

Whole Rock Inorganic Elemental Data Toolkit: case studies from East Coast Canada

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Introduction

The use of whole rock elemental geochemistry in the oil industry is currently increasing, particularly within the unconventional plays of North America. However, elemental geochemistry can be applied to a range of scenarios including conventional and unconventional plays, a range of depositional environments, and a range of rock types. The geochemical data produced from a single sample contains information on the sediments provenance, the climate, weathering, transport, environment of deposition, and diagenesis which all influence the samples geochemical fingerprint. Geochemistry not only provides a means to correlate, but also provides information of the mineralogy, organic content and lithological classification.

Chemostratigraphy entails the zonation of sedimentary rock successions based on stratigraphic variations in their whole rock inorganic geochemistry. These geochemical variations reflect changes in the mineralogy of the sedimentary rocks, which themselves are due to changes in provenance, climate, depositional environment and diagenesis, with the geochemical variations ultimately linked to changes in provenance and climate being the most significant with respect to chemostratigraphy. For example, Hildred et al. (2010) demonstrated the homotaxial nature of a two-valley system using changes in the concentrations of provenance-related elements, whereas Ratcliffe et al. (2010) described how elements whose concentrations are influenced by climate changes can be used for chemostratigraphic purposes. Chemostratigraphic correlation may be small scale high resolution studies through individual fields, or large scale basin studies. Chemostratigraphy is increasingly being used alongside traditional techniques, such as biostratigraphy, which provide an absolute chronostratigraphic framework for the chemostratigraphy, which provides a higher resolution of stratigraphy over the same interval.

As whole rock geochemistry is a reflection of the whole rock mineralogy, the geochemistry provides a means of calculating a normalised mineralogy for each sample (Rosen et al, 2004). This technique allows the rapid production of mineralogical logs for the study wells which can be used to aid interpretation of petrophysical logs and controls on reservoir quality. The technique of normative mineralogy can be used without any mineralogical data, but for a calibrated model a subset of XRD is required.

Whole rock geochemistry also provides a means of high grading samples for organic analysis, such as TOC and Rock Eval. Marine conditions have been shown to increase concentrations of uranium and molybdenum during periods of anoxia (Tribovillard et al, 2012), which is attributed to changes in the oxidation state associated with reduction caused by organic matter decay.

Herein this paper a case study from the Grand Banks East Coast Canada is used to demonstrate the application of whole rock elemental geochemistry to stratigraphic and mineralogical situations. The East Coast Canada database contains over 70 wells, with close to 10,000 ICP geochemical analysis, and contains wells from the Scotian Basin round to the Saglek Basin, with high well concentrations within the Jeanne d'Arc and Flemish Pass (Figure 1).

Analytical Method

Whole rock inorganic elemental data is generated from various instruments from laboratory based inductively coupled plasma (ICP) to portable X-ray fluorescence (XRF) units, which can be used within laboratory, core store or wellsite settings. However, to ensure the production of consistently accurate and precise data it is important to make use of certified standard reference material (SRM) during the analysis of the unknown samples.

The preparation of the sample is also key, while core is the most desirable sample, ditch cuttings are the most common owing to the respective costs. However, ditch cuttings may contain a host of contaminants from barite drilling muds to a range of LCM material. Geochemical analysis is usually an afterthought and not the consideration of drilling teams; it is therefore important to have protocols in place which mitigate these contaminants as much as possible.

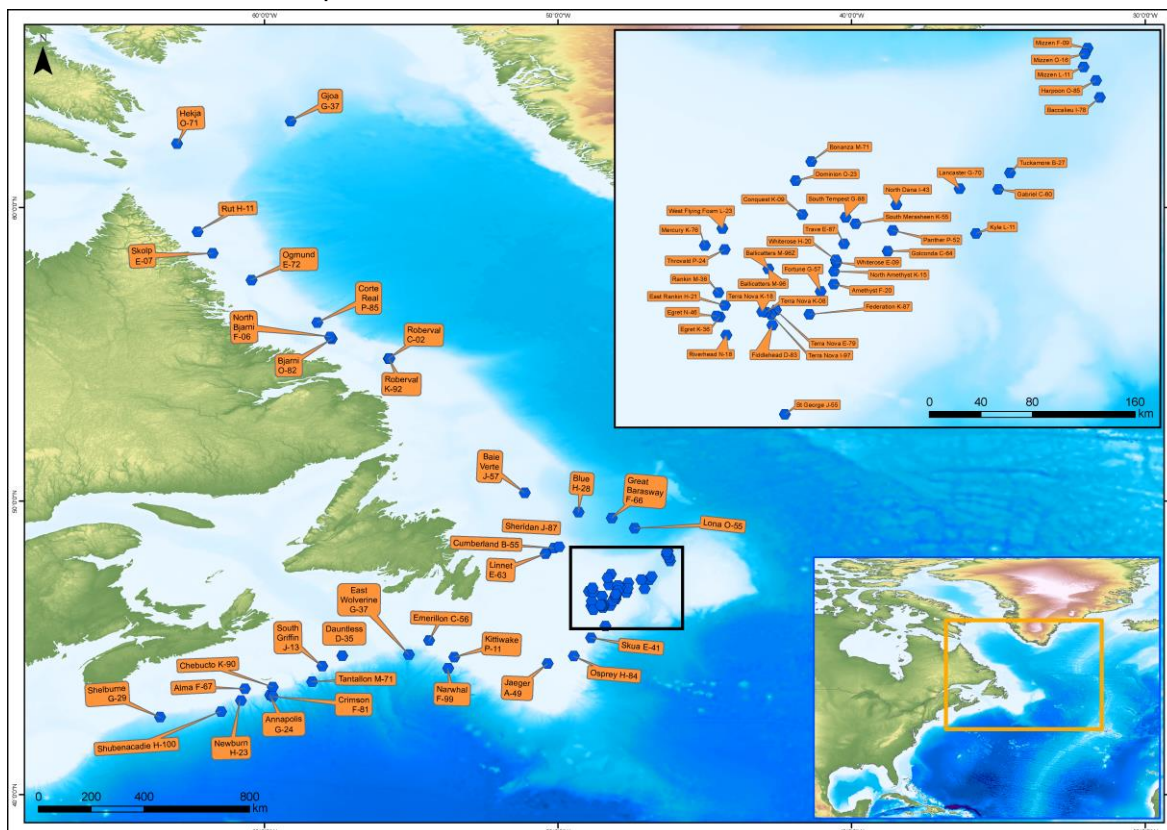


Figure 1. Location map of study wells within the East Canada database

Examples

Within the following example ICP data has been collected on Jurassic, Cretaceous, and Lower Palaeogene successions encountered within study wells of the Grand Banks Area, 16 wells are used here for illustration purposes; two are from the Carson Basin, four from the Jeanne d'Arc Basin, four from the Outer Ridge Complex, three from the Flemish Pass, and three from the Orphan Basin. The Grand Banks area is within deep water to the east of Newfoundland. The objectives of this study were to characterise the study intervals based on geochemistry and establish a chemostratigraphic zonation for each well based on the siltstone, and siltyclastone fractions. While extensive exploration has been carried out on the Grand Banks, disagreements do arise within well stratigraphy. Within the study wells of the Grand Banks two orders of chemostratigraphic zonation are made. Mega sequences, which represent the first order division of the zonation, and sequences, which represent the second order division.

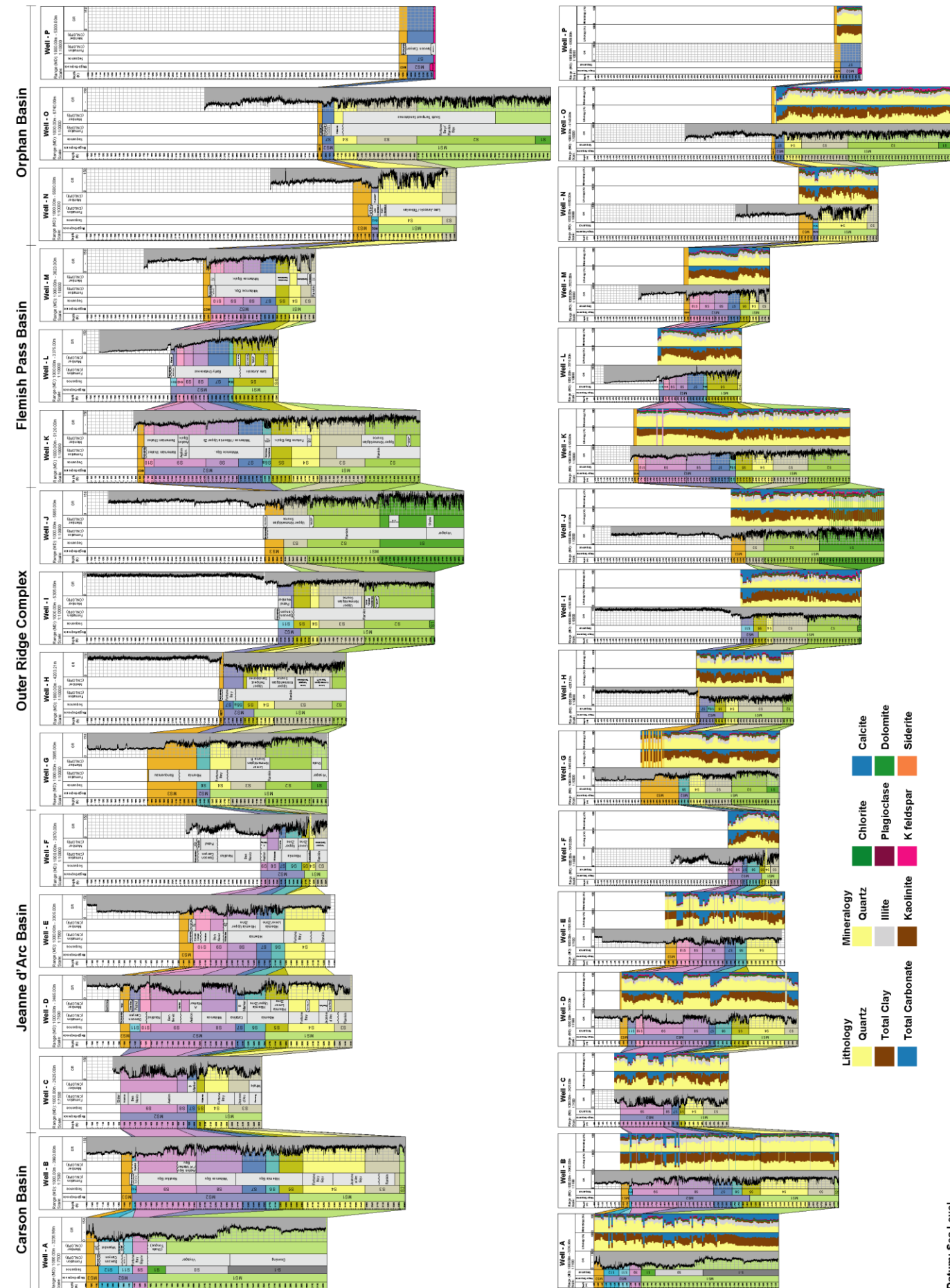


Figure 2. Chemostratigraphic zonation across the Grand Banks area, and mineralogy logs for each of the study wells

The chemostratigraphic (Figure 2) shows that the Jurassic succession is equivalent to the chemostratigraphic mega sequence MS1, while the Cretaceous and Paleogene aged strata correspond to chemostratigraphic mega sequences MS2 and MS3, respectively. Furthermore, mega sequence MS1 is sub-divided into five chemostratigraphic sequences S1 to S10, and their lithostratigraphic associations are as follows:

- Sequence S1 to S4 are equivalent to the Downing Formation, Voyager Formation and lower part of the Ranking Formation.
- Sequence S5 is equivalent to the upper part of the Ranking Formation, as well as the lower part of the Fortune Bay Formation.
- Sequence S6 and S7 are equivalent to the Fortune Bay Formation
- Sequence S8 to S10 are equivalent to the Dawson Canyon Formation, S10 represents the Petrel Member.

It is possible to subdivide the zonation into a third order division of chemostratigraphic packages, providing an even higher resolution zonation. The chemostratigraphic zonation is produced using the geochemistry of the siltstones, and silty claystone fractions, as the fine grained lithologies have the highest correlation potential; the sandstones have the lowest correlation potential so are constrained using the fine grained lithologies. The elements used for the correlation are suggested to reflect the variation in heavy mineral, clay mineral, organic matter and carbonate mineral abundance. Furthermore, lateral variation within the geochemical data may be used to infer sediment transport directions, for example, the chemostratigraphic sequence S4, which include the main reservoir section contains geochemical trends that suggest sediment entered from the south-west, possibly derived from the Avalon Uplift.

In addition, Figure 2 also demonstrates the calculated mineralogy logs within the example wells, and illustrates the lateral variation within the mineralogy encountered across the study area. Moreover, this technique provides a cost effective means to generate mineral logs for the study wells.

Using redox sensitive elements it has been possible to calculate an 'organic uranium' which is relatively consistent to the total organic carbon (TOC) content of the sample. Reveals organic matter abundance over the Cretaceous successions is generally low, whilst such matter is very common in the Jurassic strata associated with chemostratigraphic sequence S3. In addition, there are some local high organic intervals within chemostratigraphic sequences S1 and S2. High 'Organic U' values relating to Mega-sequence MS3 (= Paleogene strata) infer a source rock younger than those of the Kimmeridgian Egret Member (an established source rock interval in the Jeanne D'Arc Basin) which could be present in the Grand Banks area, as well as a reservoir sandstones of similar age or even younger.

Conclusions

The Grand Banks example illustrates how whole rock inorganic geochemical datasets serve multifunction roles within hydrocarbon exploration. The chemostratigraphic zonation integrated with available chronostratigraphy and lithostratigraphy, provide an independent means of correlating wells, with geochemical fingerprints that can be used to accurately define well stratigraphy. In addition, mineralogy calculated from whole rock datasets provides a fast, cost effective, alternative to large XRD sample sets for well mineralogy providing data which can be integrated into reservoir models and petrophysical interpretations. In addition, the use of redox sensitive elements as organic proxies provide a means of predicting TOC within wells and intervals over which no analysis exist.

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