CHARACTERISATION OF CARBONATE RESERVOIR HETEROGENEITY USING PROBE PERMEABILITY IMAGES, PETROGRAPHY AND BOREHOLE IMAGE LOG DATA

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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. Small-scale permeability heterogeneity within a complex nodular limestone reservoir has been evaluated using a combination of probe permeametry, petrography and borehole image logs. The limestones in the reservoir are characterised by extreme reservoir heterogeneity and have undergone a complex diagenetic history, with early compaction and porosity loss followed by a major episode of porosity generation during late burial associated with thermal karstification.

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 at a 4 mm spacing (Figure 1). The probe permeability images demonstrate the extreme permeability variation within these limestones. Large format thin sections were prepared from these sites in order to evaluate the controls on permeability distribution. Petrographical analysis indicates that the permeability variations are associated with subtle variations in microporosity and vuggy porosity development within highly corroded internodule matrix, cementation within nodules and very high permeabilities associated with vugs, moulds and fractures.

In order to characterise permeability heterogeneity outside of the cored interval microresistivity borehole image logs were used. The nodular limestones that dominate the succession have been divided, for the purposes of reservoir characterisation, into a series of image facies based on the proportion of resistive nodule to conductive internodular matrix and matrix mineralogy. Calibration with core indicates that individual image facies show a wide range in permeability, reflecting the highly heterogeneous nature of the sediments and the proportion of nodule to porous and permeable internodule matrix.

Image thresholding was undertaken to evaluate the contribution that various rock volumes make to permeability within the limestones. A series of cut-offs were determined based on the range in conductivity (colour) of the borehole image logs that were considered to be representative of the potential permeability classes within the limestones. Statistical analysis of the image log data using the cut-offs produces a continuous trace of the abundance of each potential permeability class and a figure for its cumulative abundance within the reservoir.

back to contents

Integration of the permeability images, petrography, 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.

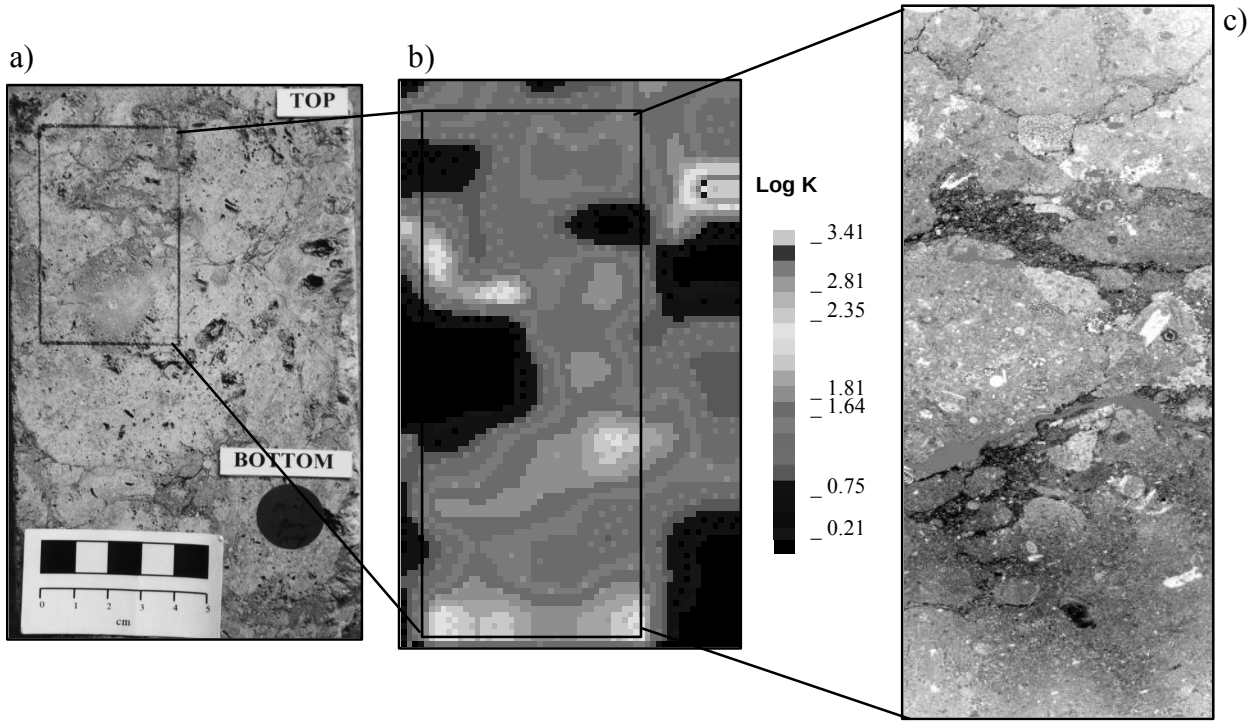

Figure 1. Probe permeameter measurements were made on representative core samples (a) on a 4 mm grid, with the results presented as probe permeability maps (b). To evaluate the controls on reservoir permeability distribution large format thin sections were prepared from the same site (c).

Image permeability class	Probe permeability range (mD)
Tight	<0.5
Low	0.5-10
Moderate	10-100
High	>100

Table 1. Probe permeability ranges for image threshold classes

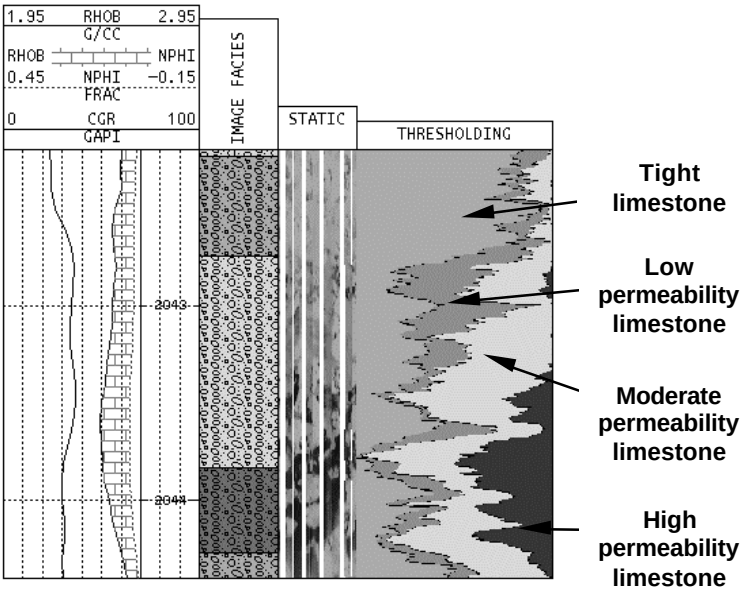

Figure 2. A series of conductivity cut-offs were established from the image logs and calibrated using the probe permeability data (Table 1) in order to provide an understanding of permeability contribution from given volumes of rock within the reservoir, and an understanding of permeability heterogeneity outside of the cored interval.

back to contents