Chemostratigraphy and sedimentary provenance analysis for the Jeanne d'Arc and Flemish Pass basins, Grand Banks, East Coast Canada

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Summary

A large dataset of results of chemostratigraphic analysis (based on data acquired via Inductively Coupled Plasma Mass Spectrometer), and collaborative geochronological analysis (stable isotope; $\delta^{13}C_{carb}$ $\delta^{18}O_{carb}$), Raman heavy mineral analysis and detrital zircon uranium-lead (U-Pb) geochronology performed on Jurassic and Cretaceous sediment of the Grand Banks has been compiled and interpreted. In this abstract we present a subset of results showing different provenance between the sedimentary succession of the Flemish Pass Basin and that of the Jeanne d'Arc Basin and a stratigraphical provenance change within the succession of the latter. Moreover, we illustrate an example of integration between results of these analytical techniques performed on the Hibernia sandstones.

Introduction

The Grand Banks area of eastern Canada is located in the deep waters offshore from Newfoundland, the main focus of this study being the area of the Grand Banks located to the east of Newfoundland and including the Flemish Pass Basin and the prolifically-producing Jeanne d'Arc Basin. This study contains data from the Jurassic and Cretaceous succession of these two basins, the Outer Ridge Complex – which separates the basins – and the contemporaneous succession penetrated by a more limited set of wells drilled in the Orphan Basin, further north, and the Carson Basin, further south.

The study area represents one of several rift basins associated with the opening of the North Atlantic Ocean, with paleogeographic reconstructions placing the area close to the conjugate Porcupine and Rockall basins (offshore Ireland) and to the landmasses of Greenland and Iberia (Masson & Miles, 1986; Shannon et al., 1995). Syn-rift Late Triassic to Early Jurassic strata include red beds, evaporites and carbonates, recording a gradual increase in marine influence. Following the Late Triassic to Early Jurassic rifting phase, thermal subsidence caused a marine transgression that resulted in the deposition of shallow marine shales and limestones (Grant & McAlpine, 1990; Driscoll et al., 1995). A significant unconformity is associated with the onset of the Avalon Uplift, a WNW–ESE-trending arch across the southeastern Grand Banks that experienced permanent uplift and erosion during the latter Early Cretaceous and is identified as source of Albian to Cenomanian sediment in the Newfoundland Basin (Hiscott et al., 2008). In the Avalon Zone U-Pb zircon ages of c. 620-580Ma have been documented (Dallmeyer et al., 1981;Krogh et al., 1983). The above terrains are possible sedimentary sources, along with granodioritic and aphanitic dacitic rocks of the Flemish Cap, a submarine high located 600 km east of Newfoundland. The Flemish Cap High consists of igneous rocks of c. 830-750Ma (U-Pb zircon ages) and onlapping Mesozoic to Cenozoic sediments (King et al., 1985).

So far, only a limited number of studies has focused on determining the provenance of detrital material deposited in the Grand Banks. Lowe et al. (2011) suggested provenance predominantly from the west for Tithonian to Berriasian sediment of the Flemish Pass Basin (Hibernia equivalent sandstones) and from the south for Hauterivian to Barremian sediment of the same basin (Avalon sandstones). The authors have also excluded the possibility of provenance from the Grenville basement, the Iberian margin or the Flemish

Cap-Galicia Bank continental areas. They applied multiple analytical techniques, including detrital zircon U-Pb geochronology; in this study we provide a much larger dataset that couples Raman heavy mineral analysis and zircon U-Pb geochronology performed on the Jurassic and Cretaceous succession of the Grand Banks.

Theory and Method

Heavy minerals are those minerals having density above 2.9 g/cm^3. They usually constitute less than 1% of a clastic rock, but are especially important with respect to provenance studies, as many (e.g., kyanite, sillimanite and spinel) originate from relatively specific 'parent' rocks. When employing HM analysis as part of a provenance study, taking into account the possible effects of processes capable of modifying the HM assemblages (such as hydraulic sorting and mineral dissolution, Morton & Hallsworth, 1999) is needed as these processes might hide the original provenance signal.

Heavy minerals are concentrated and separated from disaggregated sedimentary rocks by using 'heavy' liquids (e.g., a lithium metatungstate solution having a density of 2.89 g/cm^3). Subsequently, the separated HM grains can be identified via either optical analysis or Raman spectroscopy; for this study we applied the second technique, as reliable, cost and time effective. Details about the separation of HM grains are given in Mange & Maurer (1992), whereas their identification by Raman spectroscopy is described in Andò & Garzanti (2013).

Additional techniques, including Frantz magnetic separation, are employed to isolate detrital zircon grains, with their ages being determined by U-Pb geochronology, via laser ablation - inductively-coupled plasma - mass spectrometry analysis. To take account of instrument bias, the results of the analysis are compared with the Plesovice zircon standard (Sláma et al., 2008). The ages of the zircon grains are presented in the form of concordia diagrams (Ludwig, 2008) and any particularly discordant data are rejected.

Coupled with Raman heavy mineral analysis and detrital zircon U-Pb geochronology, we have also performed (i) Inductively Coupled Plasma Mass Spectrometer (ICP-MS) analysis in order to determine the chemical composition of the sediment and, based on the data, build-up a chemostratigraphic subdivision and correlation of the succession and (ii) stable isotope ($\delta^{13}C_{carb}$ $\delta^{18}O_{carb}$) analysis on the inorganic carbonate fraction of the same succession, in order to have a chronological reference for the chemostratigraphic interpretation.

Examples

This study provides data for more than one-hundred-and-fifty samples, collected from eighteen wells, and we provide here key examples to show the power of the dataset.

In well Harpoon O-85 (Flemish Pass Basin), zircon geochronology performed on a total of nine cuttings samples shows predominance of Neoproterozoic ages (49.5% of total analyzed zircon grains for Jurassic samples and 56.4% of total analyzed zircon grains for Cretaceous samples), followed by abundant Paleoproterozoic and Paleozoic zircon ages. In well Terra Nova I-97 (Jeanne d'Arc Basin) the same analysis has been performed on a total of thirteen cuttings samples and results show that (i) Jurassic sediment contains similar amounts of Palaeozoic, Neoproterozoic (the most represented Era), Mesoproterozoic and Paleoproterozoic zircon ages and even a peak of Mesozoic zircon ages, whereas (ii) Cretaceous sediment displays predominance of Neoproterozoic grains (43.7%) and abundant Paleozoic grains (26.7%). Moreover, results of Raman heavy mineral analysis shows dominance of ultrastable minerals (zircon, tourmaline, rutile) and occurrence of different amounts of monazite, apatite, along with small proportions of other minerals, such as amphibole and garnet. Therefore, it is interpreted a different provenance between the Flemish Pass and the Jeanne d'Arc basins; a major provenance change occurring between Jurassic and Cretaceous times is interpreted for the Jeanne d'Arc Basin. In addition, zircon grains aged c. 830-750Ma and, therefore, associated with possible provenance from the Flemish Cap granodiorite (King et al., 1985) have been observed in Cretaceous samples of well Harpoon O-85, whereas these ages are rare in other samples of the two wells. Minerals documented in the Flemish Cap granodiorite by King et al. (1985), such as amphibole, pyroxene and epidote, are also observed.

The second example refers to the correlation between the Hibernia sandstones penetrated by well Terra Nova I-97 (Jeanne d'Arc Basin) and Hibernia equivalent sandstones penetrated by well St George J-55 (Carson Basin). On the base of chemical data (derived from ICP-MS analysis), Hibernia equivalent sandstones have been divided in three chemostratigraphic packages, named S6a (the deepest), S6b and S6c (the shallowest) and differentiated on the base of variations in the abundance of some key elements and key elemental ratios, based on varaitions in Si, Zr, Ti, Nb, Ta, Rb, U, Th, Ga, V and the REEs associated with changes in quartz, feldspar, heavy minerals, clays and organics. In the same well (St George J-55) results of stable isotope analysis show a strong negative anomaly in the $\delta^{13}C_{carb}$ curve for the succession corresponding to package S6a. In well Terra Nova I-97, we interpret – from chemical data – occurrence of packages S6b (very thin) and S6c (about 100m thick), whereas S6a has not been recognised. This is supported by both isotopic analysis (the $\delta^{13}C_{carb}$ negative anomaly observed in St George J-55 does not occur in Terra Nova I-97) and detrital zircon geochronology. In well St George J-55 samples associated with S6a are characterized by Mesozoic zircon ages, whereas S6b samples contain Mesozoic aged grains and also abundance of older zircon grains, including abundant Mesoproterozoic and Paleoproterozoic grains. On the contrary, in well Terra Nova I-97 Mesozoic, Mesoproterozoic and Paleoproterozoic grains are abundant only in the sample associated with package S6b, whereas the zircon population of shallowest samples (i.e., package S6c samples) is dominated by Paleozoic and Neoproterozoic zircon ages.

Conclusions

The above examples show that from our multidisciplinary dataset it is possible to recognise provenance changes occurring both stratigraphically (i.e., within the sedimentary succession deposited in a specific basin) and geographically (i.e., between the sedimentary successions deposited in different basins during the same geological period). It is also shown that provenance-related data can be used not only for determine the provenance of the sedimentary succession of the Grand Banks, but also to support the chemostratigraphic correlation interpreted for the study area. The final aim of this study is to provide a robust dataset to help modelling ground-truth sediment provenance and gross depositional environment maps.

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