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Influence of Mineralogy and Macroporosity on Reservoir Quality: Example of the Upper Mannville Incised Valley Fills in West-Central Alberta

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Incised valley fills of the Upper Mannville contain significant gas resources in West-Central Alberta. These reservoirs resulted from the erosion of complex drainage networks associated with major relative sea level fall episodes and their subsequent filling by fluvial to estuarine sandstones. The immature modal composition of these sandstones suggests that they were sourced from uplifted crystalline basement with limited chemical weathering. This resulted in a complex mineralogy which made these reservoirs prone to various dissolution and cementation processes during burial compaction and diagenesis.

The variable mineralogy of these incised valley fills has a strong impact on their reservoir quality. Wireline logs, DSTs and production data from hundreds of wells in addition to conventional core analysis data, have demonstrated the great variability of the reservoir properties of these sandstones, at both regional and local scales. Furthermore, interpretation of reservoir quality and fluid saturation from logs is impeded by the strong influence of lithology on porosity and resistivity logs. Consequently, a good understanding of the variability of the mineralogy and its impact on the porosity and permeability is crucial for reducing the risk in exploring and developing these types of reservoirs.

This contribution presents the results of a detailed investigation of the petrography, quantitative mineralogy and petrophysics of 90 samples from the Upper Mannville incised valley fills in West-Central Alberta. The analyses include optical microscopy on 71 core samples, advanced mineral mapping techniques using SEM coupled with energy dispersive X-ray spectrometry (QEMSCAN) on 21 core samples and 19 cutting samples, as well as conventional porosity and unsteady state permeability measurements on 21 core samples (Darcylog on crushed cores).

The sandstones are arkosic with various amounts of quartz, K-feldspar, plagioclase, mica, detrital and authigenic clays, pyrite and calcareous cements and nodules. The total amount of carbonate ranges from 0 to 69% in volume and comprises dolomite and calcite cements and large siderite nodules. Clay content varies between 4 and 29% in volume, with various proportions of smectite, illite, mixed-layer clays, kaolinite and chlorite. A clear negative correlation exists between clay and carbonate content and suggests an adverse effect of clay on carbonate cementation. Calcite appears to be the last carbonate cementation phase and the most destructive for porosity. Siderite is frequently observed as an early grain rimming cement and is commonly post-dated by other cement phases such as dolomite, calcite and kaolinite. Locally where siderite grain rimming cements have not been post-dated by more pervasive cementation, significant porosity and good reservoir quality may be preserved. However, in general, clay-rich samples exhibit better reservoir quality because of their lower carbonate cement content. The different types of porosity observed include primary intergranular porosity, secondary porosity related to feldspar dissolution and microporosity associated with clays.

The porosity of the analyzed samples ranges from 3 to 21%, with permeability varying from less than a microdarcy to 30 md. The porosity-permeability relationship is not well defined in the high porosity range (18-21%), where permeability varies from 1 to 30 md. Macroporosity was quantified using QEMSCAN mineral maps with a ten micron beam stepping interval, and was found to offer a better correlation with permeability than total porosity. In the low porosity range, microporosity dominates and the permeability is less than 1 md.

Core data is rarely available in the study area and evaluating reservoir quality using cuttings is valuable. Total porosity and permeability measurements were performed on small volumes of crushed cores, because quantities of cuttings available for this study were too small. However, this method can be widely applied to cuttings, providing that each sample is at least 1 cc in volume. Thanks to the strong correlation between macroporosity and permeability, the macroporosity determination were used as a proxy for permeability in cuttings. Permeability and macroporosity combined with mineralogy and texture information provide a practical way of defining rock types from cuttings. These rock types can be used to help evaluate prospective zones and design drilling and completion strategies in these challenging reservoirs.