[PS]Chemostratigraphic Recognition of a Disconformity in Mississippian Strata of the Northeast Appalachians, New Brunswick, Canada*

Nazrul Islam[1] and Dave Keighley[1]

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[1]Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick, Canada (z1x61@unb.ca, keig@unb.ca)

Abstract

Mississippian strata host the only onshore gas field in Atlantic Canada at McCully, southern New Brunswick. Strata overlying the current tight-gas reservoir unit and shale-gas target (Albert Formation, Horton Group) consist of carbonate-evaporite rocks (Windsor Group) that are enclosed by ~ 2 km of redbeds assigned to a lower Sussex Group and upper Mabou Group. To date, this latter unit lacks significant marker beds and there is no significant biostratigraphic recovery, despite recent extraction of ~5 km of drill core from eight wells. Research on this core relates to hydrogeological and stratigraphic issues with Mabou strata.

Broadly, mudstone, siltstone and sandstone at the base of the Mabou Group gradually coarsen upward into conglomerate, and are considered the result of active alluvial fan progradation from the northeast. Also encountered in several of the cores was a single interval of localized, horizontally laminated to cross-stratified bluish grey sandstone, containing carbonaceous plant fragments and siltstone intraclasts. Although the interval can also be recognized in wireline logs, there does not appear to be a correlative reflector in seismic.

One hundred eighty five samples from four boreholes have so far been analyzed using ICP-MS and XRD. Chemostratigraphic analysis of various elemental ratios has revealed two packages bounded by an interval that correlates with the grey sandstone beds and intraclasts. Changes in the ratios are interpreted to mark a broader population of mineral species in the upper package. This further implies variation in the provenance and substrate environment of the alluvial-fan sediment either side of a disconformity represented by reduced horizons and rip-up clasts produced by sediment reworking along this boundary.

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ABSTRACT

Mississippian strata host the only onshore gas field in Atlantic Canada at McCully, southern New Brunswick. Strata overlying the current tight-gas reservoir unit and shale-gas target (Albert Formation, Horton Group) consist of carbonate-evaporite rocks (Windsor Group) that are enclosed by ~ 2 km of redbeds assigned to a lower Sussex Group and upper Mabou Group. To date, this latter unit lacks significant marker beds and there is no significant biostratigraphic recovery, despite recent extraction of close to 5 km of drill core from 8 wells. Research on this core relates to hydrogeological and stratigraphic issues with Mabou strata.

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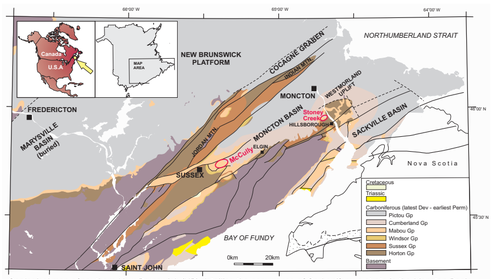
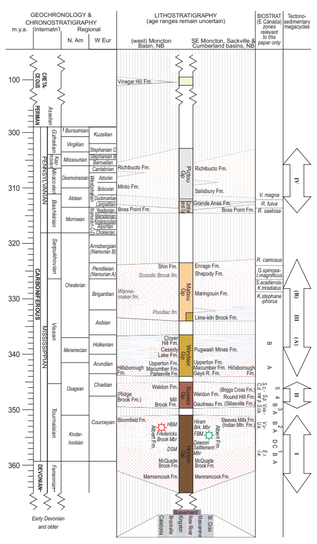
A total of 131 samples from three boreholes have so far been analyzed using ICP, ICP-MS, and XRD. Chemostratigraphic analysis of various elemental ratios has revealed two packages bounded by an interval that correlates with the grey sandstone beds and intraclasts. Changes in the ratios are interpreted to mark a broader population of mineral species in the upper package. This further implies variation in the provenance and substrate environment of the alluvial-fan sediment either side of a disconformity represented by reduced horizons and rip-up clasts produced by sediment reworking along this boundary.

INTRODUCTION

The original Potash Corp. Saskatchewan (PCS) mine extracted salt and potash from Cassidy Lake Fm. (Windsor Gp) evaporites. Water seepage eventually spurred the search for a deeper saline water depository. PCS teamed with Corridor Resources Inc., who had the local oil & gas exploration license, to drill McCully #1 which struck commercial gas in Hiram Brook Mbr. (Albert Formation, Horton Gp) tight sandstone in 2000.

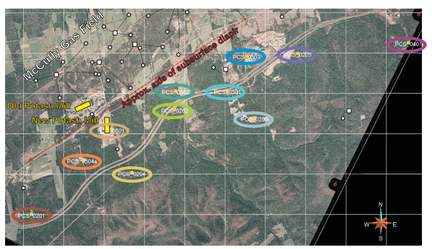


Geological map of southern New Brunswick (NB) detailing the occurrence of Carboniferous strata in the Moncton Basin. The Stoney Creek oil and gas field has produced intermittently since 1911. The McCully gas field came on-stream in 2003.

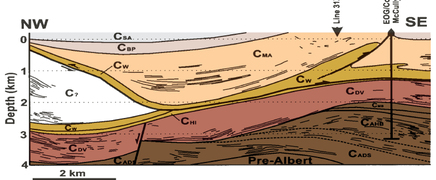


Stratigraphic subdivisions of southern New Brunswick including the Moncton Basin.

Delineation of the McCully field helped identify a new potash deposit on the south side of a Windsor Gp diapir. Further potash exploration resulted in the coring of 11 boreholes through Mabou Gp redbeds and down into Windor Gp strata. This project was initiated to determine the sedimentology and stratigraphy of the red-bed succession.



Google map of the area east of Sussex, NB. 1km grid squares added. The old mine extracted salt and potash from the northern limb of a subsurface salt diapir. Almost all gas production from the McCully field has been from beneath this limb. New salt exploration (colour coded) has been south of the diapiric axis.

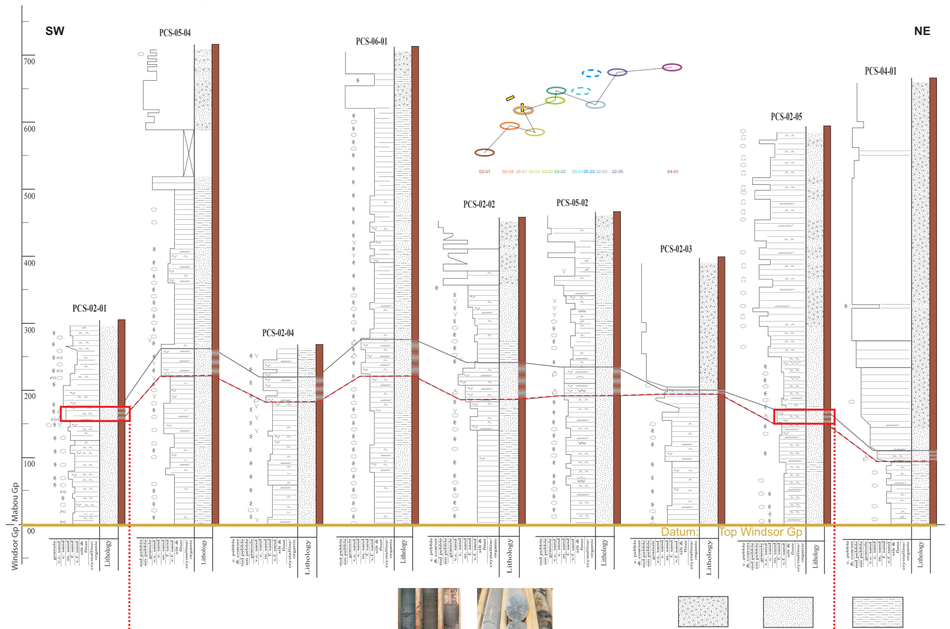


Interpreted cross-section of seismic line 6 that runs NW-SE and located slightly northeast of the map shown above. The wedge of uncoloured strata is undrilled and assumed to be mostly Sussex Gp. From Wilson 2006 PhD thesis.

Southern New Brunswick (NB) is underlain by a thick Carboniferous succession (locally over 4km), which has been subdivided into many formations that are assigned to 6 groups.
The Windsor Gp comprises cycles of limestone-evaporite deposits with interbedded red strata. The group is defined on the first and last occurrence of non-clastic strata (this occasionally leaves Hillsborough Fm. red-beds without a group assignment).
In the far SE of NB, post-Windsor redbeds have been formally divided into the Maringouin, Hopewell Cape, Shepody, and Enrage formations (collectively: Mabou Gp). However, in the Sussex region, due to limited and poor outcrop, few formal units have been defined. Mostly, the informal units of Anderle et al. (1979) have been used: conglomeratic units (Wannamaker fm.) interfinger with both a lower
muddy (Poodiac fm.) and upper sandier unit (Scoodic Brook fm.).
The new core affords the opportunity for a detailed study of the succession and a more formalized lithostratigraphy.

SEDIMENTOLOGIC LOGS

Sedimentological logging of nearly 6km of redbeds from 11 boreholes (9 boreholes illustrated herein) produced two major findings
> The redbed succession coarsens both upward and toward the northeast (conglomerate facies are coarsest, thickest, and occur closest above datum in borehole 04-01).
> A distinct unit of greybeds, often with plant fragments and rip-up clasts of rounded mudstone, occurs in most boreholes around ~200m above datum.
IS THIS UNIT STRATIGRAPHICALLY IMPORTANT?



Photographs courtesy: PCS

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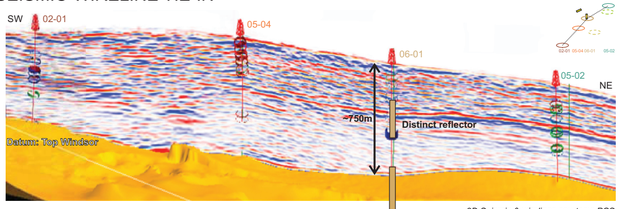
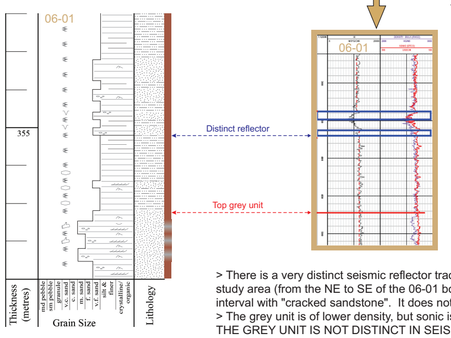
SEISMIC-WIRELINE TIE-IN



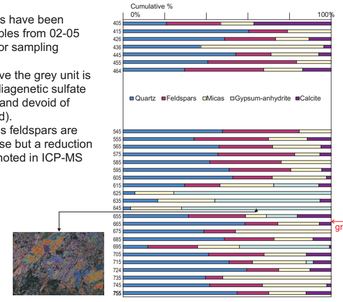
3D Seismic & wirelines courtesy: PCS

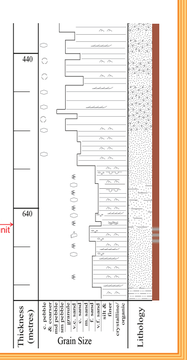


> There is a very distinct seismic reflector traceable across most of the study area (from the NE to SE of the 06-01 borehole). It ties to an interval with "cracked sandstone". It does not equate with the grey unit.
> The grey unit is of lower density, but sonic is similar to overlying beds. THE GREY UNIT IS NOT DISTINCT IN SEISMIC AND WIRELINES

XRD AND THIN-SECTION ANALYSES

Most XRD analyses have been performed on samples from 02-05 (see next section for sampling protocol)
> Immediately above the grey unit is an interval rich in diagenetic sulfate (mostly anhydrite) and devoid of feldspars (?leached).
note: XRD indicates feldspars are mostly of plagioclase but a reduction in Na or Ca is not noted in ICP-MS samples.





CHEMOSTRATIGRAPHY (ICP-MS ANALYSES)

> For borehole 02-05, samples were collected systematically at regular intervals. For the other two boreholes (02-01, 05-04), samples were collected by random-number (depth) generation.

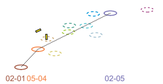
> In all cases, to minimize variation resulting from grain-size factors, material was collected from the finest grained bed within 1 m of the designated sampling depth (no sample was collected if material was coarser than a fine sand).

>ICP-MS analyses was undertaken on solutions of samples from the boreholes, quality controlled using a selection of standards (work by Actlabs, Ontario; ISO 17025 - see company website for analytical details). Since no external reference samples were run, and sampling programs varied, comparison between wells can only be qualitative.

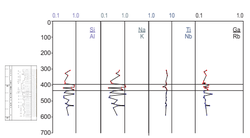
> For crossplots of elements typically associated with diagenetic phases (e.g. Ga in kaolinite, Rb in illite; Ca-Mg not plotted) there is no change across the grey zone. High correlations with similar regressions indicate few, and similar, mineral phases are present containing these elements both above and below the grey zone.

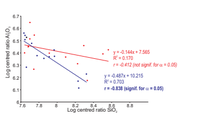
> For crossplots of elements more commonly associated with detrital phases (e.g. Nb, Ti in heavy mineral phases; and Zr, Cs not plotted), there is a high correlation (blue dots) below the grey zone, indicating few mineral phases with these components. Within and above the grey zone (red dots), regression lines typically have different slopes and wider scatter (indicating a wider variety of minerals mixing), possibly indicating more diverse provenance.

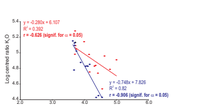
> For crossplots of major elements often used to indicate sediment maturity (Si-Al, K-Na) and usually predominant in the detrital fraction, there are again typically major differences above (red) and below (blue) the grey zone. Below there are always significant correlations (small scatter) indicating a limited number of mineral phases; above, there is greater scatter (more diverse provenance).

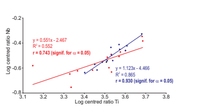


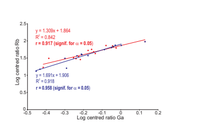
02-01
n = 28 (n_{red} = 15, n_{blue} = 13)



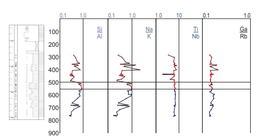


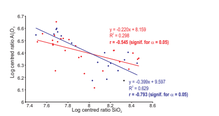


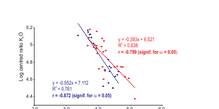


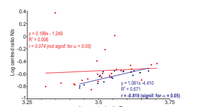


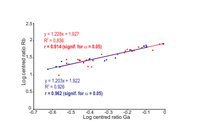
05-04
n = 44 (n_{red} = 26, n_{blue} = 18)



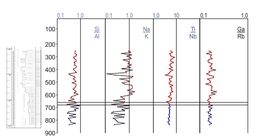


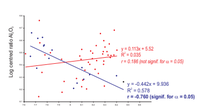


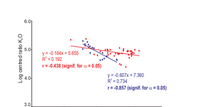


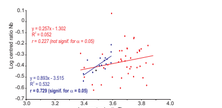


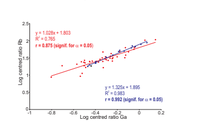
02-05
n = 59 (n_{red} = 43, n_{blue} = 16)





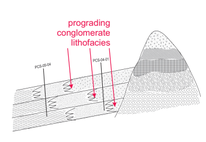




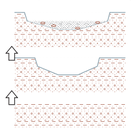


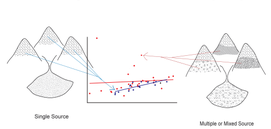
DISCUSSION (INTERIM CONCLUSIONS)

> The general lithofacies distribution suggests an alluvial fan to floodplain model, with the proximal fan located toward the northeast. Over time, the conglomerates were able to prograde further toward the southwest.



> The grey coloured interval contains numerous rip-up clasts of mudstone, particularly near the base of the interval. This suggests incision (base-level fall) and reworking. Preservation of plant fragments (no diagnostic palynology identified: G Dolby, pers. comm. 2013) and patchy grey colouration indicates a more prevalent reducing environment during infill of the incised ?valley/canyon.

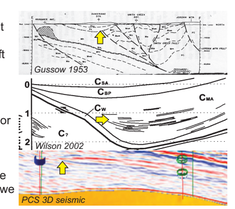




> Elemental geochemistry indicates a more varied suite of minerals within and above the grey interval. More varied source rocks would be weathered and eroded from the hinterland, either due to stream capture producing a larger hinterland exposing more varied lithologies, or uplift and unroofing of more varied lithologies.

> Base level fall / incision can result in development of a disconformity. This may be related to general uplift and change in the hinterland.

> Gussow (AAPG, v. 37, 1953) previously suggested an angular unconformity within the post-Windsor red-beds of the Moncton Basin, although later workers have downplayed / ignored its potential importance. In examined core there is no distinct angular break, hence we only describe a 'disconformity'.



> Herein, it is suggested that the unconformity represents the Asbian break between cycle IIIA and IIIB, and results in red-beds that cap Windsor Gp deposition being in contact with overlying beds of the main Mabou Gp deposition. However, because of the lithostratigraphic definition of the Windsor Gp, where equivalent redbeds cap this succession (and because there is no unconformity recognizable in the field), these redbeds have been lumped in with the Mabou Gp.

ACKNOWLEDGEMENTS

Actlabs undertook the ICP-MS analyses. Ven Reddy (Dept of Earth Sciences UNB) provided the XRD analyses. Funding was provided by Potash Corporation of Saskatchewan.

PotashCorp
Helping Nature Provide