The Reservoir Quality of Tithonian Sandstone from Mizzen F-09; the application of whole rock inorganic geochemical data

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Introduction

Reservoir quality primarily reflects the properties of porosity and permeability, the ability to store a fluid and transport it between the particles that make up the rock. Reservoir quality data is predominantly measured during the acquisition of routine core analysis (RCA) data on core plugs. From the plugs subsequent analysis, such as petrography, scanning electron microscopy (SEM) or QEMSCAN may be carried out. However, these techniques are time consuming and costly, requiring specialist equipment, therefore this study presents a supplementary technique; the application of whole rock inorganic geochemistry for reservoir quality assessment.

Reservoir quality is greatly influenced by 1) depositional environment and 2) diagenesis, both of which can be modelled and understood with the application of whole rock geochemistry. Individual environments of deposition do not have their own geochemical signature, but the geological processes that occur within those environments can be manifested within the geochemical fingerprint. For example, a channel sand may be characterised by high Si/Al values as clay minerals are winnowed from the sediment by the high energy within the environment. Low energy environments would be characterised by lower Si/Al, but also the type of clay mineral may reflect the environment – high Ga within an enhanced chemical weathered zone that has been subaerially exposed could reflect kaolinite formation, while Cs is concentrated in illite/smectite and can be used as a proxy for marine conditions and would be interpreted as deposition within an outer shelf or represent a marine flooding event. Fluvial systems may be characterised by high K/Al values reflecting the mineralogical immaturity of the sediment, while high Zr/Sc values may reflect the continued reworking of sediment within a tidally influenced area. Diagenesis may reflect physical changes, such as compaction, and these will have very limited geochemical expression. However, precipitation and dissolution of authigenic phases will alter the mineralogy and therefore reflect changes in the geochemistry.

The application of whole rock geochemistry provides two developments with the understanding of reservoir quality; the first is a preliminary assessment of the mineralogical controls on the reservoir quality based on the changes in whole rock geochemistry. Analysing the samples first for geochemistry provides a cost effective and rapid means to pre-screen the samples before the selection of thin sections there by increasing the efficiency of petrography/SEM/QEMSCAN work. In addition, geochemical data also provides a means to establish the geochemical controls on the reservoir quality and predict the quality of the sandstones within adjacent reservoir sections that are only sampled by ditch cuttings material. It is also predict the depositional facies in cuttings by characterising the geochemical signal of individual facies in core sections as a means to calbrate the geochemical facies in cuttings. This can be cross checked by sedimentological and E-log calibration in the core and electro facies in cuttings.

This study focuses on the Mizzen wells, F-09, O-16 and L-11, located within the Flemish Pass Basin of the Grand Banks, offshore Newfoundland. Whole rock geochemical data is acquired from samples with corresponding RCA data, the geochemical controls on the reservoir quality are established and selected thin sections are taken to test these interpretations. Furthermore, with the establishment of the geochemical controls the reservoir quality is then predicted within the equivalent reservoir sections of the Mizzen L-11 and Mizzen O-16 in which the Tithonian reservoir sandstones are sampled through ditch cuttings. As a demonstration facies data (Haynes et al. 2014) is geochemically characterised to establish how the facies is manifested within the geochemical data.

Methodology

For this study samples (Table 1) were selected and analysed for whole rock geochemistry using inductively-coupled plasma - optical emission spectrometry (ICP-OES) and inductively-coupled plasma - mass spectrometry (ICP-MS) instruments. Samples are prepared using the fusion technique advocated by Jarvis & Jarvis (1992a & 1992b).

Table 1. Study from the Tithonian aged reservoir intervals

Well	Core	Cuttings	Total
Mizzen F-09	69	-	69
Mizzen L-11	-	31	31
Mizzzen O-16	-	57	57

Geochemical & reservoir quality

An initial assessment of the sample's lithology based on the geochemistry identifies the occurrence of sandstones and carbonate cemented sandstone, with some minor occurrence of siltstones and silty claystones. The RCA data of the Mizzen F-09 samples show a positive correlation between the porosity and permeability (Figure 1) and data plot along a compaction and cementation trend as defined by Cade et al (1994). In addition, the samples lithology implies there is a good control on reservoir quality – carbonate cemented samples are characterised by low porosity and permeability implying that the predominant impactor on reservoir quality is the distribution of the carbonate cement phases.

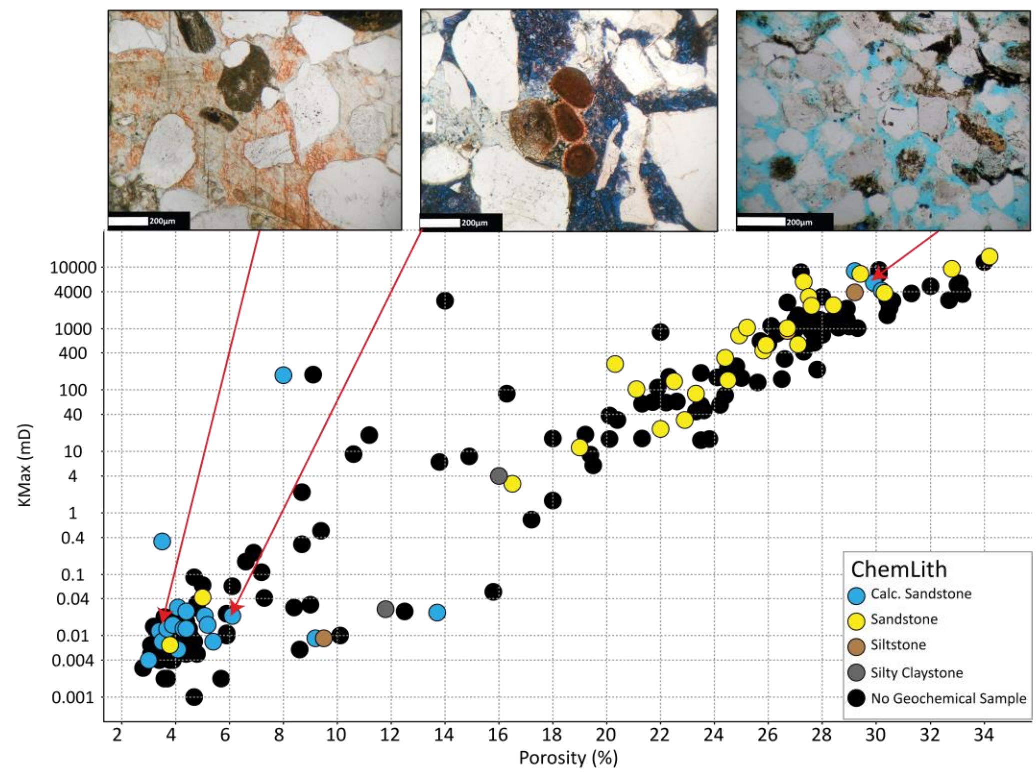

Figure 1. Porosity-permeability cross-plot for Mizzen F-09, and selected thin sections of samples with abundant Ca content

Furthermore, it is apparent that some high Ca samples, which are classified as carbonate cemented are characterised by high porosity and permeability. These samples have been thin sectioned and show that several the sandstones contain a high proportion of carbonate allochems, which adds to the total Ca value recorded on the ICP. This contrasts with a number of carbonate cemented sandstones that show pervasive ferroan and non-ferroan carbonate cements (Figure 1).

Core to cuttings

Identifying the key geological controls on the reservoir quality, and the geochemical cut-offs that define the good from poor reservoir allow the equivalent reservoir sections sampled with ditch cuttings to be assigned a predicted reservoir quality. Figure 2 demonstrates the predicted reservoir quality over the Tithonian sandstones within the Mizzen wells that are adjacent to the F-09 well. Overall, there is a reasonable match between the predicted reservoir quality and the calculated reservoir quality index (RQI), which as been calculated from the core data. However, what is also apparent is that this technique is dependant greatly on the representivity of the sample, any potential contamination of the sample, and the sampling resolution of the cuttings.

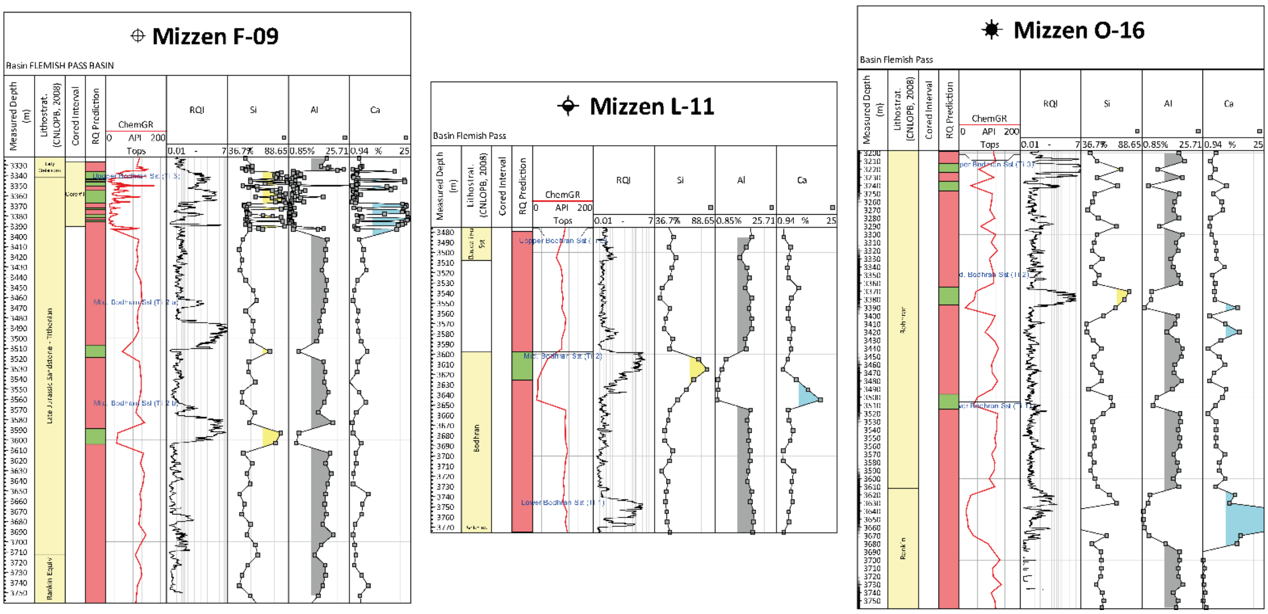

Figure 2. Predicted reservoir over the equivalent Tithonian sandstone within the Mizzen wells.

Geochemistry & Facies

The facies interpretation of the Mizzen F-09 core was published by Haynes et al. (2014), and this has been appled to constrain the geochemical sampling program. The porosity-permeability crossplot (Figure 3) demonstrates that the tidal modulated fluvial typically represents the best reservoir - characterised by the high porosity and permeability values However, the fluvial facies are characterised by the lowest porosity and permeability values and have poor reservoir quality. The porosity and permeability values have been calculated to a reservoir quality index (RQI) based on the equation:

$$RQI = 0.0314(k/\phi)0.5$$ (Amaefule et al. 1993)

Where RQI is the reservoir quality index in μm, k is permeability in mD and ϕ is the porosity as a fraction. The RQI elemental crossplot (Figure 3) demonstrate the that distribution of carbonate, that is principally associated with the fluvial facies is the predominant limiting factor on reservoir quality. In contrast, the tidal modulated fluvial are characterised by the lower Ca values and predominantly represent the good reservoir. Furthermore, Figure 3 demonstrates selected geochemical profiles plotted along with the facies determined by Haynes et al. (2014). High Ca distribution is noted within the fluvial facies and is associated to the distribution of carbonate cement (plus subordinate amounts of limestone clasts). Furthermore, the higher K/Al value within the fluvial facies are infered to reflect more mineralogically immature sediment. The tidal modulated fluvial is characterised by higher Zr/Al and Zr/Sc values, which are interpreted as in increase in the energy of environment of deposition. The estuarine sandstones are characterised by even higher Zr/Sc and Zr/Al values, which is inferred to reflect the continued winnowing of the clay material from the sediment. The gradual increase in the Cs/Rb values reflects the increasing marine setting of Haynes et al. (2014) facies with Cs being typically associated with marine smectite.

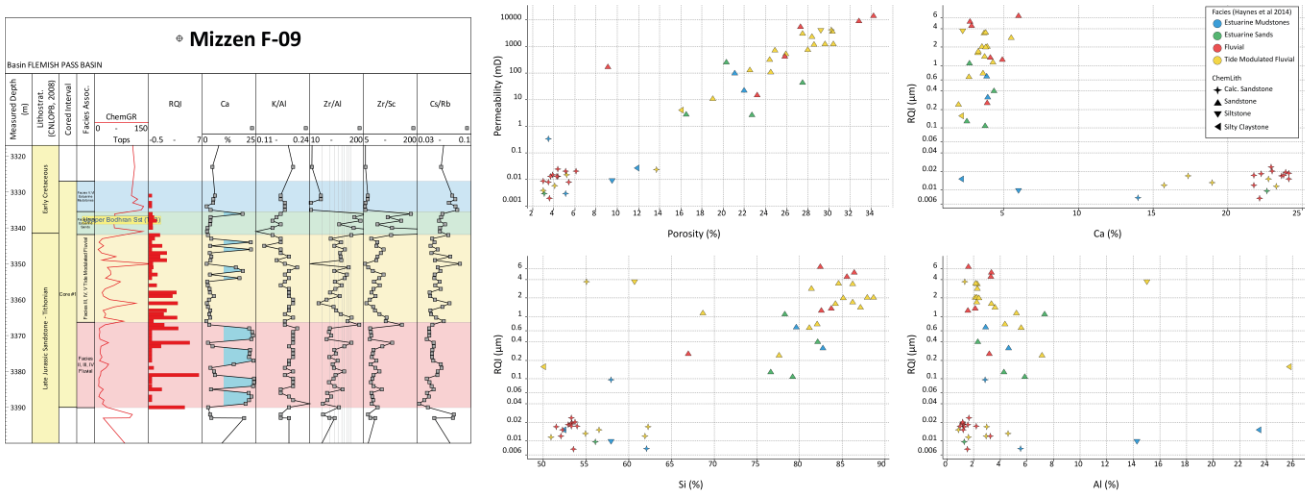

Figure 3. Facies interpretation of Mizzen F-09 (Haynes et al. 2014), selected geochemical profiles and reservoir quality of the facies

Conclusions

This study demonstrates that the geochemical assessment of the samples provides a pre-screen of the samples and that the reservoir quality within the Mizzen F-09 core is predominantly controlled by the distribution of the carbonate cement phases, which are abundant within the lower part of the core deposited under fluvial facies (Haynes et al. 2014). The cut-offs defined within the geochemical plots are applied to the Tithonian reservoir within the wells with no cores and show a good match to predicted RQI values. However, this work flow is limited by the representivity of the sample, extent of cavings contamination and sample resolution. Reservoir quality within the Mizzen F-09 core appears to be somewhat dependent on the facies, with very poor reservoir quality identified within the fluvial facies. An initial investigation of the geochemical signature of the facies show that geochemical responses can be interpreted back to an inferred geological process.

Acknowledgements

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