detrital components were combined according to hierarchical categories and statistical and cluster analyses (using SPSS) were performed on cement groups in relation to porosity and permeability. Thin-section and scanning electron microscopy images were screened to understand mineral relationships and paragenetic sequences.

For single well locations basin modeling was performed using the software PetroMod 2015 to determine burial history, including the temperature and pressure history of the studied location based on calibrated 1D models. The 1D and the TNO-produced temperature, maturity, and pressure 3D basin models were combined with petrography to establish locally dominant mechanisms of cementation. For a selected area (K5, K6, L5 and L6 blocks), paragenetic sequences of events were reconstructed. Additionally, fault modelling, differentiation of gas/water wells and contacts, overpressure, gas compositions and clay volume calculation was undertaken for the case study area.

1.3 Results

Although mechanical compaction has a major impact on the reservoir quality, particularly in clay matrix/clay laminae rich sediments, reservoir quality is also clearly reduced by cementation. Aeolian deposits have generally a lower detrital clay content, better soring and better reservoir quality than fluvial and sabkha/lacustrine deposits. Overall, the main cements that decrease porosity and permeability are carbonates (particularly ankerite) and to a lesser degree sulphates (mainly anhydrite). High contents of illite cement are responsible for permeability reduction.

The illite/kaolinite ratio does not increase with depth, as previously assumed. Instead, prolonged deep burial likely lead to significant illite formation. This is preferred in fluvial environments, particularly in proximal alluvial unconfined and overbank deposits where high detrital clay contents could be converted to authigenic illite.

The acidic fluids from the coal-bearing Carboniferous strata are responsible for significant dissolution and precipitation of a variety of minerals. They promote the dissolution of feldspar, early carbonate cements (calcite and dolomite) and Fe-oxides. On the other hand they encourage the growth of kaolinite, illite, ankerite, siderite and barite. The dissolution of feldspar delivers significant amounts of aluminium and silica for kaolinite and a quartz formation. The original feldspar content may thus have been central to kaolinite, quartz (and partly illite) formation. The influx of the acidic Carboniferous fluids tends to cause a zonation in the authigenic mineralogy (up to a few 10-100m vertically and few km laterally). A kaolinite zone is followed by an illite zone and an ankerite zone is followed by a dolomite zone.

Evaporitic conditions towards the Silverpit and the Zechstein strata promoted the precipitation of sulphates and carbonates (initially as gypcretes, calcretes and dolocretes). Also the Slochteren sandstones experienced an increase in anhydrite, ankerite, barite and dolomite cements towards the Zechstein and Silverpit. The formation of these minerals was either synsedimentary or by fluid expulsion from the Silverpit playa lake towards the adjacent Slochteren sandstones during early burial. Upon further burial, P/T increase lead to conversion of gypsum to anhydrite and calcite to dolomite or ankerite (depending on Fe^{2+} activity). In evaporative environments the burial resulted in further saturation and precipitation of dolomite that was transferred to ankerite by continuous solid solution during intermediate and late diagenesis.

A further impact on sulphate (mainly anhydrite) cementation also likely occurred during the late Jurassic inversion. The elevation of the Silverpit and Zechstein evaporites to the ground-water level led to dissolution of sulphates via meteoric fluid interaction. However, to facilitate the fluid transport to and precipitation of anhydrite in the Slochteren sandstones an fracture network or tectonic juxtapositioning with Zechstein/Silverpit evaporites is required. The juxtapositioning of the Carboniferous, Silverpit and Zechstein against the Slochteren deposits did have an impact on cementation, however a more rigorous fault study is necessary to identify the locations.

The diagenetic models can be used to predict locations of enhanced cementation of a particular cement or cement combination and the related porosity/permeability loss. The conceptual diagenetic models presented in this study may vary locally and therefore regional effects (e.g. magmatic activity) need to be considered before applying the models for reservoir quality prediction.

1.4 Recommendations

The results exemplify that the research on a multi-vintage and multi-source petrographic data can deliver an understanding of diagenetic processes that are related to reservoir quality. The study of cementational reservoir quality reduction could be greatly improved by accessing more (currently confidential) petrographic data and including new analyses on more (already existing) core material. To be able to reconstruct the paragenetic sequences with more certainly a good cement dating procedure is required. Facies and sub-environment interpretation needs to be improved and extended, as it may provide more information than revealed in this study. Consequently, a detailed geological subsurface model is essential to propagate cementational trends and trace fluid flow pathways.

1.5 The project

The project was successful. It achieved its main goal and all partners worked constructively together. Part of the work has been presented at the EAGE 2017 in Paris. Session: 2.04 Diagenesis in Clastic Reservoirs under the title: Cementation in the Dutch Upper Rotliegend siliciclastic reservoirs
(http://earthdoc.eage.org/publication/publicationdetails/?publication=88330)

1.6 Acknowledgment

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