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Chemostratigraphic correlation within the Grand Banks, with a view of constraining sandstones for provenance analysis

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Introduction to the Grand Banks

The Grand Banks of eastern Canada lies in the deep waters offshore Newfoundland and incorporates a series of rift basins associated with the opening of the North Atlantic Ocean. Mesozoic and Cenozoic strata rest unconformably on Palaeozoic basement, with the Jurassic and Cretaceous rocks forming the main source and reservoir units within the area. Despite extensive exploration and discovery within the Jeanne d'Arc Basin, recent discoveries in the Flemish Pass Basin to the north, have highlighted a greater oil potential within the area. However, exploration in this northern frontier is hampered by a lack of well penetrations, whilst the deep water and arctic conditions makes for challenging drilling conditions. As a consequence, a firm understanding of the regional geology is vital to petroleum exploration within the area. Furthermore, the need for a greater understanding of the sediment provenance terrains and pathways active during the Mesozoic is apparent, however, in order to tackle such an investigation, it is important to firstly have a clear understanding of stratigraphy. To go some way in addressing this, a chemostratigraphic study was conducted on twenty wells spanning the Orphan, Flemish Pass and Jeanne d'Arc basins, in addition to wells from the Outer Ridge Complex. The main aim being to establish a robust chemostratigraphic correlation, which can ultimately be used to constrain key sandstone bodies, which only then, can be targeted for further provenance investigation.

Elemental Geochemistry

Inorganic elemental chemostratigraphy involves the characterisation and correlation of rock successions based on stratigraphic variations in their constituent minerals, or in their proportions of accessory phases. The technique is particular sensitive to variations in clay minerals, heavy minerals and lithic components that in turn, can be linked to changes in palaeoclimate and palaeoenvironment, provenance and periods of volcanism.

The current study utilises inorganic geochemical data acquired via inductively-coupled plasma – optical emission spectrometry (ICP-OES) and inductively-coupled plasma – mass spectrometry instruments. Sample preparation and analysis followed the procedures advocated by Jarvis & Jarvis (1992a & 1992b) and resulted in quantitative data being acquired for forty-nine elements, including ten major elements, twenty-five trace elements and fourteen rare earth elements. The geochemical data were acquired solely from cuttings material and comprise a variety of siliciclastic lithologies, the majority of which have a strong calcareous component.

Chemostratigraphic Zonation

The study intervals collectively encompass sediments from the Jurassic Downing, Voyager, Rankin and Fortune Bay formations, the Cretaceous Hibernia and Dawson Canyon formations and the base of the Palaeogene Banquereau Formation. However, as no one well incorporates each of the recognised formations, a composite well section was erected as a reference on which to compare subsequent well penetrations. The resultant reference section was then subjected to a consistent order of interpretation, resulting in the establishment of a hierarchical, chemostratigraphic zonation, which consists of three chemostratigraphic mega-sequences, ten chemostratigraphic sequences and a total of twenty chemostratigraphic packages.

The chemostratigraphic divisions are erected from the siltstone and finer grained data and are primarily founded on elements which can be linked to detrital minerals, thus enabling the correlation to be extended across the greater study area. In particular, elements such as Nb, Ta and Ti, amongst others, can be tied to specific heavy minerals, which provide information on sediment provenance. Other parameters such as V, Fe and Mg can be tied to depositional processes and can be utilised to highlight any changes in palaeoenvironment, whilst elements such as U and Zn, can be directly tied to TOC concentrations and can be used to highlight organic rich sections.

Provenance Implications

Lowe *et al*. (2011) present heavy mineral, U-Pb geochronology and grain morphology and chemistry data to elucidate sediment provenance within the upper Jurassic to Lower Cretaceous sandstones from two wells within the Flemish Pass Basin. Comparison of the published heavy mineral data (*op. cit.*) with the sandstone geochemical data acquired from the same wells, highlighted the element to mineral associations of the heavy mineral grains encountered in the basin. This identification allowed the geochemical data from the sandstone and by extension, the finer grained lithologies, to be used to assess the vertical and spatial distribution of the heavy mineral grains, which provided information on provenance as well as sediment input.

Isocon maps (maps that contour based on element concentrations) were constructed from the fine-grained geochemical data. The maps use data for Nb, Ti and Ta and thus reflect the distribution of heavy minerals (e.g. rutile and titanite). Heavy mineral assemblages can be affected by hydrodynamic conditions, such that the assemblages can be preferentially sorted and winnowed (Morton & Hallsworth, 1999). As a consequence, heavy mineral assemblages will typically be more abundant closer to the source of the clastic detritus, with these maps therefore, allowing an inference of sediment pathways to be made throughout different time slices, even in the finer grained fraction, where more traditional provenance analyses are generally less effective.

Conclusions

The inorganic geochemical data acquired from the twenty wells allowed for an independent, chemostratigraphic correlation to be erected, which ultimately tied wells from the Jeanne d'Arc through to the Flemish Pass and Orphan basins. The fine grained-based correlation can be used to constrain key sandstone bodies, which only then can be confidently targeted for further provenance work. In addition, the fine grained geochemical data relating to specific heavy mineral species can be used to assess provenance and sediment input points active during different time slices within the Mesozoic.

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