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High-resolution 3D X-ray microtomography as tool to investigate size distribution of grain phase and pore space in sandstones

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The geometry and internal structures of sandstone reservoirs, like grain size, sorting, degree of bioturbation, and the history of the diagenetic alterations determine the quantity, flow rates, and recovery of hydrocarbons present in the pore space. In this respect, processes influencing the deep reservoir quality in sandstones are either of depositional, shallow diagenetic, or deep-burial origin. To assess the effect of compaction and cementation on the pore space during diagenesis, we investigated a set of sandstone samples using high-resolution microtomography (μ-CT).

By high-resolution μ-CT, size distributions (in 2D and 3D), surface areas and volume fractions of the grain skeleton and pore space of sandstones and – in addition - of mineral powders have been determined. For this study, we analysed aliquots of sandstones that exhibit either complete, partial or no cemententation of the pore space, and sets of mineral powders (quartz, feldspar, calcite). As the resolution of the μ-CT scans is in the μm-range, the surface areas determined for sandstones and powders do detect the geometric surface of the material (Kahl & Holzheid, 2010).

Since there are differing approaches to "size" parameters like e.g., long/short particle axes, area equivalent radius, Feret-diameter (2D), and structural thickness (3D), we decided to illustrate the effect of various size determinations for (a) single grains, (b) grain skeletons, and (c) pore space. Therefor, the computer-aided morphometric analysis of the segmented 3D models of the reconstructed scan images comprises versatile calculation algorithms.

For example, size distribution of the pore space of partially cemented sandstones can be used to infer the timing of the formation of the cement in respect to tectonic/diagenetic activities. In the case of a late-stage partial cementation of a Bunter sandstone, both pore space and cement phase show identical size distributions. On the contrary, the anhydrite cement of a Rotliegend sandstone exhibits a size distribution that is shifted to higher values than the size distribution observed in the unfilled pore space: Here, the anhydrite cementation inhibited compaction, which was only active in the uncemented regions of the rock.

In general, for quality prediction of sandstone reservoirs, high-resolution microtomography offers a great potential to quantify important rock properties but also to deduce the formation history of sandstones.

References

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