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Reservoir characterization of eolian deposits in Mesozoic rift settings: Examples from the Minas Subbasin, Nova Scotia

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Summary

The architectural elements, provenance and reservoir characterization of the Red Head Member eolian sandstones are investigated using stratigraphic and mineralogical techniques to determine analog reservoir characteristics of these sediments, deposited as late-stage rift basin fill. These observations and preliminary conclusions may be applied to on-going exploration of the Scotian Basin.

Introduction

The late Triassic Red Head Member of the lower Blomidon Formation (sensu Olsen and Et-Touhami, 2008) outcrops on the north shore of the Minas Subbasin, within the east-west trending Minas fault zone, which acts as the northern boundary for the Minas Subbasin **(Figure 1).** The evolution of the Fundy Basin as well as the mode and distribution of basin sediment fill in the Triassic and early Jurassic is controlled by the geologic setting and the tectonic history. The Fundy Basin beneath the Bay of Fundy formed in the early Mesozoic from the initial break-up of Pangea (Withjack et al., 2012). This extensional event occurred along relict suture lines that represent pre-existing basement structures from previous orogenic collisions. In this segment of the rift, the suture line is represented by the cobequid-chedabucto fault system that separates the Appalachian Avalon terrane and Meguma terrane.

The east trending Minas Subbasin **(Figure 1)** is thought to have developed similarly to the Fundy Basin, except that the controlling fault is an oblique strike slip fault that makes up the Cobequid–Chedabucto fault system along the northern part of the basin. Study of outcrops and seismic data shows that the Fundy Basin has been variably influenced by this major, pre-existing transverse fault (Cobequid–Chedabucto fault system) with a complex history of movement (Wade et al., 1996). The deposition of continental sediment within Triassic rift basins along the North American Atlantic margin is associated with the break-up of Pangea, with noted similarities in their evolution and sedimentological trends (Olsen and Et-Touhami, 2008).

The Red Head Member **(Figures 2)** comprises approximately 33 m of red sandstone (Nadon & Middleton, 1984) interpreted as deposited under primarily eolian conditions. The succession is interbedded with several meters of fluvial sandstone, pebbly sandstone, and conglomerate. At the base of the eolian deposits is a unit of upper Wolfville Formation that comprises channelized and unconfined fluvial deposits, which grade upward into lacustrine sediments deposited under arid to semi-arid conditions. The fluvial system may have originated from the south.

Eolian dunes occur in self-organized patterns that are dependent on sufficient supply of sand-sized sediments, adequate wind energy for sediment transport and conditions that promote deposition of the transported sediment. Eolian dunes can form in desert regions of broad continental plains, or in arid regions of relatively confined rift basins. The preserved strata of the Red Head Member eolian strata were probably deposited as barchan-type dunes by winds blowing towards the southwest (approximately 254 degrees), which are consistent with the northeast trade winds. Barchans tend to occur in isolation around areas of limited sand supply and can subsequently coalesce laterally to form barchanoid ridges, which increase in dimensions with increasing sand supply.

There is high preservation of eolian sediments in the upper units of the Fundy succession with the eolian deposits possibly derived from the recycling and remobilization of older fluvial sandstone deposits of the Wolfville Formation, by wind. These eolian sediments are usually well sorted by wind action during transport, exhibiting a good to excellent visible porosity noticeable in outcrop and having significant concentrations of quartz and feldspars. The erratic nature of wind patterns, lateral extent variation of dunes, as well as vertical heterogeneity in permeability due to the cross bed thickness are some complexities associated with these potential hydrocarbon reservoirs that could develop baffles and barriers to fluid flow in the subsurface.

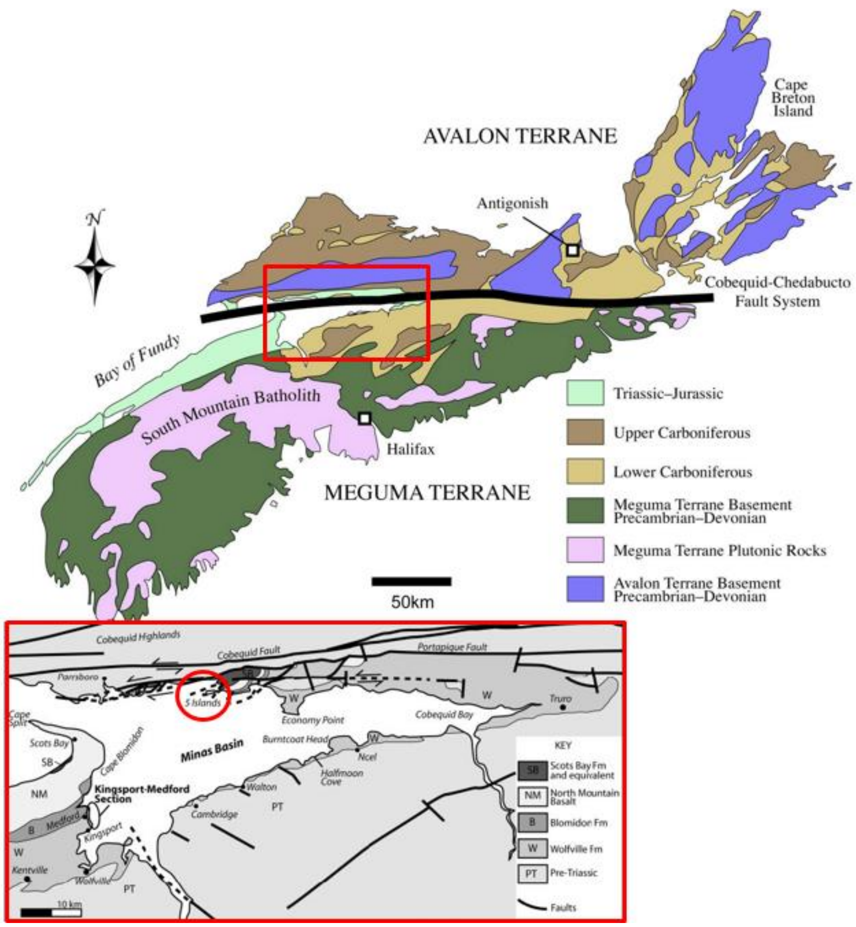

Figure 1. A geologic map of Nova Scotia showing the Avalon and Meguma terranes juxtaposed along the Cobequid-Chedabucto Fault system (Keppie, 2000) with the location of the study area (Five Islands) in red circle on a geologic map of the Minas Subbasin (modified from Leleu and Hartley, 2010).

Methods

Outcrop measured sections, photomosaics, coupled with detailed scintillometer and XRF measurements were used to characterize the outcrop sediment; combined with mineralogical analysis of ten samples from Red Head Point for detailed petrographic study and geochemical analyses. Eight samples are from the eolian facies and 2 mudstone samples from the overlying red beds of the Blomidon Formation. A handheld XRF apparatus was used to analyze the bulk powder X-ray fluorescence of the samples for geochemical concentrations, classification of the sands to determine the provenance and mapping geochemical content to petrographic observations by means of the Sand-class scheme (after Herron 1988). Grain counting by means of point counter attached to the microscope was also carried out on the thin sections to determine porosity.

Preliminary Results

i) ***Architectural Elements and Stratigraphic Order***:

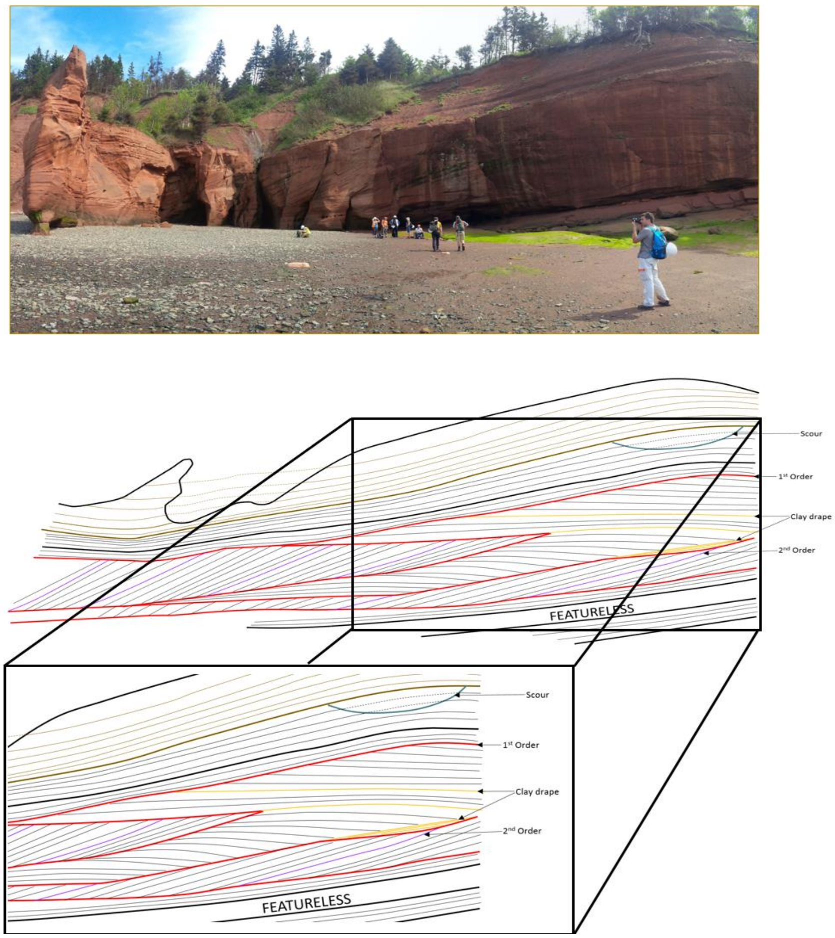

Figure 2. Outcrop annotation and a close up of the outcrop annotation showing the bounding surfaces in association with their respective sand body geometries.

Outcrop of the Red Head Member; appear to have various bedset orientations easily distinguished by their respective order of bounding surfaces **(Figure 2).** These bounding surfaces occur at different scales as a consequence of bed form migration of different hierarchies. Red lines are representative of the first order of bounding surfaces that tend to be well preserved around the base of the draa. Brookfield (1977) described this order of bounding surface as usually flat lying and the most extensive associated with the migration of large-scale dune/draa bodies. The purple lines correspond to the second order bounding surfaces that are sometimes regularly spaced and relatively evenly dipping, attributed to the dune migration transverse to the larger draa unit. The third order-bounding surface that results from short-term changes in wind distribution and velocity pattern (Brookfield, 1977) is not observed in the section. The presence of clay partings and foreset drapes in the eolian section is indicated by the yellow lines, which may suggest the presence of an interdune unit. A channel scour is indicated by the grey line at the top right of the section, and may have resulted from a possible backflooding event associated with the early stages of sea-level rise (Jordan and Mountney 2010) due to a decrease in the source area relief through progressive erosion and sediment discharge within a hydrologically closed basin.

Mineralogical Analyses: The Red Head sandstones exhibit simple diagenetic history having an increased level of porosity with minor compaction and negligible amount of cement. The grain size distribution of the sandstones in thin section shows that they possess a variable grain size relationship, mostly showing a bimodal distribution. Sand grains dominantly range between very fine and very coarse (0.1-1 mm), although finer silt sized grains exists in a few samples. The shape of detrital grains varies from subangular to subrounded, with well-rounded, resistant quartz grains observed to be the most dominant grain type in the samples.

Observations and Conclusions

Based on the sandclass diagram **(Figure 3),** the sands of the Red Head Member appear to plot well within the subarkosic zone that is characterized by a relatively high amount of quartz, with the remainder dominated by K-feldspar contents. As an indicator of mineralogical maturity and stability, the high SiO2 / Al2O3 and low Fe2O3/K2O ratios observed from the plot suggests that the sands are mineralogically mature and stable. This maturity may be linked to long sediment transport distance and increased abrasion from high energy winds during transport, with high presence of stable rock forming minerals quartz and feldspar suggesting a low temperature and pressure effect.

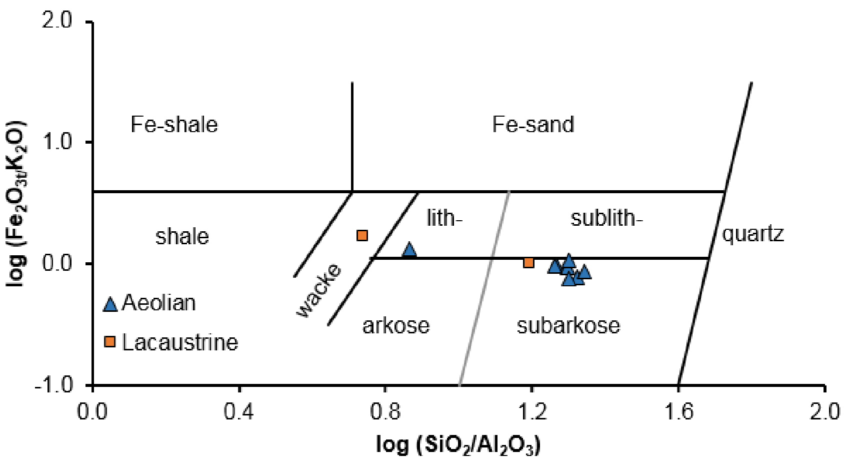

Figure 3. A sand class plot for the geochemical classification of the Red Head Member eolian sandstones (after Herron 1988).

The deposition of eolian facies is common amongst subsiding fault bounded basins in North America occuring as part of a transitional depositional environment between distal braided fluvial deposits and playa lacustrine deposits and show a similar diachronous stratigraphic evolution amongst rift basins of the eastern North Atlantic Margin. Based on this observation, subsidence is thought to be the key factor controlling this architecture. This in turn is a major controlling factor upon which the preservation of these eolian deposits depends on. Subtle grain size variations are associated along laminae within the cross beds of the Red Head sandstones and there is a relationship to the thickness of the cross bed strata. These have implications for fluid flow in subsurface reservoirs.

Acknowledgements

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Compilation of references in progress, as research is ongoing.