Mineralogy, Sedimetology and Facies Description of a Potential Cretaceous Shale Gas Play in Western Manitoba

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Overview and Objectives, Stratigraphic Framework

Shale gas plays are becoming progressively more important in the energy market as gas production from conventional reservoirs decreases. With the advances in exploitation technology gas production from shale has become viable and economic. The first modern exploration of shallow shale gas in Manitoba was initiated by EOG Resources Canada Inc. in 2003. Three shallow wells were drilled in the Waskada Field and perforated in the Assiniboine Member of the Favel Formation (Figure GS-X04-1). These wells did not produce gas and were abandoned in 2006–2007 (Nicolas, 2008). Additionally, in 2006-2007 Tundra Oil and Gas Partnership drilled three wells in Cretaceous shale units; which were also abandoned (Nicolas, 2008).

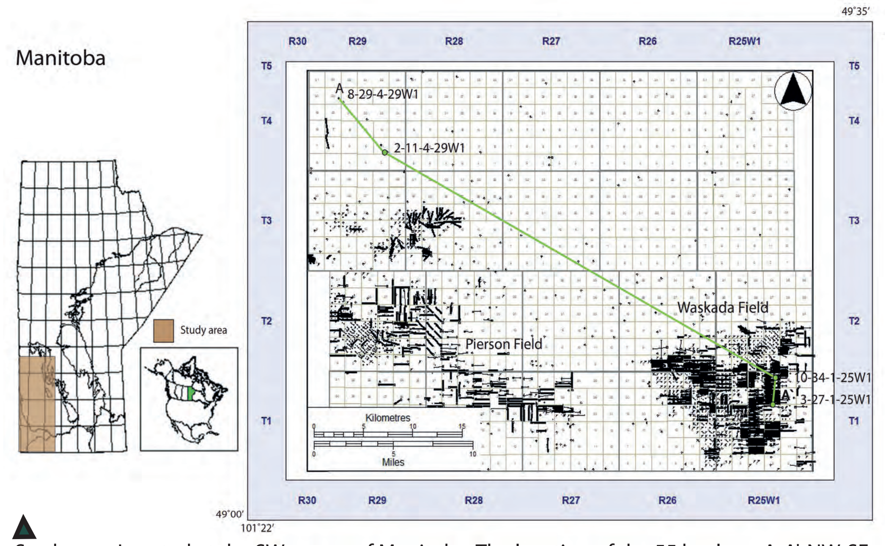
Based on previous studies southwestern Manitoba is a good candidate for extracting gas from shale formations at shallow depth (Nicolas and Bamburak, 2009). However, there is need for more studies in order to find the most productive shale intervals in the area and to design the proper techniques for gas extraction. Research in this recently started project will address several of these issues to better understand the shallow shale gas potential of these units. Previous work mainly focused on outcrops, whereas this project integrates these studies with subsurface data, core and well-logs to provide a link between the surface and subsurface where the potential gas resource exists.

This study is being conducted on Upper-Cretaceous formations in southwestern Manitoba including the Upper Ashville, Favel, and Carlile formations. This study examines a number of wells drilled in this area. The goal of this study is to provide information needed to improve exploration in the new and unproven unconventional shallow shale gas play. Detailed subsurface mineralogical and geochemical studies are conducted on cores from a number of wells in this area. The data presented in this work are from well 3-27-1-25W1 located in Waskada oil field.

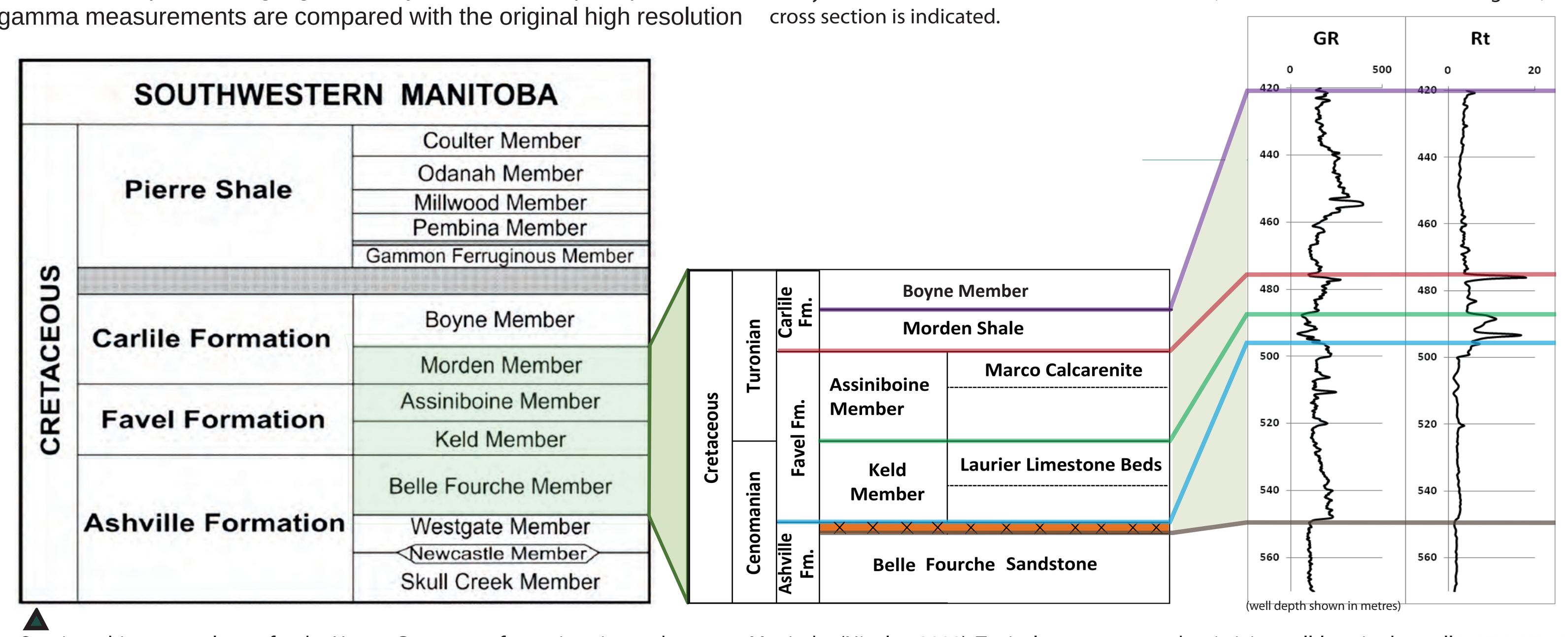
- **Core examination, well-log and petrographic analysis** are used to investigate the sedimentary structures, grain size, ichnology and bioturbation degree, and consequently to describe the facies scheme. Six main facies are identified ranging from non-calcareous organic mudstone to highly calcareous, bioturbated very fine-grained sandstone representing a change from offshore fissile shale to shallow water carbonate-rich lithologies. The bioturbation intensity varies from rare to moderate representing more distal environmental settings from relatively anoxic to oxic interfaces. Bentonite beds occur at different intervals in the wells indicating volcanic activities during deposition. It may be possible to use these bentonite beds for high resolution dating of the strata as well as for lateral stratigraphic correlations.

- **X-ray Fluorescence**, from core and powdered samples, along with X-ray Diffraction are used to identify mineral composition and elemental abundances. One objective is to look at minerals with a link to their types of occurrence within these units. For example, carbonate occurs in three different forms through shale units including; laminae of carbonate foram grains within shale beds, coccolith accumulations and as calcite fiber in thin to thick well -preserved bivalves (Inoceramus) laminae. These different styles of carbonate show relatively similar bulk mineralogy. However, each style affects the reservoir properties and behavior in a different way. It is crucial to conduct mineralogical studies in association with sedimentological observations in order to get the most realistic interpretation, understanding and analysis.

Gamma ray values are calculated based on radioactive element concentrations measured through X-ray Fluorescence as well as using a hand-held gamma ray tool (RS 230). Additionally, gamma ray values are acquired using a gamma ray core scanner (SGR). All these gamma measurements are compared with the original high resolution



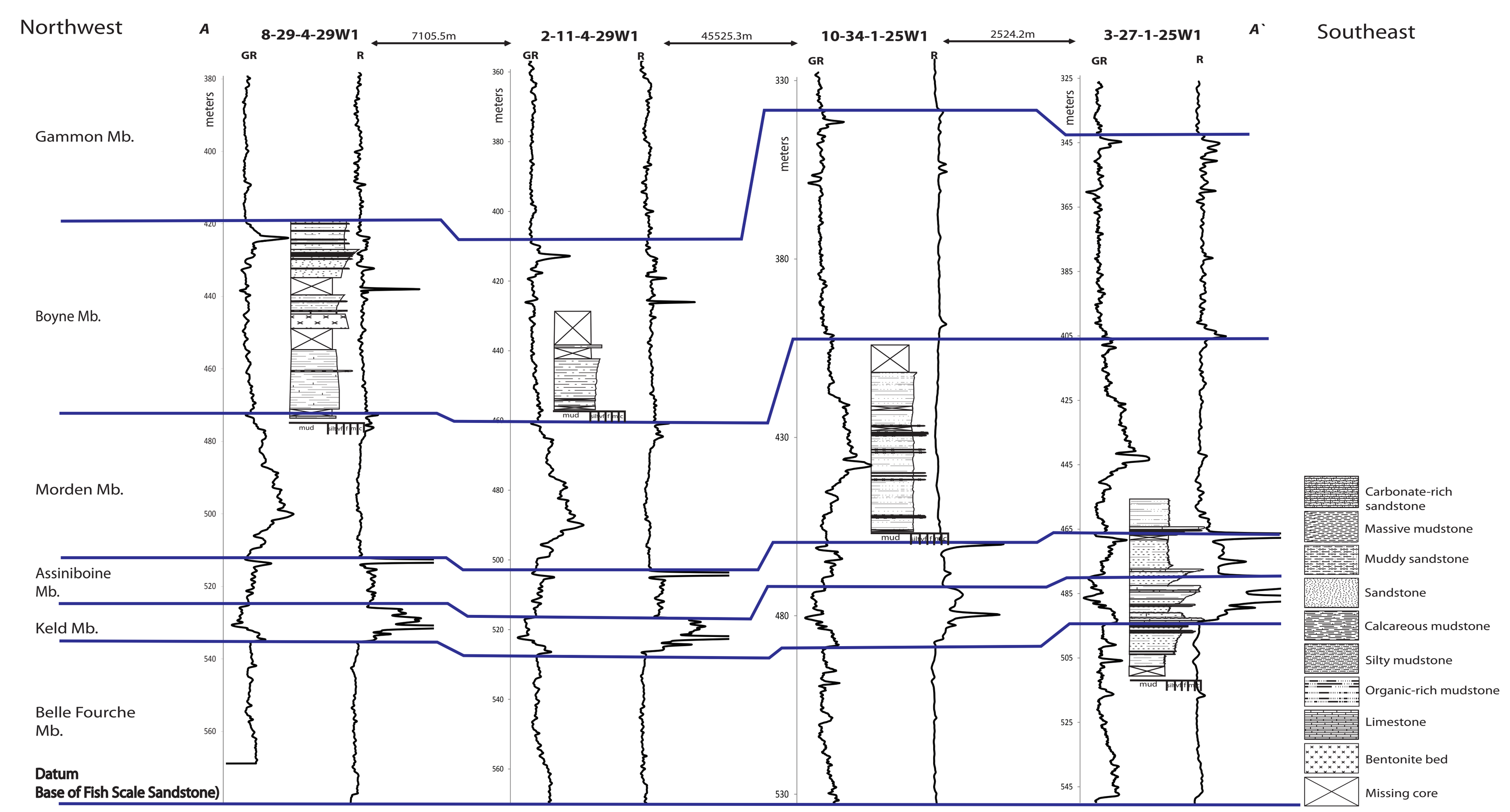
Study area Located at the SW corner of Manitoba, The location of the 55 km long A-A', NW-SE cross section is indicated.



Stratigraphic nomenclature for the Upper-Cretaceous formations in southwestern Manitoba (Nicolas, 2008). Typical gamma-ray and resistivity well-logs in the well 3-27-1-25W1.

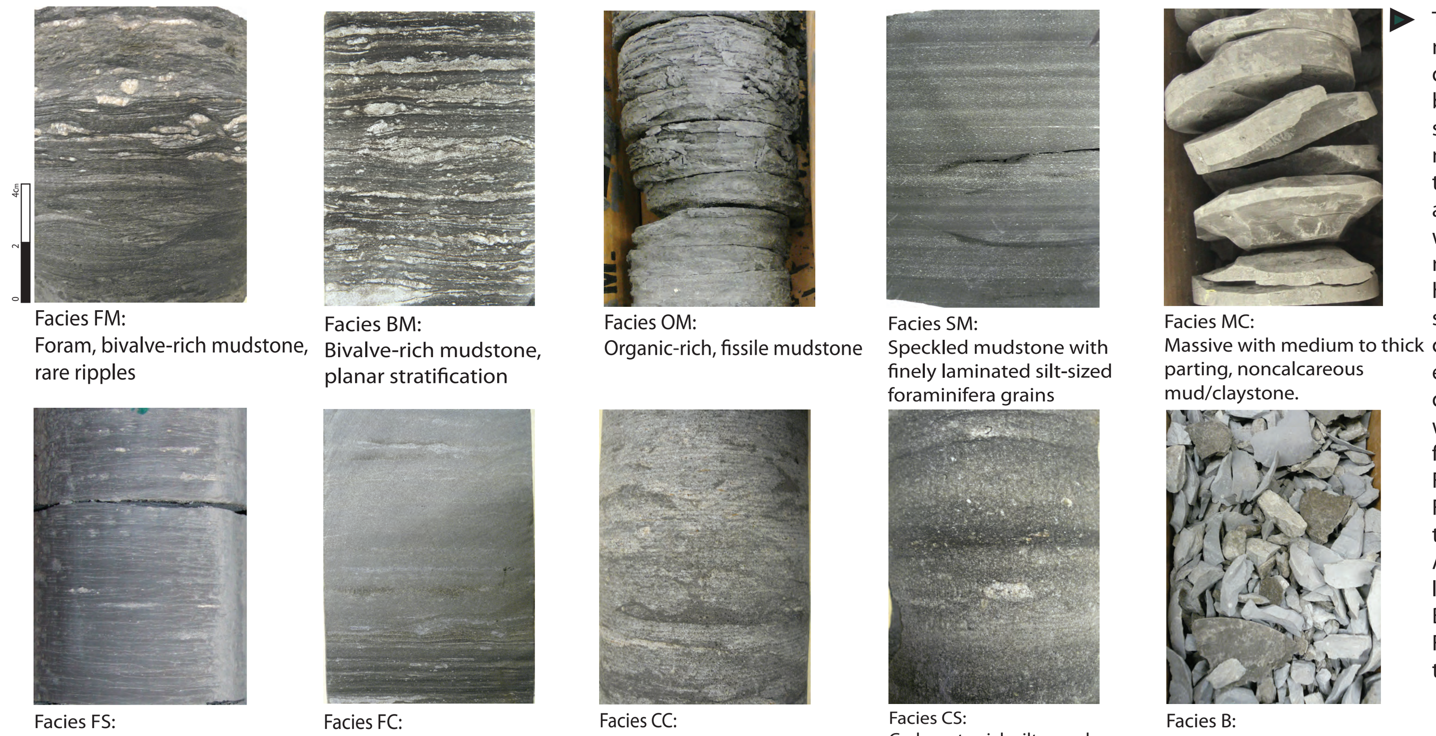
Area outcrop views. (a) Keld member (Favel formation) outcrop by the Wilson river. (b) Assiniboine member (Favel formation) and its top Marco calcarenite located by the Virmilion river. Also lower part of the Morden is shown on top of the hill. c) Boyne memebr (Carlile formation) and the bentonite beds within the interval.

Lithologs, Facies and Mineralogy



Geophysical well Log (gamma ray and resistivity) with stratigraphic markers for upper Ashville, Favel and Carlile Formations. Facies 1 through 10 are shown in lithology logs.

Facies Description



Facies FM: Foram, bivalve-rich mudstone, rare ripples

Facies BM: Bivalve-rich mudstone, planar stratification

Facies OM: Organic-rich, fissile mudstone

Facies SM: Speckled mudstone with finely laminated silt-sized foraminifera grains

Facies MC: Massive with medium to thick parting, noncalcareous mud/claystone.

Facies FS: Slightly to noncalcareous fissile shale, rare broken bivalve fragments

Facies FC: Fine-grained carbonate (limestone), rare bioturbation

Facies CC: Coarse-grained carbonate (limestone), heavily bioturbated

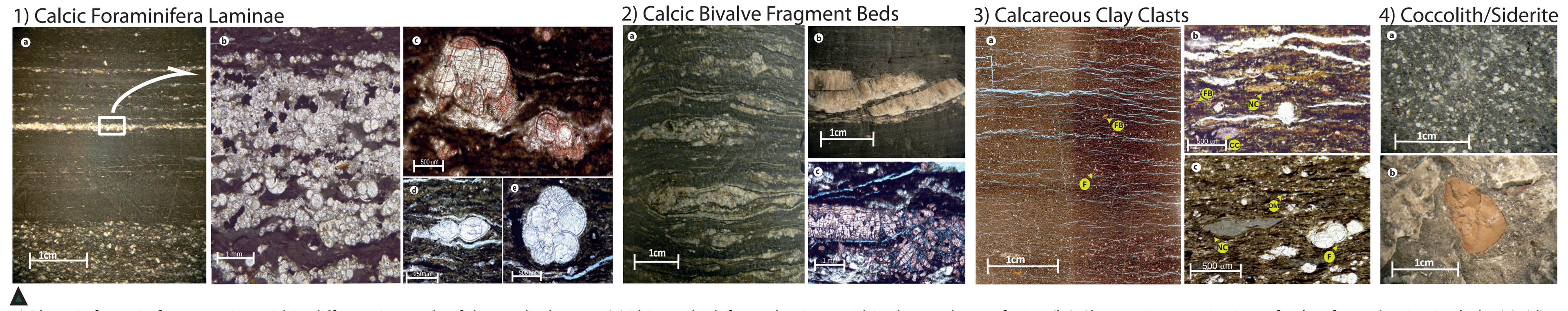
Facies CS: Carbonate-rich silty sandstone, common bioturbation

Facies B: Massive or normally graded bentonite beds

These facies are recognized based on grain size, mineralogy, fossil content etc. The mud-dominated facies with the lowest degree of bioturbation are interpreted as being deposited below storm-wave base in a marine environment. The mud-dominated fossiliferous facies are interpreted to be deposited in a marine shelf environment above storm wave base but below fairweather wave base. These contain planar stratified Inoceramus shell hash beds deposited by storm-induced, higher energy currents reworking the shallow shelf. The sand-dominated facies are comprised of coarse-grain carbonate grains reflect the shallowest water facies which, together with the high degree of bioturbation, suggest deposition in a well oxygenated proximal offshore to lower shoreface setting.
Facies OM is more dominant in Morden interval. Facies BM and FM are mostly covering the Keld interval. CC facies is occuring on top of the keld and Assiniboine members as resistant, carbonate layers. Facies MC was only detected in the upper Belle Fourche member of the Ashville formation. Facies B or bentonite beds are occuring through the whole section as thick to very thin beds.

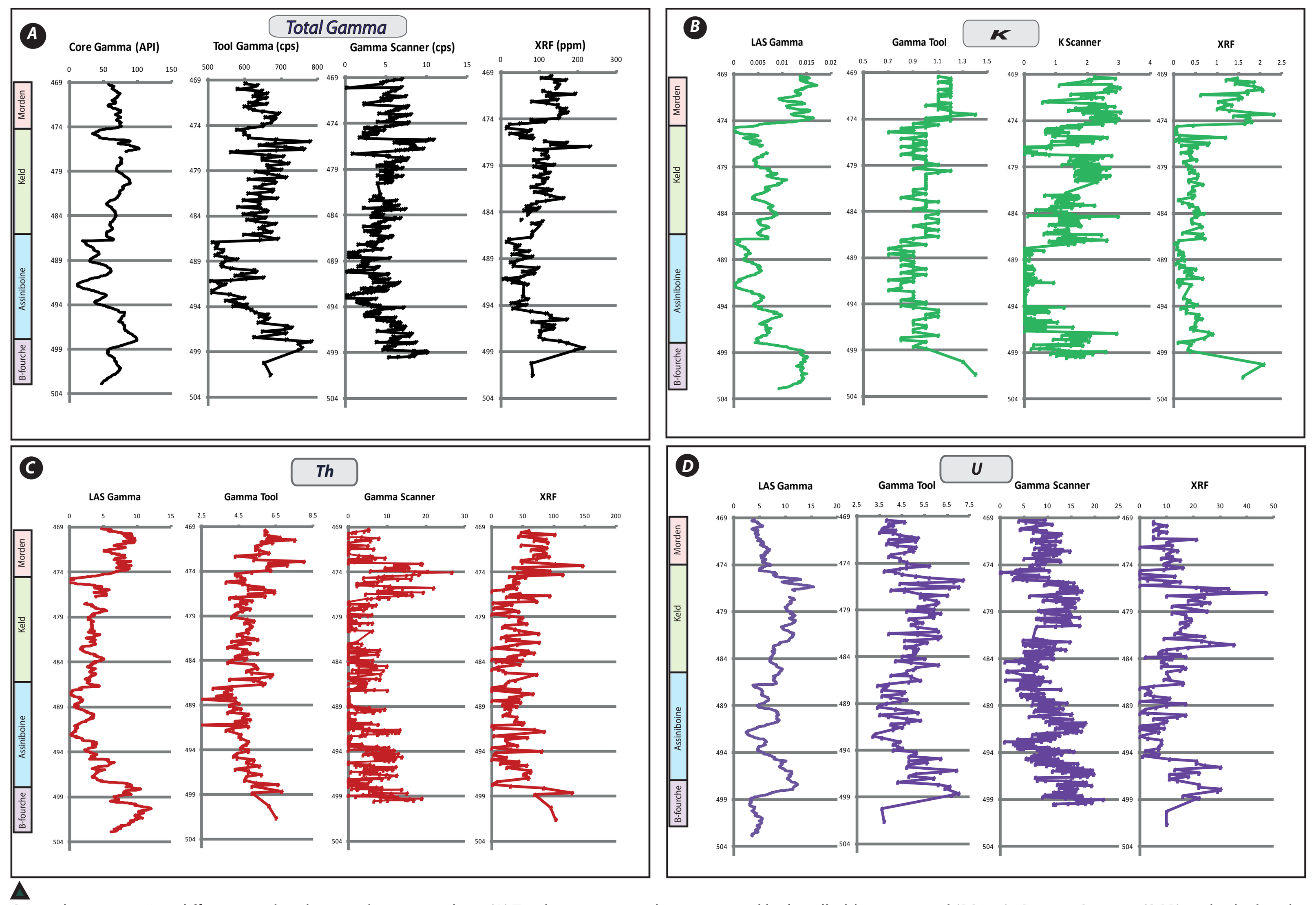
Carbonate Types of Occurance

1) Calcic Foraminifera Laminae
2) Calcic Bivalve Fragment Beds
3) Calcareous Clay Clasts
4) Coccolith/Siderite

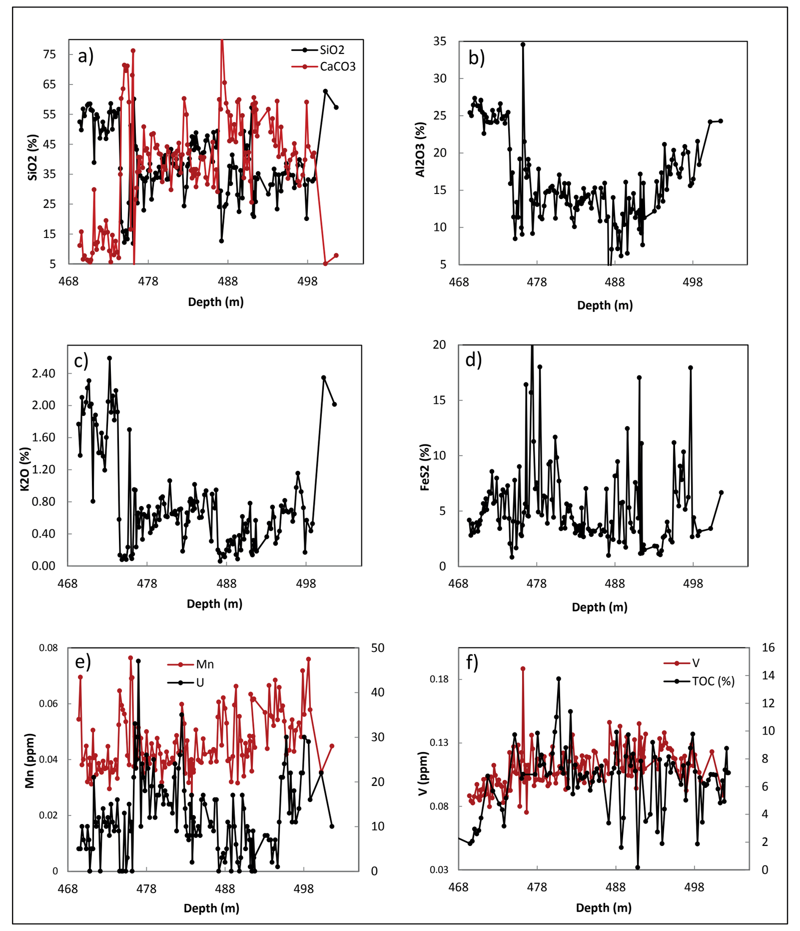


1) Planctic foraminifera occuring within different intervals of the studied strata. (a) Thin to thick foram laminae within the mudstone facies. (b) Closer microscopic view of a thin foram lamina in shale. (c), (d) and (e) Different foraminifera speices within mudstone. 2) (a) Core veiw of interlaminated Inoceramid shells hashes within dark grey calcareous mudstone. (b) Closer view of prismatic Inoceramid shells. (c) Microscopic view of a red dyed shell. 3) (a) Overall thin section view of a shaly facies. (b), (c) Calcareous and noncalcareous clay clasts in shale (CC) and non-calcareous clay clasts (NC), organic material (OM), forams (F) and phosphatic fish bones (FB). 4) (a) Coccolith accumulations (pellets) in silty mudstone. (b) Siderite grain in calcareous silty.

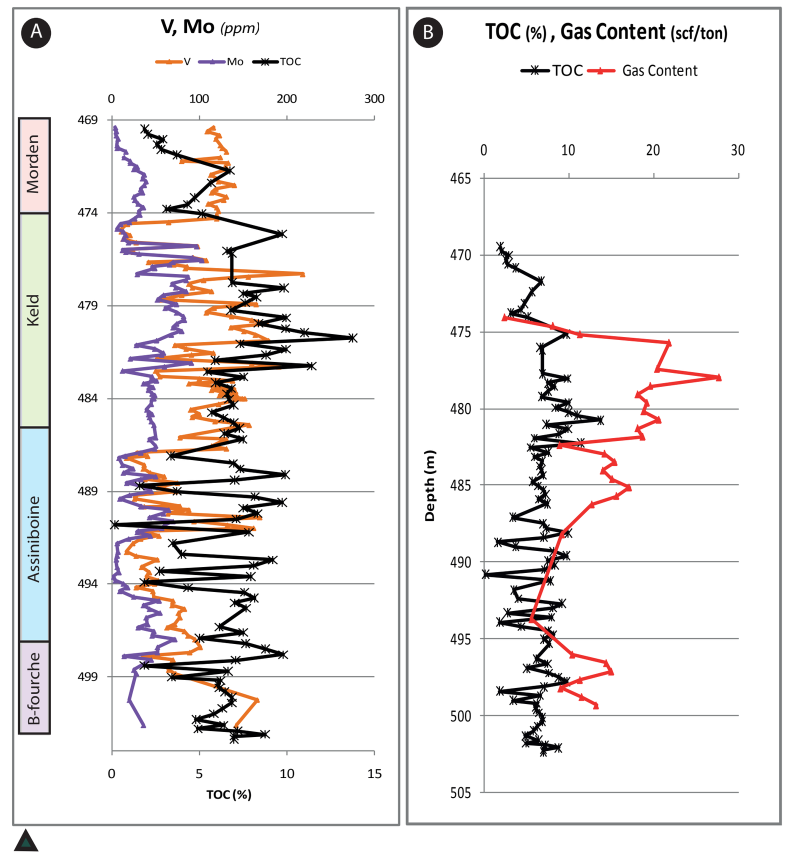
Total and Spectral (K, Th, U) Gamma, Geochemistry



Cross plots comparing different total and spectral gamma values. (A) Total gamma ray values measured by handheld gamma tool (RS350), Gamma Scanner (SGR) and calculated gamma ray from XRF tests, respectively, showing a good match with core gamma (LAS). Measurements for core gamma are taken continuously whereas reading in handheld gamma tool, XRF tests and gamma scanner are taken in discrete points. (B), (C), (D) Spectral gamma values measured by mentioned techniques plotted against original spectral gamma values from core showing a reasonable match.



Cross-plots of different elemental compositions vs. depth for the well 3-27-1-25W1. Mineralogical data are generated by ED-XRF. a) Percentage of SiO2 and CaCO3 versus depth showing the reverse relationship between the two major oxides. b) Values of aluminum oxide versus depth showing the same trend as silica in plot A. c) Showing the values for potassium oxide. Note that this trend almost matches the aluminum and silica trends. d) Pyrite content. e) Uranium and manganese, that displays an inverse relationship between the two. f) TOC percentage plotted along vanadium content as a reducing environment indicative element (TOC data from well report provided by CBM Solutions LTD, 2002).



(A) Reducing environment associated elements (V and Mo) plotted against TOC values. vanadium can be used as a proxy for higher TOC values (Swanson, 1961). (B) TOC values vs. gas content. Note higher concentrations of gas occures at shallower depth with relatively constant values of organic matter.

References:

Nicolas, M.P.B. 2008: Summary report on petroleum and stratigraphic investigations, southwestern Manitoba; in Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 171–179.

Swanson, V.E. 1961: Geology and geochemistry of uranium in marine black shales, a review; United States Geological Survey Professional Paper 356-c, United States Government Printing Office, Washington.