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Sedimentological Analysis and Permeability Prediction within Highly Heterogeneous Carbonate Reservoirs using Borehole Image Logs

APLIN, GRAHAM F., AJAY K. SAPRU, and MARK J. F. LAWRENCE, Baker Atlas Geoscience, Aberdeen, Scotland

Carbonate reservoirs often display considerable heterogeneity ranging from the reservoir to the micro-scale, which can result in significant variations in permeability and hence producibility. Understanding permeability distribution is of fundamental importance in reservoir characterization. Borehole image logs have been used to predict lithofacies and permeability distribution within heterogeneous carbonate reservoirs and examples from two contrasting but highly heterogeneous reservoir types have been studied.

The first reservoir is characterized by considerable small-scale permeability heterogeneity associated with thin (cm-scale) vuggy bioclastic-rich facies that form high permeability streaks and cemented intervals associated with stylolites that form tight zones. These thin beds are below the resolution of standard openhole logs but are readily identified from the borehole images. The borehole images have been calibrated using core and an image facies scheme has been established. The image facies have been used to predict lithofacies distribution and lithofacies stacking patterns within uncored wells. A permeability ranking has been applied to each image facies and used to provide an estimate of permeability distribution and heterogeneity within uncored wells.

The second reservoir comprises a succession of thermally karstified nodular carbonates characterized by extreme small-scale permeability heterogeneity. Probe permeability analysis was undertaken on representative core samples and a series of probe permeability images generated from 2–dimensional permeability grids measured on slabbed core surfaces. The probe permeability images demonstrate the extreme permeability variation within these limestones. Petrographical analysis of large format thin sections from these sites indicates that the permeability variations are associated with subtle variations in microporosity and vuggy porosity development within the highly corroded internodule matrix, cementation within nodules and very high permeabilities associated with vugs, moulds and fractures. Borehole image logs were used to characterize permeability heterogeneity outside of the cored intervals. Image thresholding was undertaken using borehole microresistivity image logs to evaluate the contribution of various rock volumes to permeability based on a series of cut-offs, these cut-offs were calibrated using the permeability images. Integration of the permeability images, petrography, borehole image facies and thresholding provided an understanding of the complex relationships between depositional and diagenetic controls on reservoir heterogeneity and allowed the distribution of high permeability zones to be identified.

These studies demonstrate that where borehole images are calibrated with core data they can provide a meaningful understanding of permeability heterogeneity within complex carbonate reservoirs.