Variations in Illite Concentration: A Mapping Tool for Porosity Preservation in Tight Clastic Deep Reservoirs

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Extended abstract

Geologic Overview and Objective

The Ordovician tight clastic sequences of Arabia are interpreted to have been deposited as glaciogenic amalgamated turbidite fans analogous to the Mesozoic turbidites of Tanzania, E. Africa (Fig.1). Characterizing the marked heterogeneity in these potential hydrocarbon prospects is vital to achieving economic success in the exploitation of regional hydrocarbon resources. One of the key parameters to characterize is porosity. Previous studies investigated the role of clays such as chlorite and illite in preserving porosity by inhibiting quartz overgrowth (Fig.2). This paper explores the use of variations in clay concentration, namely illite, to produce regional maps for porosity preservation within the tight clastic deep reservoirs of the Arabian Peninsula. However, existing petrophysical models do not accurately represent the mineralogy of these reservoirs due to the large difference in resolution between what is resolvable from logs and measurable from cores. Hence, core data have been collected and analyzed as part of this study to calibrate log-derived mineral volumes, which serve as a mapping tool for porosity preservation to be used for prospect generation, sweet spot identification and risk analysis.

Glaciomarine Turbidite Fans

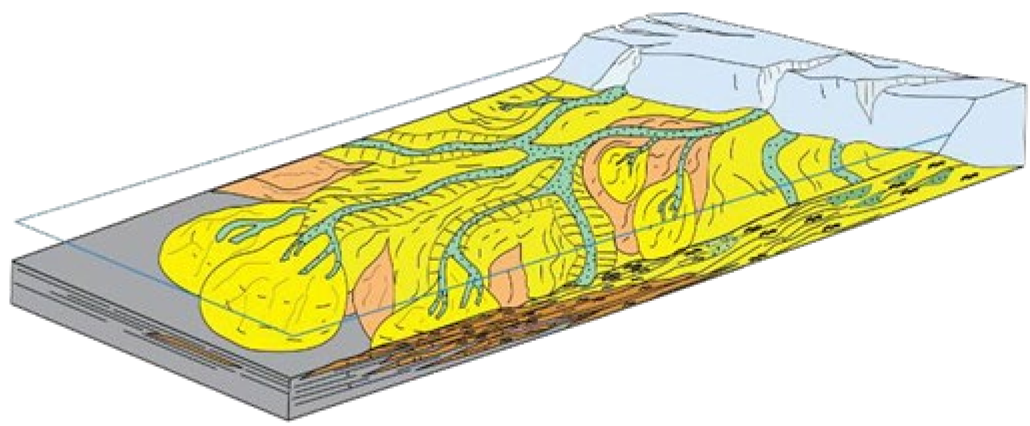

Figure 1: Schematic diagram of glaciomarine turbidite fans. Figure modified from Deschamps et al. (2013).

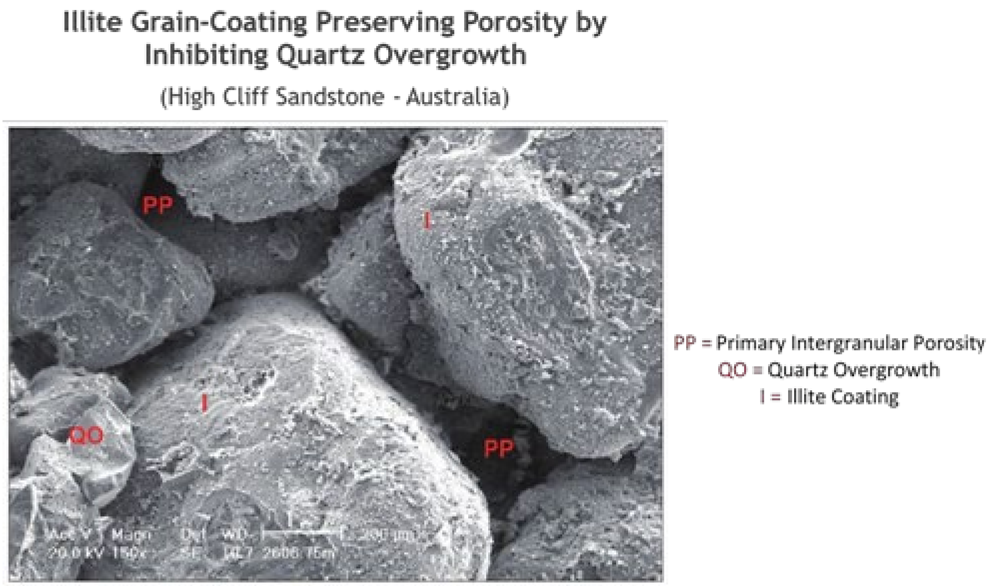

Figure 2: Interconnected primary porosity shielded from quartz overgrowth by grain-coating illite. Figure reproduced from Ferdinando et al. (2007).

Methodology

Thin-sections and SEM images were prepared from 973 core samples taken from 26 vertical wells targeting the first 300-500 ft of tight Ordovician sequences, where previous studies indicated that micro- pores are the dominant regional porosity type. Samples were selected to include four major sedimentological rock types (RT1 to RT4) prevalent in the study area after a depositional analogue in East Africa modified by Fuhrmann et al., (2022) (Fig.3 and 4). RT1 represents the highest reservoir quality, while RT4 the lowest, accordingly. A point count analysis was conducted on the basis of 300 counts per thin-section to obtain illite and quartz cement volume percent, while porosity was measured conventionally in core plugs using He injection. Various XRD datasets acquired separately by different service providers were also examined.

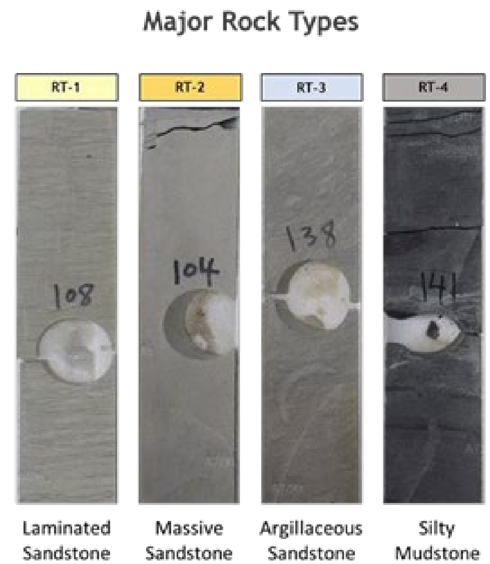

Figure 3: The four major sedimentological rock types prevalent in the study area. Figure Compiled by Mohammed Al Ahmed from core images taken by Fahd Almalki

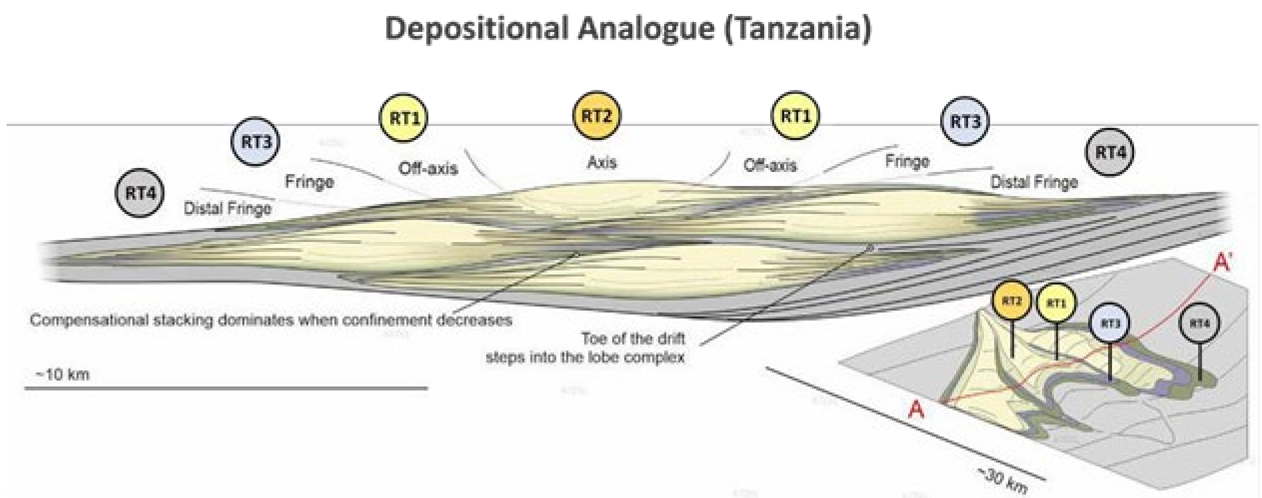

Figure 4: Turbidite fan stacking pattern and facies distribution analogue from offshore Tanzania, E. Africa. Figure modified from Fuhrmann et al. (2022).

Results and Discussion

He porosity vs point count cross-plots generally show a clear positive correlation between illite concentration and porosity (Fig.5). RT1 has the highest concentration of fibrous authigenic illite formed in pore space primarily within a laminated quartz-rich sandstone. Conversely, quartz overgrowth is prevalent in RT2, where clay laminae are subtle and low in frequency. This is generally coincident with lower porosity compared to RT1. The lowest concentration of fibrous illite is mostly found in RT3 and RT4, which consist of argillaceous sands and silt, respectively, with high detrital clay content. These rock types are also the least porous.

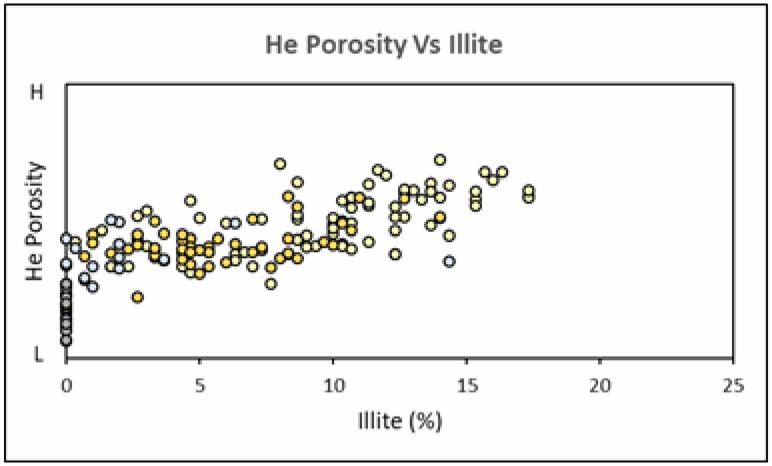

Figure 5: He porosity from conventional core analysis (CCA) plotted against fibrous authigenic illite from point count data analysis.

The results above indicate that porosity is mostly hosted within illite micro fibers shielding the matrix from quartz cementation; where fibrous illite is lacking, either detrital clays, including amorphous illite, or quartz cement fill the pore space leading to a reduction in porosity. SEM and thin-section images support this proposition (Fig.6).

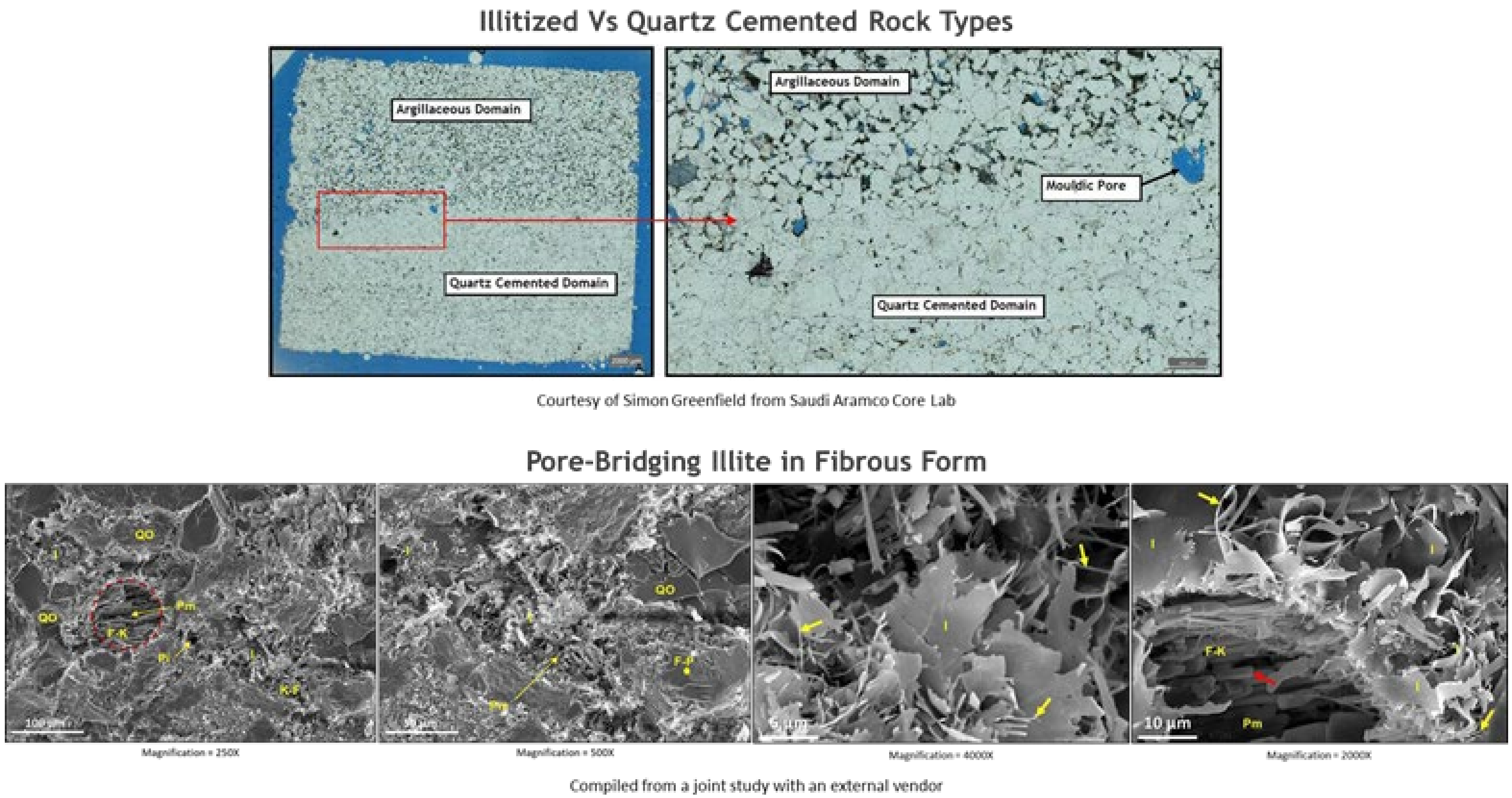

Figure 6: (Top) A thin-section image showing the illitized and quartz cemented sandstone facies (i.e. RT1 and RT2), where the former clearly displays higher visual porosity. (Bottom) SEM images of progressively higher resolution (left to right) showing fibrous pore-bridging illite.

A conclusive relationship could not be determined using XRD, as measured illite concentrations were much lower in comparison to point count, due to resolution limitations in the sampling technique. The concentration of authigenic illite measured through point count did not exceed 20%. In theory, the porosity vs illite curve beyond data coverage will plateau and eventually start to decline as pore volume is reduced. More data is being collected to verify this premise and to calibrate current petrophysical models with sufficient accuracy. In addition, in an attempt to better represent petrographic observations in petrophysical outputs, a density-based approach has been employed to generate a volume of clay curve representative of illite laminations hosted within the reservoir facies (i.e. RT1 and RT2) to allow the use of variations in illite concentration to serve as a mapping tool for porosity preservation. The preliminary results from 26 wells showed a good match between this calculated curve and log- based total porosity (PHIT), and an inverse relationship with GR (Fig.7). However, the quantitative output of this density-based curve was found to only work reasonably in reservoir facies (RT1 and RT2), in alignment with the results obtained from the point count data analysis. In non-reservoir facies (RT3 and (RT4), the volume of clay calculated is not satisfactory. Hence, the applied formula is being adjusted to remedy this issue. At this stage, this approach can be employed to generate qualitative regional porosity preservation maps.

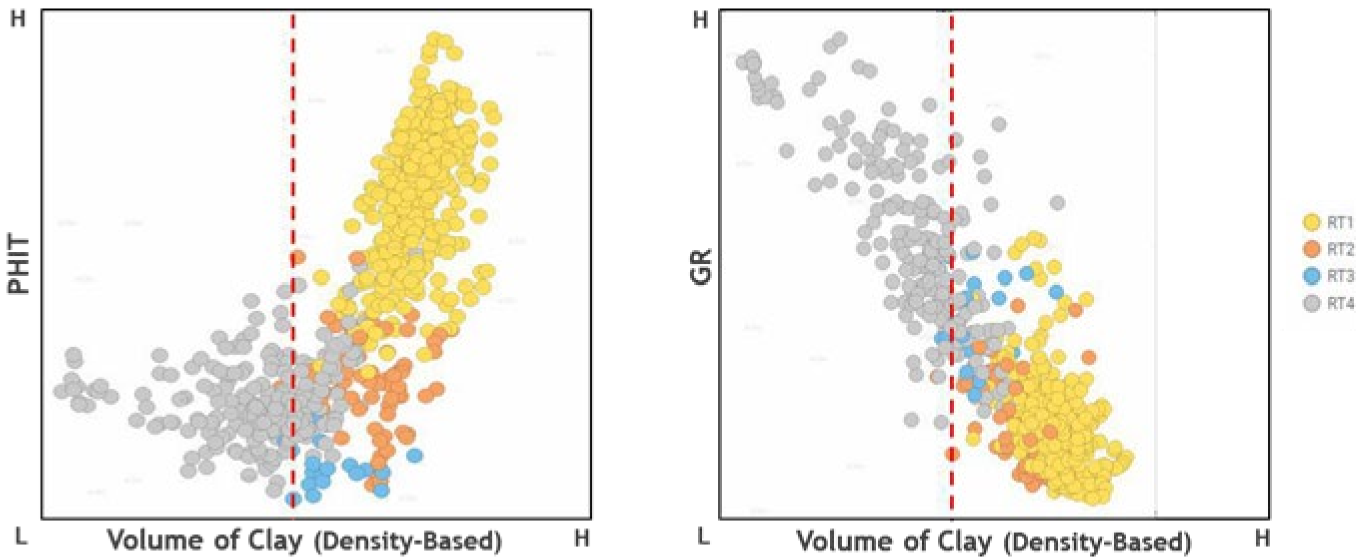

Figure 7: (Left) Log-based total porosity (PHIT) plotted against volume of clay generated empirically from density- based equations. (Right) GR plotted against volume of clay generated empirically from density-based equations.

References

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