InSite

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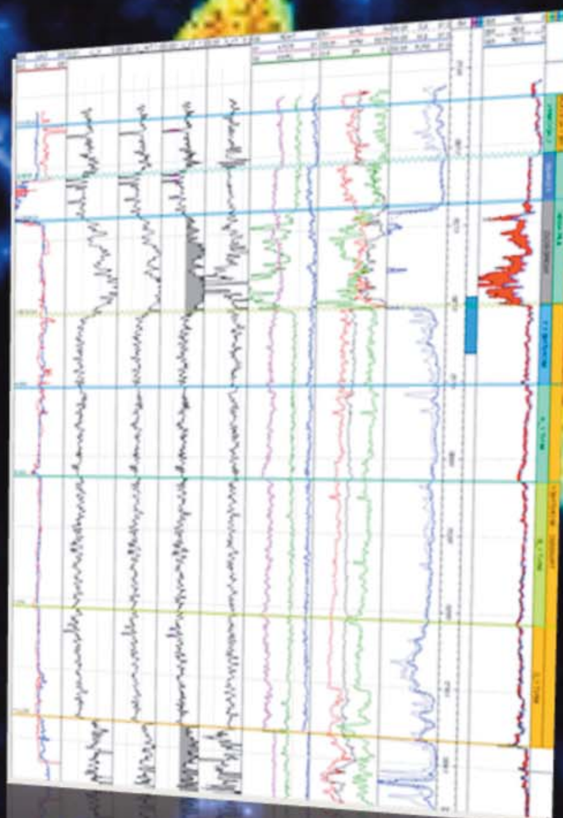
Fall 2012 Issue 31 Volume 1



InSite

CWLS Magazine **Fall 2012**

Issue 31 **Volume 1**

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This will be the final printed edition of the *InSite* publication

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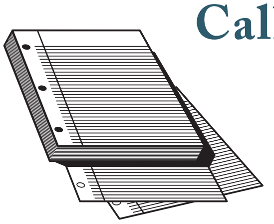
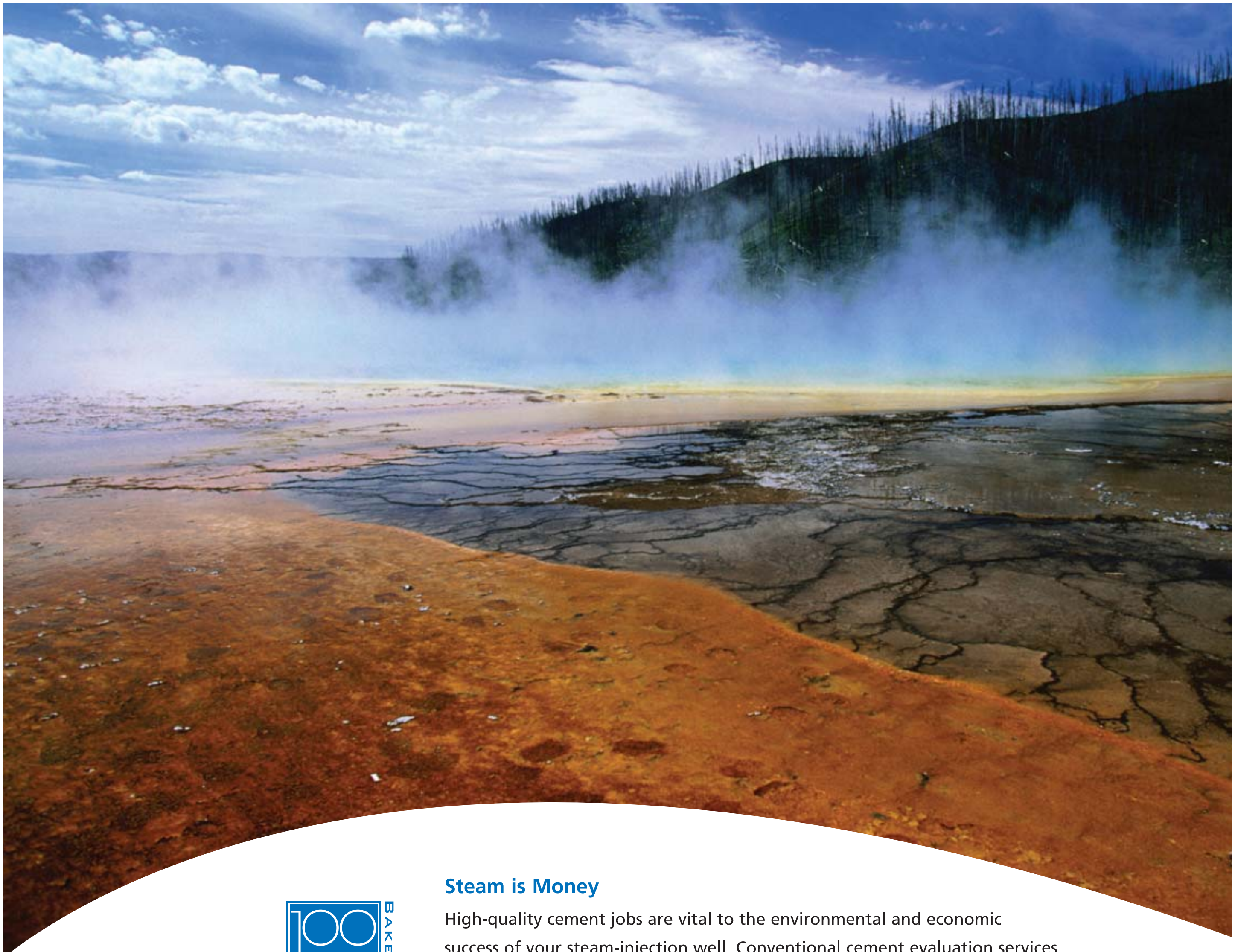


Call for Papers

The CWLS is always seeking materials for publication. We are seeking both full papers and short articles for the InSite Magazine. Please share your knowledge and observations with the rest of the membership/petrophysical community.

Contact publication Co-chair:
Joelle Meulenkamp - Joelle.meulenkamp@halliburton.com or
Jeff Dickson - jefdickson@suncor.com



LAS 2.0 Software Updated November 2011

An updated version of the software "LAS Applications" is available to the CWLS members. The software was designed by C. Struyk using Microsoft Visual Basic on the .NET 3.5 platform and runs on Windows XP, Vista, and Windows 7. It can be found on the CWLS website (www.cwls.org) under the tab "Products/Las Info" and then going to the link labeled "LAS 2.0 Application Software November 2011".

The LAS Applications software was designed to handle the batch processing of LAS files where the output of one process becomes the input to the next process. Files that do not require changes are automatically passed on to the next process. If a file cannot be processed, the problems encountered are documented in the "events log" and a copy of the file is sent to the directory "C:\LasApps\FaultyFiles". At the completion of this automated process the user can specify the directory in which to save the resulting files.

The software includes the following routines under the menu item "Processes/Routine LAS processes":

- Correct LAS files for common errors: The common errors include blank lines and non-printable characters. These are removed or in some cases replaced by a space.
- Convert LAS version 1.2 to version 2.0
- Convert LAS version 3.0 to version 2.0
- Correct start, stop, step problems
- Resample LAS files (includes a filtering algorithm that can be set manually)
- Set depth direction
- Wrap and unwrap LAS files. .
- Convert depth units from metres to feet/ feet to metres.

Additional routines can be found under menu item "More Tools"

- Change curve mnemonics in LAS files
- Convert text to Las 2.0
- Merge LAS files
- Other includes: Unzip, change file extensions, collect LAS mnemonics, collect Rmf data, filter LAS files.

Bugs/problems can be reported to k.c.petrophysics@gmail.com

Case Struyk

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You have given back our freedom
You have lived up to your name

Petrophysics !!!
May your spirit never die
Hold your candle to the darkness
You're the keeper of the flame

Petrophysics !!!
Keep believing in the dream
Truth is stronger than the shadows
Keep it shining in your eyes

Petrophysics !!!
May the skeptics disappear
May your depth plots live forever
May their beauty fill your lives

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You can hold your head up high
You have given back our freedom
You have lived up to your name

Petrophysics !!!
May your spirit never die
Hold your candle to the darkness
You ARE the keeper of the flame.

Contributed by: E. R. (Ross) Crain, P.Eng.
With apologies to Kris Kristofferson

Petrographic and Petrophysical Comparison of the Montney Formation in the Sturgeon Lake South Area

F.F. Krause, A.C. Wiseman, K.R. Williscroft, N. Solano,
N.J. Morris, R. Meyer & R. Marr
Department of Geoscience, University of Calgary

Summary

Application of the scientific method can be a tedious and time-consuming task. Consequently, it is only human to take advantage of expeditious short cuts to ease this process. As a result, we sometimes rely heavily on tool-derived technological interpretations without crosschecking this evidence against that available from more labour intensive tools. In this study of the Montney Fm., a stratigraphic interval that hosts unconventional oil and gas reservoirs in the Western Canadian Sedimentary Basin (WCSB), we examined the responses of total gamma ray (TγR), photoelectric (P_e) and spectral gamma ray (SγR) logs and cross-referenced the interpretations based on these logs with those obtained from thin-sections and drill cores from the Sturgeon South Lake area in west-central Alberta (Figure 1). Notably, the interpretations based on the logging tool responses suggest that the formation is a shale that contains significant amounts of illite and mica. On the other hand, evaluations of the petrographic analyses from rock samples indicate that the Montney Fm. is a mixed carbonate-siliciclastic deposit, specifically a dolomitic, feldspathic and quartzose siltstone with minor muscovite, iron sulphides, and trace illite. This study demonstrates that geology is a multidisciplinary endeavour where remote sensing tools can provide useful data. For example, total gamma ray (TγR), photoelectric factor (P_e) and spectral gamma ray logs (SγR), provide detailed information regarding rock properties, but the interpretations need to be regularly "ground truthed".

Introduction

TγR logs and P_e logs of the Montney Fm. collected in the Sturgeon Lake South area typically have radioactivity responses that range from 60°-150° API and 2.3-3.8 Barns/e, respectively (Figure 2). While this log response quintessentially is attributed to shale, explorationists working in the Western Canada Sedimentary Basin (WCSB) have learned that in the Montney Fm. this logging record is not as it seems and instead is a function of non-clay radioactive minerals. In this study, with the aid of SγR and P_e logs, optical thin section microscopy, microprobe chemical element maps, point count analyses, and X-Ray diffractometry (XRD), we document the nonradioactive and radioactive minerals characteristic of the formation.

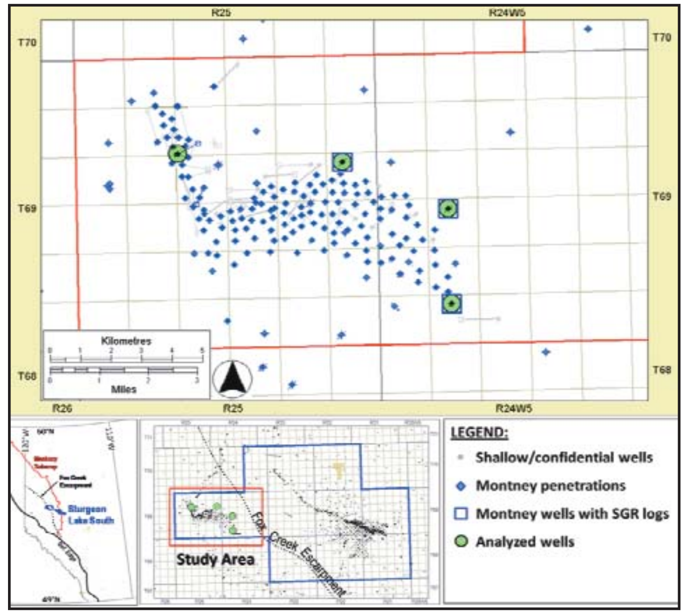

Figure 1: Location of the wells analyzed in the Sturgeon Lake South field of west central Alberta.

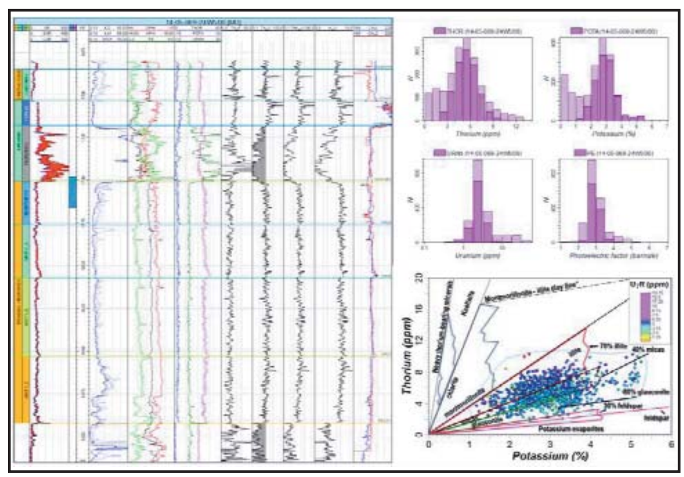

Figure 2: Example of SγR and conventional well logs suite for well 14-05-069-24W5 that encompasses the Montney, Fernie and Cadomin formations. The Th vs. K & U crossplot, and the histograms depict only the Montney Fm. interval.

Theory and Methods

Logging Tool Responses:

As is customary, SγR logs are plotted against depth on 3 separate tracts to illustrate the concentrations of the 3 most common naturally occurring radioactive elements in rocks, namely potassium (K as %), thorium (Th as ppm) and uranium (U as ppm). In TγR logs radioactivity is presented in a single tract in API units, as the 3 tracts of the SγR logs are summed after applying vendor specific API unit multipliers to each radioactive element. As is apparent in SγR logs of the Montney Fm. bulk U concentrations average between 2-4 ppm, Th concentrations are higher and range between 3-8 ppm, and K concentrations are higher still and range between 1.2 – 4%. Using the Schlumberger chart (CP-19) it is apparent that the crossplotted Th and K concentrations fall within the illite field of this chart. As a consequence, this result would be interpreted to indicate that there is a significant contribution from illite clay to the observed TγR response of the formation (Figure 2).

Petrologic Tool Response:

Thus predictions supported by SγR analyses indicate that illite is the source of the bulk radioactive mineral response in the Montney Fm. However, this prediction is not supported by petrological examinations including thin sections observations, microprobe and XRD analyses. Instead the minerals observed in thin sections, in order of abundance, are quartz, dolomite, orthoclase, albite, muscovite and iron sulfides. Assessments of XRD analyses of whole rock and clay-size fractions (2µm and <2µm) confirm the presence of these same minerals, but in addition we also note that illite is observed in trace amounts in the clay-sized fractions (Figure 5). As a consequence, the dominant K sourcing minerals are muscovite and K- feldspars, which include both orthoclase and sanidine. Microprobe analysis of these dominant K bearing minerals revealed K concentrations of 8-9 wt% for muscovite and 10-14 wt% for K-feldspars (Table 1). While our point count sample size is small it would appear that in the Montney Formation the greatest proportion of K is contributed by K-feldspars and muscovite and not illite clays.

Mineral	Published Wt%	This Study Wt%
K-feldspar	10.9-16	10-14
Muscovite	7.9-9.8	8-9
Illite	3.5-8.3	
Dolomite	0.07	
Quartz	0.08	

Table 1: Potassium Wt % from published data and this study for common minerals within the study interval (Rider, 1996; Luthi, 2000).

Grain Size & Diagenesis

Modal analyses performed on the dominant siliciclastic fragments (quartz, albite, and K-feldspar mineral grains) reveal values ranging from 3.5-6.5 Ø with median diameters in the range of 4.2-4.7 Ø, the size of coarse silt. Notably, chemical elemental maps and quantitative geochemical data of euhedral and subhedral dolomite grains expose particles with rounded, silt-sized, Fe-free cores, and syntaxial, rhombic and polygonal,

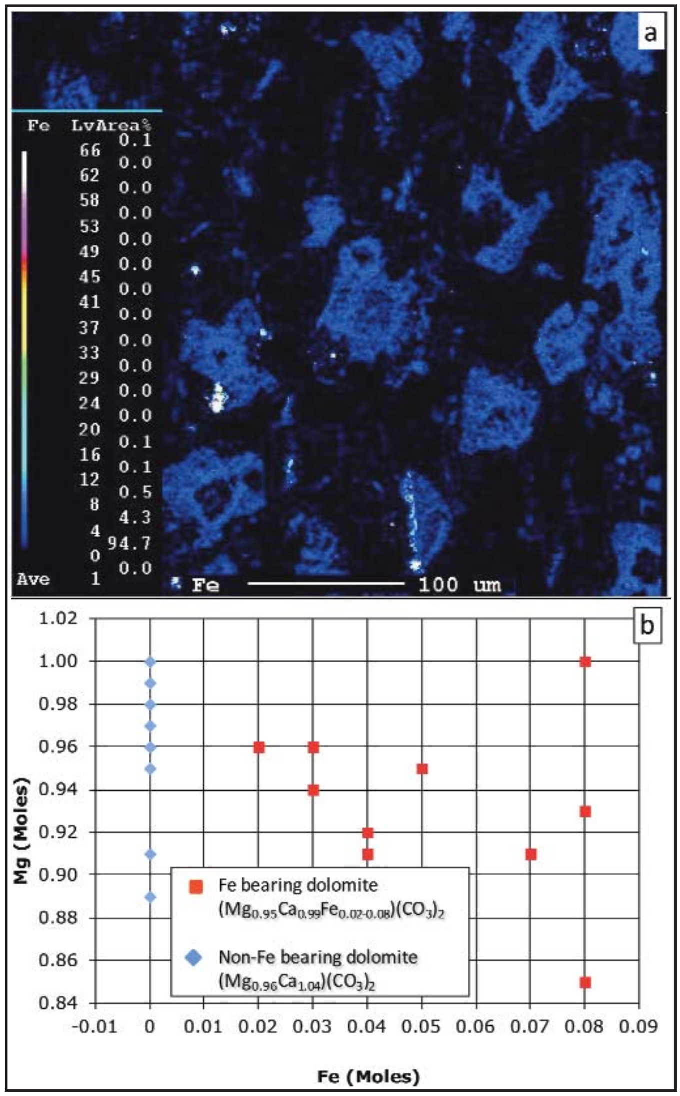

Figure 3: (a) Fe chemical element map showing distinct Fe-bearing overgrowths with Fe-free cores; (b) Molar compositions of Mg and Fe in dolomite, showing two clear dolomite populations.

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Petrographic and Petrophysical Comparison *continued…*

Fe-bearing cemented rims. The rounded Fe-free cores are interpreted to represent a silt-sized, detrital precursor that was subsequently overgrown by an Fe-bearing dolomite phase. Consequently, this diagenetic change enlarged the transported Fe-free dolomite particles to rhombic crystals that are typically coarse silt to lower very fine sand-sized as observed with optical petrography and microprobe analysis (Figure 3). Additionally, point count analysis done on microprobe chemical element maps bring to light that the K-feldspar grains have an average grain size of 4.7 Ø, whereas albite grains have an average grain size of 5.2 Ø. This difference in grain sizes, in conjunction with the lower degree of rounding observed in the K-feldspar grains,

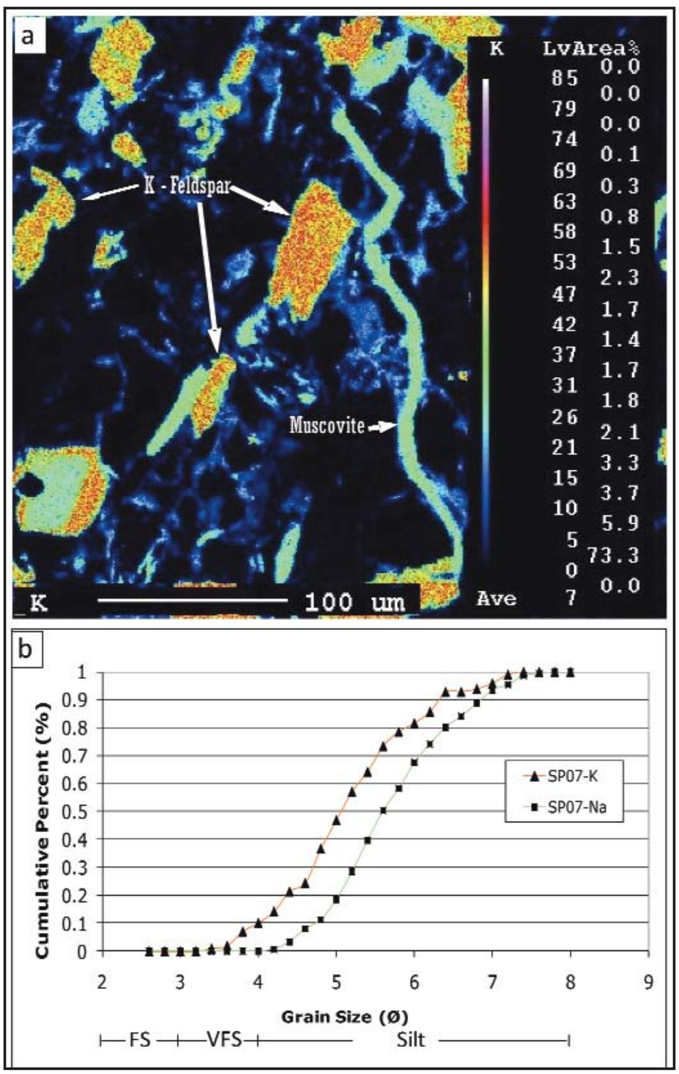

Figure 4: (a.) K element map showing feldspar and muscovite mineral grains; (b.) Cumulative percent grain size curves for K and Na bearing feldspars showing coarser grain size population within the K-feldspars (orange) than Na-feldspars (green).

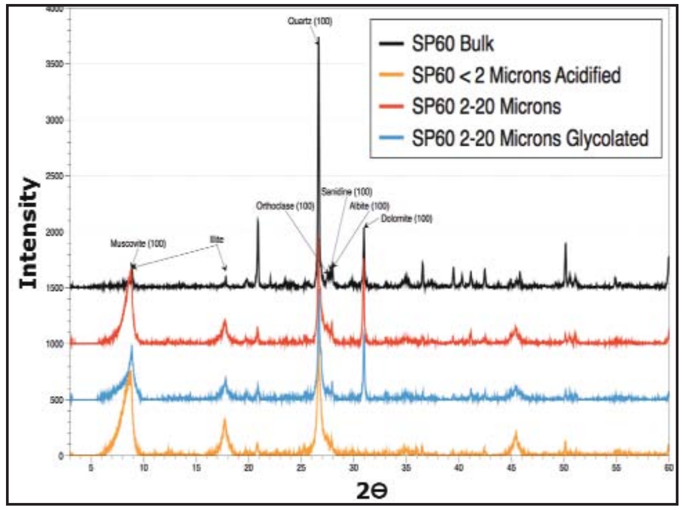

Figure 5: XRD spectra from different size fractions from a single sample. From the bulk sample analysis it can be inferred that the relatively amount of illite is low as the peaks for quartz, feldspars and the dolomite are much more prominent.

also provides strong evidence for post-depositional modification of K-feldspar grains by K-feldspar overgrowths (Figure 4). Thus, post-depositional modification of both dolomite and K-feldspar detrital grains by dolomite and K-feldspar mineral precipitates has increased the overall proportion of dolomite and K-feldspar minerals in the formation.

Conclusions

The combination of petrophysical and petrological analyses of data from several samples of the upper Montney Fm within the Sturgeon Lake South area spark the following conclusions:

1. The Montney Fm. In the Sturgeon Lake South area was deposited as a mixed carbonate-siliciclastic siltstone;
2. Authigenic mineral overgrowths of feldspar and dolomite result in the enlargement of detrital feldspar and dolomite grains;
3. Conventional interpretation of Th vs K cross plots from SγR data lead to overestimation of clay content in the formation;
4. The high K response seen in SγR logs is due to the presence of b/w 10-15% K-feldspars and 3-5% micas rather than abundant illite clay;
5. Lastly, our study illustrates that geological interpretations based on gamma-ray logs should be confirmed with rock samples from the formations under scrutiny.

References

Luthi, S.M., 2000. Geological Well Logs, Springer-Verlag, Berlin, 373 pp.

Quirein, J.A., Gardner, J.S., Watson, J.T., 1982. Combined natural gamma ray spectral/litho-density measurements applied to complex lithologies. SPE Annaul Technical Conference and Exihibition, New Orleans, Society of Petroleum Engineers of AIME, Paper 10.2118/11143-MS, 14 pp.Rider, M., 1996. The Geological Interpretation of Well Logs, 2nd Edition, Gulf Publishing Co., Houston, Texas, 280 pp.

Rider, M., 1996, The Geological Interpretation of Well Logs, 2nd Edition, Gulf Publishing Co., Houston, Texas, 280 pp.

Schlumberger, 2000, Log interpretation charts, 2000 Edition, Sugar Land, Texas, pages 4-29 & 4-30.


Schlumberger

Archiving Electronic Wellbore Data Using Metadata: Update 2011

Case Struyk
Chairman, CWLS Metadata Committee

Summary

In late 2009 the CWLS was approached with the concept of an automated method to archive wellbore data. This resulted in the creation of the CWLS Metadata Committee and was followed by a presentation at the 2010 GeoCanada conference and a CWLS technical talk. This article provides a short review of the concepts of using the metadata concepts in archiving electronic wellbore data and presents the progress/changes that have been made since its introduction.

These changes include the addition of additional defined metadata elements, and the simplification of the summary information tags on "pdf" and MS-DSO-compliant files. Optical character recognition (OCR) software was tested for its ability to extract metadata information from unstructured files. The results were very good and will significantly reduce the need for and importance of summary information tags. The archival software used for testing purposes was updated to handle more file types (las, dlis, pds, tif, pdf files) and uses optical characterization software to extracting metadata information from the unstructured files.

The original paper "An Automated Method to Archive Wellbore Data" that is located on the CWLS website under the "Products/Metadata" tab will be updated in early 2012 to include items discussed in this article.

The Concept

The oil industry currently uses manual and non-standardized methods to store and retrieve wellbore data. This process can be automated, using techniques similar to those of a public library, by defining a metadata element set for wellbore data and extracting that information from the electronic files.

A public library collects basic information about books using key words such as "title", "author", "publisher", etc., transfers this information to library reference cards, and then organizes the reference cards so that they can be searched to retrieve a specific book. In the computer world, electronic files are analogous to books and metadata is analogous to library reference cards. A library system can be created for electronic files by collecting the metadata information for each file into a common database.

Extracting metadata information from files with a known structure (structured files) such as 'las', dlis', 'pds' files can be done programmatically without any user input. Unstructured files ("tif", "pdf", files) require more effort because the files are generally images and do not have a predefined structure that lends itself to the easy collection of metadata information. The original concept was that metadata information for unstructured files could be added to the file's summary information tag by the creators of the files (Figure 1). That may not be as necessary today as first envisioned. Tests with optical character recognition (OCR) software suggest that metadata information can be readily collected from unstructured files with acceptable accuracy and minimal user interaction.

A Review of the Details

A list of metadata elements for wellbore data is shown in Figure 2. The user can define more as dictated by his needs. The first three metadata elements as shown in Figure 2 are of an organizational nature while the remaining ones are descriptive.

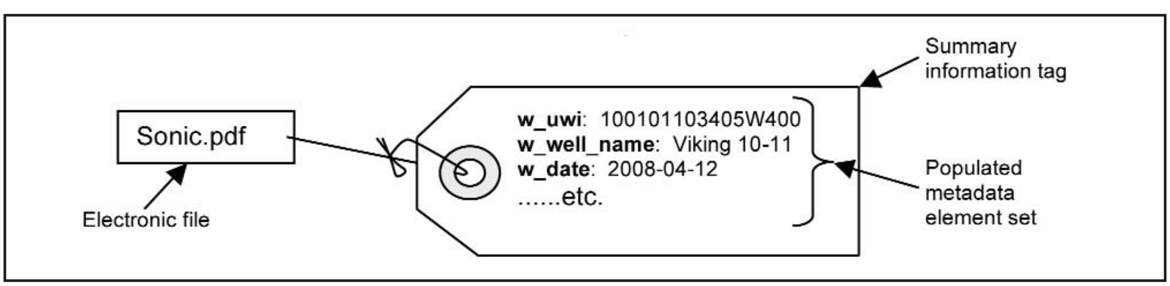

Figure 1: A conceptual illustration of a summary information tag

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Archiving Electronic Wellbore Data *continued…*

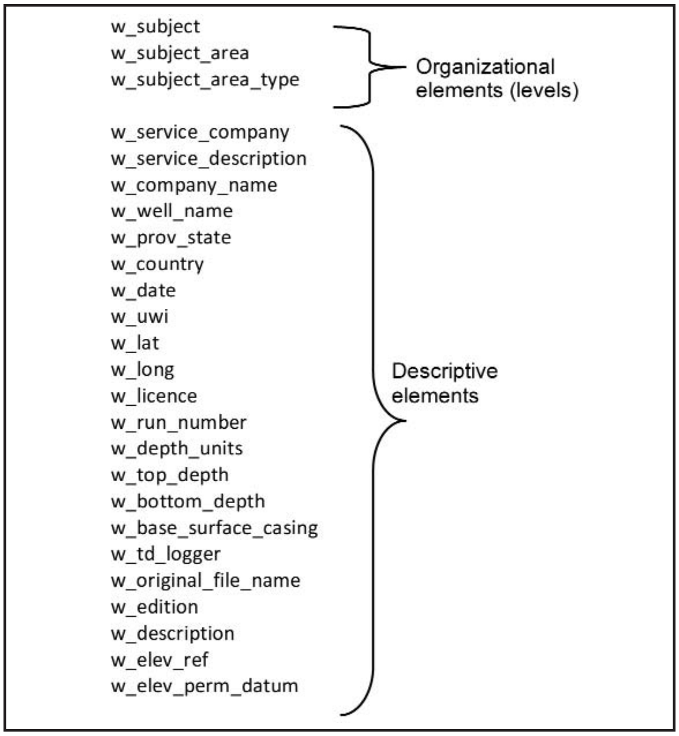

Figure 2: Metadata Element Set for Wellbore Data

The three elements of an organizational nature are further illustrated in Figure 3. The metadata element "**w_subject**" identifies that this is welbore data and will (for now) always be "wellbore_1.0". The metadata element "**w_subject_area**" consists of the major categories relating to resource exploration/exploitation. The focus of this article is log and core data and therefore these categories have been subdivided further under the metadata element "**w_subject_area_type**". All metadata elements must be lowercase, begin with "w_" and cannot include spaces or tabs. The metadata information relating to the elements can contain spaces but must be lower case.

For archiving purposes file names need to be unique to avoid overwriting issues and to allow them to be positively identified in the database. The file naming convention presently being used is shown in Figure 4. The design of the file name is as follows:

1. The file name begins with the 16 character UWI, allowing files to be sorted by UWI.
2. A three character abbreviation for the "w_subject_area" follows.

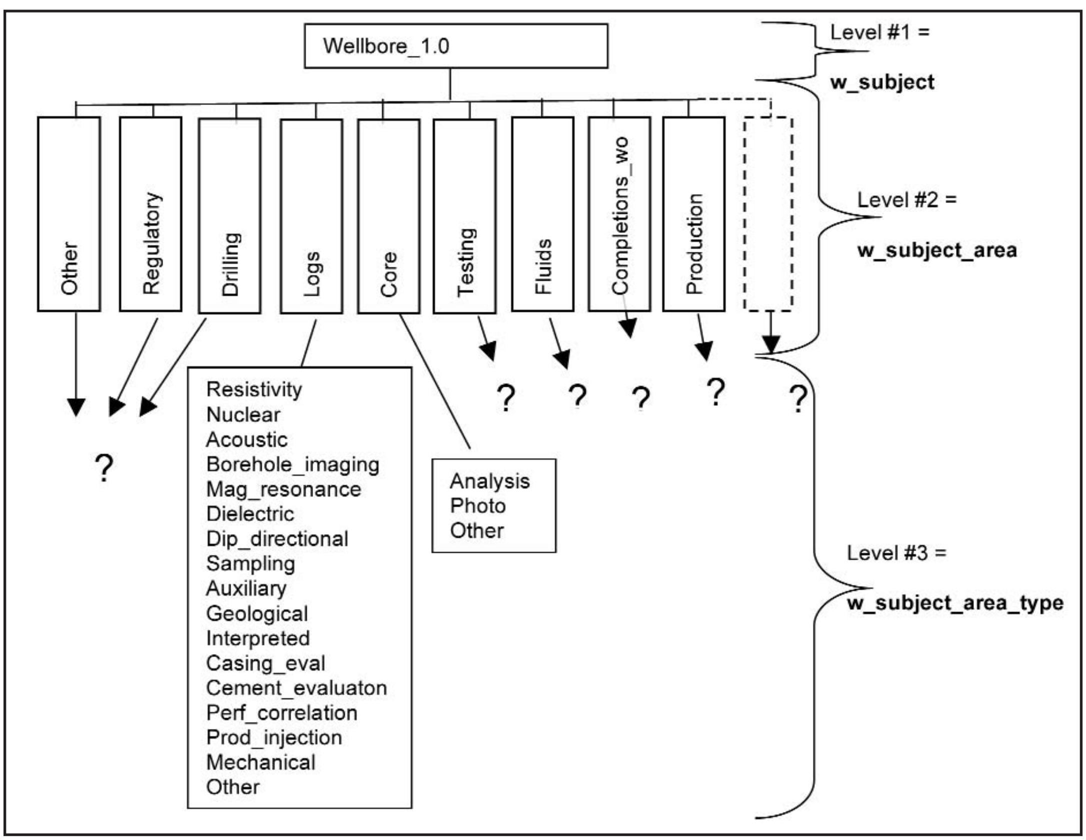

Figure 3: The three organizational levels for wellbore data (the schema)

3. A series of two character abbreviations for the "subject_area_type" is added next.
4. A reference number follows. It consists of "yyyy_aaaaa", where "yyyy" refers to the year, and "aaaaa" is the number consisting of five alphanumeric characters to create a numbering system with a base of 36. This reference number can handle about 60,000,000 files annually. The underscore within the reference number may be replaced by a short version of the company name.
5. The file name finishes with an extension indicating file type.

Updates/Changes

1. The list of metadata elements was expanded to include 'w_td_logger' (see in Figure 2 for complete list)
2. The tags applied to unstructured files have been simplified such that all of the metadata elements are preserved under one tag named "w_wellbore". This is applicable to "pdf" files and Microsoft-DSO compliant files. Tags for "tif" files remain stored under the tag 270. The content of the tag is a space (ASCII 32) delimited string containing the metadata elements and their information.

   Figure 5a provides the metadata elements for an example file. The metadata elements are converted to lower case and collected into a single string that is space delimited as illustrated in Figure 5b (unused metadata elements may be excluded). This string of text is preserved under the tag "w_wellbore" (or tag 270 in the case of a "tif" file). Extracting the information from this text string is done by parsing it on the characters "w_" and to create an array of the metadata elements and their information. Parsing each array element with a space delimiter will separate the metadata element from the metadata information.
3. The optical characterization software (OCR) was successfully used to extract text from the headers of core photos and logs. Higher quality images (150 bits per inch or more) provide more reliable answers, however acceptable results can be obtained from images with 96 bits per inch. OCR results can be further enhanced through the use of some simple logic (e.g. "nell name" probably refers to "well name"), using unique well identifier (UWI) wizards and by comparing the results to other data sources (e.g. determining if the licence number agrees with the UWI).

   OCR software is somewhat dependent on the design of the header and therefore may require additional fine tuning as new varieties of log header are encountered. OCR results are excellent. The OCR software can reliably extract metadata information from the majority of log and core related unstructured files. Its use will reduce the need for summary information tags on unstructured files.

The Software

This software used to test the archival concept was expanded to handle more types of files in a more automated fashion. It was built using Microsoft's Visual Basic on a .NET 3.5 platform and can be connected to a variety of relational databases (MS Access, SQL Server, Oracle). It handles structured files ("las", "dlis", "pds" files), and unstructured files ("pdf", "tif" files) of logs, interpreted logs and core photos using OCR software. All reasonable OCR results are accepted by the software except for the UWI, which must be compared by the user to the image on the screen. If a UWI is found within the file name or the path of an unstructured file, it is automatically assumed to be correct and eliminates the need for user interaction.

The software is presently set up for wellbore data located in western Canada using the National Topographic System (NTS) and Dominion Land Survey (DLS) system for unique well identifiers. Modifying the system to handle other areas will be addressed as needed.

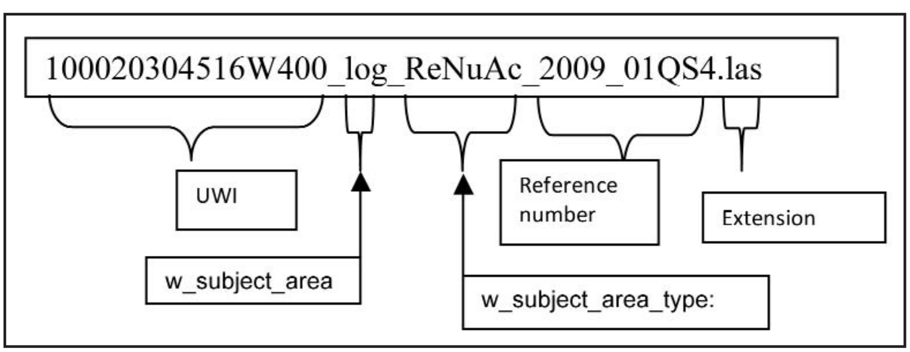

Figure 4: File naming convention used in pilot project

Continued on next page…

Archiving Electronic Wellbore Data *continued…*

w_subject	wellbore_1.0
w_subject_area	logs
w_subject_area_type	acoustic nuclear resistivity
w_sevice_company	abc wireline services
w_service_description	dil-bhc-cnl-fdc
w_company_name	efg oil company limited
w_well_name	efg well #4
w_prov_state	alberta
w_country	canada
w_uwi	100123409414W400
w_licence	123456
w_date	12 feb 2009
w_depth_units	m
w_top_depth	123.5
w_bottom_depth	456.4
w_base_surface_casing	-999.25
w_td_logger	462.3
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w_edition	final
w_description	gr ild ilm ils cal rhob drho dt cnl ncnts fcnts
w_elev_ref	178.5
w_elev_perm_datum	170.5

Figure 5a: Example of a Populated Metadata Element Set SetSetFile

w_subject wellbore_1.0 w_subject_area logs w_subject_area_type acoustic nuclear resistivity w_service_company abc wireline services w_service_description dil-bhc-cnl-fdc w_company_name efg oil company limited w_well_name efg well #4 w_prov_state alberta w_country canada w_uwi 100123409414W400 w_licence 123456 w_date 12 feb 2009 w_depth_units m w_top_depth 123.5 w_bottom_depth 456.4 w_td_logger 462.3 w_original_file_name main.pdf w_edition final w_description gr ild ilm ils cal rhob drho dt cnl ncnts fcnts w_elev_ref 178.5 w_elev_perm_datum 170.5

Figure 5b: Example information stored under the summary information tag "w_wellbore" (tag 270 in 'tif' files)

Conclusions

1. One item was added to the original/initial metadata element set (w_td_logger).
2. Tag information has been simplified for "pdf" files and MS-DSO compliant files.
3. Optical character reorganization software significantly reduces the need for and importance of summary information tags on unstructured files.
4. Software has been designed to test the concept.

References

An Automated Method to Archive Wellbore Data, April 30, 2010, www.cwls.org

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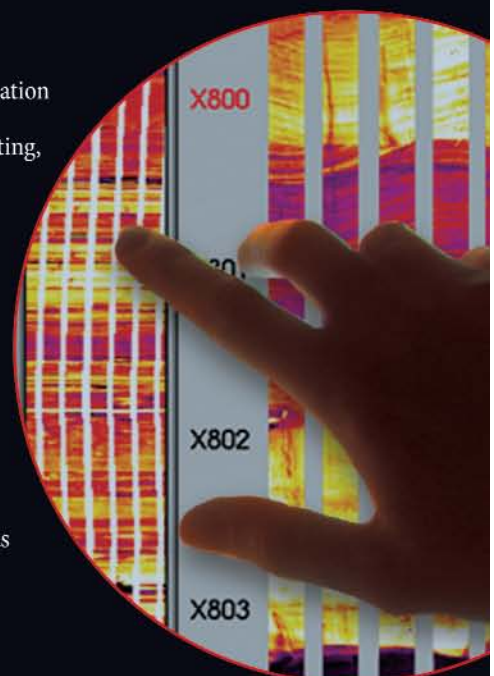

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Rock Typing and Definitionof Flow Units, Montney Formation (Unit C), West-Central Alberta

Omar Derder
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Abstract

Quantitative and qualitative petrophysical analysis of tight gas reservoirs has been challenging due to the heterogeneity of reservoir characterization of properties like porosity, permeability and fluid saturation. This paper focuses on the Unit C of the Lower Triassic Montney Formation in the Pouce Coupe Area of west-central Alberta, Canada. Out of five wells, the 13-12-78-11W6 well was chosen due to a comprehensive data set collected from it for this study. The objective of this paper is to integrate geological core analysis with petrophysical properties to better understand low-permeability Montney reservoirs.

The petrophysical characterization integrated the analysis of pore throat aperture radii (control of fluid flow) and fluid distribution in the reservoirs. In addition, the integration of geological and petrophysical data is a key used for rock typing and the determination of petrofacies. The petrophysical measurements were used to identify different lithofacies that had similar petrophysical properties. Three rock types, or petrofacies, were identified; each defined by unique petrophysical properties and would contribute to the gas production differently. In order to determine flow units, Winland/Pittman plotting demonstrated that only one flow unit is recognized, despite different storage capacities for each rock type.

Introduction

The Triassic Montney is among the recently targeted tight unconventional natural gas reservoirs in the Western Canadian Sedimentary Basin WCSB, and continues to be an active exploration play. The Montney is expected to produce approximately 9% of the total Canadian natural gas production by 2020 (Gatens, 2009). Difficulties in the reservoir characterization include: (i) the lab-based methods employed for permeability measurements; (ii) the proper estimation of the complex pore size distribution in order to quantify the gas and fluid capacity due to the diagenesis; (iii) development of the relationship of the tight gas sand reservoirs between the rock types and hydraulic flow.

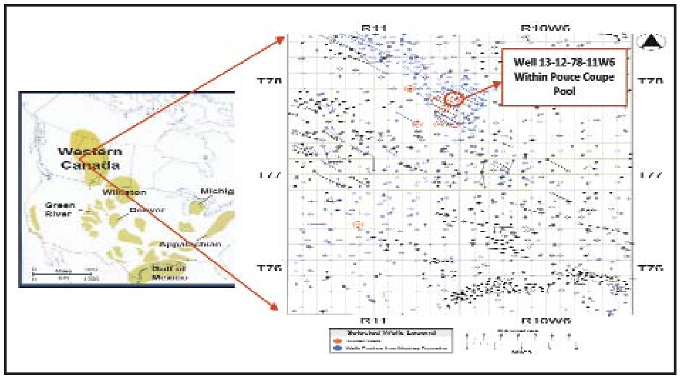

Figure 1: Location Map of the studied well 13-12-78-11W6 (left inset map from Zaitlin & Moslow, 2006)

This paper is focused on the reservoir properties from the Lower Triassic Montney (MnFM) in well 13-12-78-11W6 from the vicinity of Pouce Coupe (Figure 1). The objective of this study was to investigate and evaluate the permeability distribution, utilizing well log data and geological interpretations. The reservoir characterization process included: (i) defining the rock type and lithofacies within the reservoir; (ii) determining the distribution within the reservoir zones and identifying flow units.

Methodology and Procedure

In order to identify and differentiate rock types, core samples are used to determine typical petrophysical properties of the studied unit. This analysis is done at each core point for correlation with the petrophysical and log properties. Subsequent work focused on correlating, comparing and evaluating the parameters existing from core and well logs data.

As a part of the drilling program, a 17.5m core interval was obtained from the study well including both the reservoir and non-reservoir intervals. The MnFM has been subdivided into two informal members that correspond to grain-size distribution and bulk density variations. Over these particular depths, the Montney C (MnC) and Montney B (MnB) units were cored. The MnC represents the upper part of the studied core of 13.41m, and the lower cored MnB was not included in this study. The MnC in the subject well is comprised of a series of stacked very fine sandstone/siltstone-shale packages, as illustrated by the core shown in Figure 2.

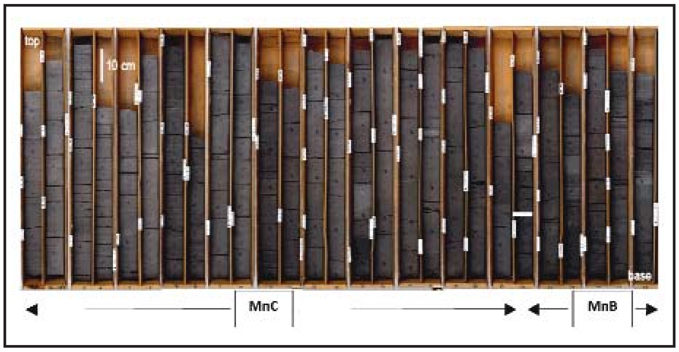

Figure 2: Core interval 2196-2213.22m in well 13-12-78-11W6, consists of grey to light grey very fine grained sandstone, siltstone and shale. Siltstone thickness decreases upward from 4 to 1cm; with an upward increase in sandstone and siltstone content (Pedersen et al., 2011)

Routine core analyses (RCA) on the full diameter core was performed by CoreLab in order to obtain porosity (Ø), permeability (k), grain density (ρ) and water saturation (S_W) at conditions not reflective of the *in-situ* reservoir condition. However, the profile (probe) permeability was important to the study because it provided a permeability measurement at a finer scale and can identify trends that are unobservable by the RCA. In addition, the profile permeability was useful in defining the vertical heterogeneity in the MnFM reservoir.

A total of 485 measuring points were taken in the MnC unit. Profile permeability was measured by pulse-decay permeameters at confined pressures to correct the probe to *in-situ* conditions. Ten core plugs were analyzed for ambient porosity and air permeability, followed by porosity and air permeability measured at overburden (confining) pressures. The corrected profile permeability was then correlated to the density porosity log for the MnC unit. The permeability was then averaged over seven-points and correlated to the porosity derived from the density log.

An empirical relationship based on Winland (1972) and Pittman (1992) has been used widely as the basis for deriving pore size distribution corresponding to a mercury saturation of 35%. Aguilera (2002) proposed a relationship based on a method used by Kwon and Pickett (1975). The delivery speed was used to define the flow units by providing the storage (porosity, Ø) and flow (permeability, k) calculation in the porous media at 35% mercury saturation (rp_{35}) during a mercury injection capillary pressure test (Aguilera, 2010). The pore throats can be calculated from:

$$rp35 = 2.665\left[\frac{k}{100Ø}\right]^{0.45}$$

The permeability-porosity measurements could then be related to the different sub-units (petrofacies) defined on the core and on the conventional logs. Petrofacies, as defined by Porras et al. (1999), are rocks with a similar pore throat radius and fluid flow characteristics, which once identified, can be correlated to the petrophysical properties such as porosity and permeability (Rushing et al., 2008). High resolution core measurements were applied and correlated to the petrophysical analysis to gain a better qualitative and quantitative evaluation for the cored intervals. Petrofacies were assigned to all the samples used in the study based on similar lithology, permeability, pore throat radius, and petrophysical properties. Further, an attempt was made to link the core observations and the well productivity by integrating the core descriptions.

Results and Discussion

Twenty seven core plugs from the MnC unit were analyzed using RCA, and fourteen of the permeability measurements were equal to or below 0.01mD. Permeabilities less than 0.01mD cannot be measured by the RCA due to the low resolution. Thus this data would vastly limit the interpretative potential in low permeability reservoirs. Consequently, there are large porosity variations for the same permeability values. The cross-plot of the routine air permeability and the porosity for the well is shown in Figure 3.

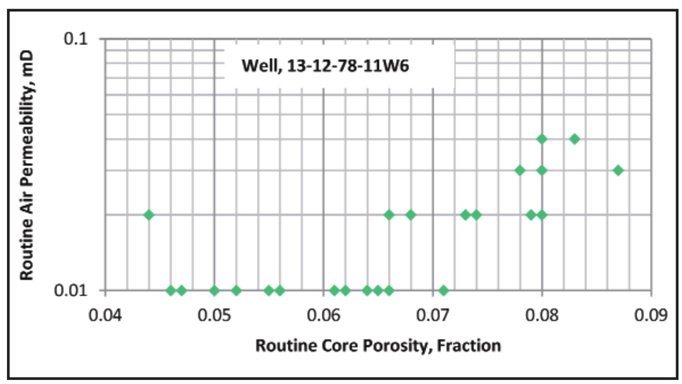

Figure 3: Cross-plot of RCA data between air permeability and porosity for the studied core, showing a poor correlation

Profile permeability analysis however, was utilized successfully for quantifying the fine scale lamination and heterogeneity. A change in the permeability with depth was observed only in the upper part of the core, and the range of permeability was quantified from 0.0008 to 0.03mD. This narrow range likely reflects the similarly narrow range in the grain size and pore throat radii. When viewed on a depth profile, this may also indicate the presence of thin, high permeability beds (Figure 4).

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Rock Typing and Defininition of Flow Units *continued…*

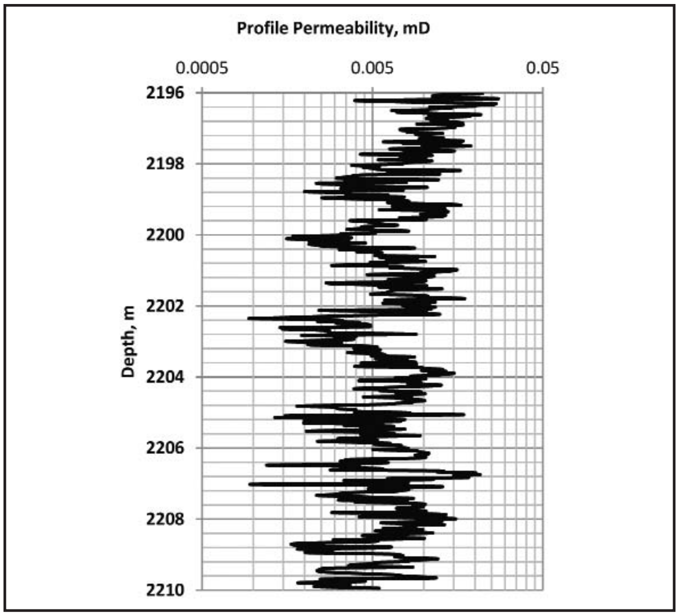

Figure 4: Profile (probe) permeability measurements on slabbed core at ambient conditions

A plot of the pulse-decay permeability measured at two net overburden stresses is shown in Figure 5. One sample point was eliminated due to no difference between permeabilities measured at either condition. Based on the ten plugs for measuring porosity and permeability at variable confining pressures, the porosity and permeability strongly decreased as the net confining pressure increased. Variation between the probe and pulse-decay in permeability is observed due to the difference in the condition of measurement (stress-dependence), and the volume of the sample size. The variation in porosity measurements has been attributed to lithological differences.

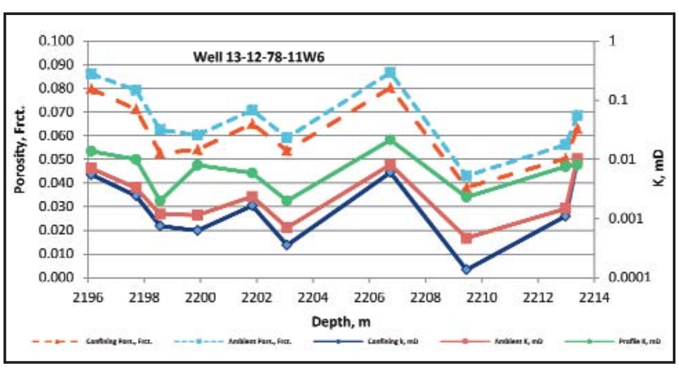

Figure 5: Plot of the porosity and permeability from ten core plug at ambient and various confining (overburden) pressures

The porosity estimates from the logs were compared to the corrected profile permeability after the latter was averaged to attempt to match the vertical resolution of the porosity logs. An acceptable correlation between the effective porosity and corrected profile permeability was obtained, and the density porosity trends generally matched the average profile permeability values from core (Figure 6).

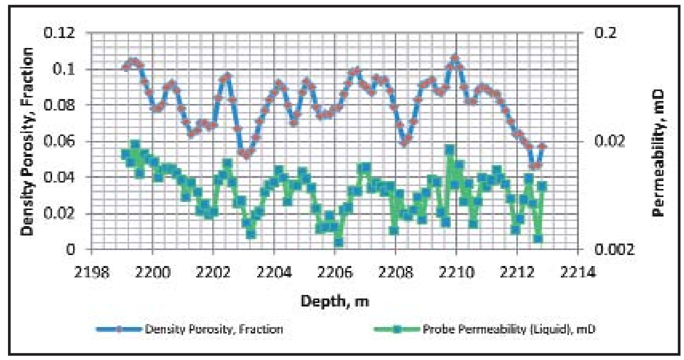

Figure 6: Comparison of density porosity with profile (probe) permeability

In order to estimate the pore throat size in the study area, the pore throat radii rp35 lines from Aguilera's equation were superimposed on the porosity versus permeability. The relationship between the permeability, porosity and pore/pore throat size is used in the recognition of the rock types and to identify the flow units. Using the permeability derived from the pulse-decay data measured at net overburden pressure, the averages of the pore throat apertures from the Winland rp35 plot suggest that the values lies between 0.05 and 0.1µm (Figure 7).

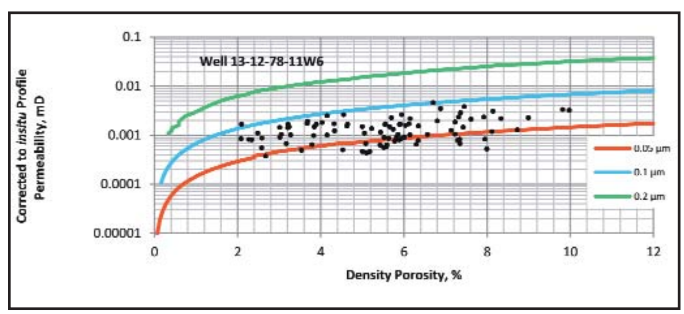

Figure 7: Winland Plot. Although, the porosity values are varied widely, only one hydraulic rock type was observed

As a result, the scale of nano-pore size dominates in the study reservoir and impacts production from the tight gas sand of the Montney Formation. Some of the data that lies outside the range of the 0.05 and 0.1µm lines may reflect the lithology-dependence of stress. The relationship between the permeability, porosity and pore throats show that only one hydraulic unit (flow unit) was identified (Figure 7). As a result, the dominant pore throat dimension (rather than porosity) controls the flow speed and capacity in reservoir rocks, helping to identify the rock quality. Decreases in pore throat size reduce the degree of interconnectivity by increasing the tortuosity, and the subsequent increase of disconnected pores, results in a decrease in permeability.

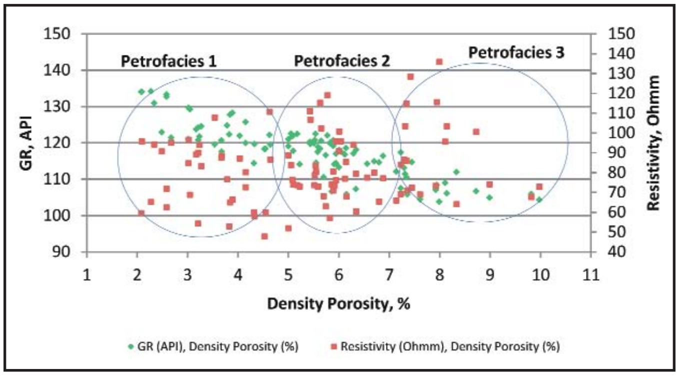

Figure 8: Petrophysical characteristics of the cored interval

The plot of the density porosity versus the gamma ray and resistivity shows the petrophysical characteristics for the relatively different petrofacies in the studied core (Figure 8). Three subdivisions (or petrofacies) of MnC have been determined through core and log analysis, which indicate a different and a unique geological setting at the time of deposition. Table 1 shows the log threshold values for the petrofacies determination in the studied core, and Figure 9 shows their distribution within the well.

The petrophysical measurement of the core can be used to bridge the gap between the core and well productivity.

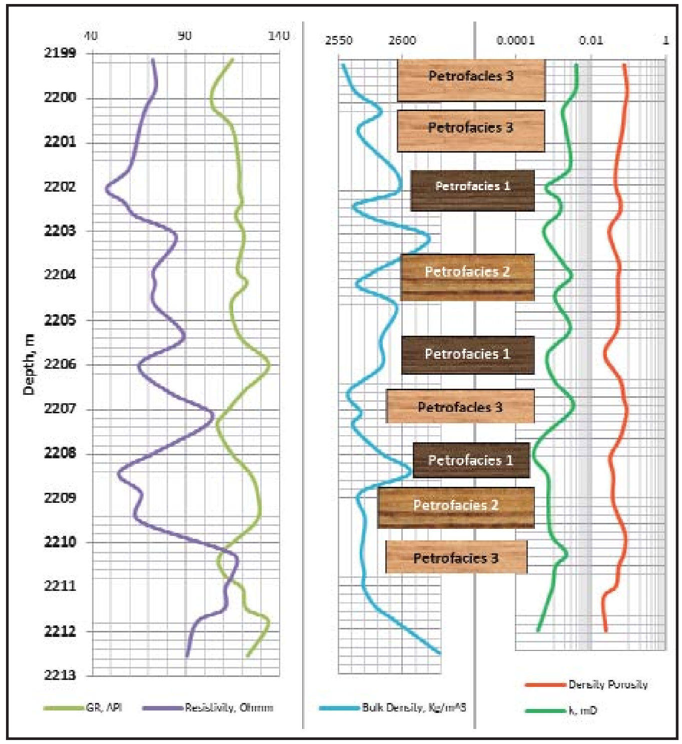

Figure 9: Reservoir distribution using an integrated geological observations, core and petrophysical properties

Petrofacies 3 is comprised of very fine sandstone-siltstone and has the highest porosity of the three identified petrofacies, ranging from 6 to 10% and permeability ranging from 0.0007 to 0.0045mD. As a result, petrofacies 3 represents the best reservoir rock in the studied core.

Petrofacies 2 represents a shaly-siltstone reservoir rock with a relatively high porosity ranging from 4.5 to 6 % and the permeability ranging from 0.0005 to 0.003mD. Petrofacies 1 is mostly a shale interval with ripple laminations, and porosities

Petrofacies sub-division	Description	Petrophysical Propoerties					
		K (mD)	Ø (%)	rp_{35} (µm)	GR (API)	Res. (Ohmm)	Rhob (Kg/m^3)
Petrofacies 1	Wavy bedded with non to low bioturbated shale and mudstone	0.0004-0.002	2-4.6	0.05-0.1	>125	<80	2582
Petrofacies 2	Planar to irregular lamination of shaly siltstone	0.0005-0.003	4.6-6.4	0.05-0.1	125	80 - 90	2579
Petrofacies 3	Coarsening and thickening up-ward siltstone to very fine sandstone	0.0007-0.0045	6.4-10	0.05-0.1	115	>90	2566

Table 1: Hydraulic rock type by threshold value of porosity, permeability, pore throat and lithology

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Rock Typing and Defininition of Flow Units *continued…*

and permeabilities less than 4.5% and 0.002mD, respectively. Petrophysically, it is the poorest quality reservoir identified from the core and is not expected to contribute much to the production.

Conclusion

In summary, the studied unit is characterized by fine to coarse silt and shale, which may be associated with narrow pore throats, low permeability; as a result, low recovery efficiency is expected. The integration of the petrophysical properties-petrofacies associations, porosities and profile gas permeabilities leads to a better understanding of gas production from low permeability rocks in MnC. The reservoir rock could be classified as one rock type on the basis of pore throat radii. Three petrofacies are relatively distinct in terms of their porosity and permeability. The unique geological factors of tight gas in the MnC render conventional interpretation techniques ineffective. Recent advances in technologies such as hydraulic fracturing, and production technology have allowed for the commercial exploitation of ultra-low permeability natural gas reservoirs.

References

1. Aguilera, R., (2010). Flow Units: From Conventional to Tight Gas to Shale Gas Reservoirs. Paper SPE 132845 presented at the Trinidad and Tobago Energy Resources Conference, Port of Spain, Trinidad, June 27-30.
2. Aguilera, R., (2002). Incorporating capillary pressure, pore aperture radii, height above free water table and Winland r35 values on Picket Plots. AAPG Bulletin, (pp. 605-624, v.86).
3. Gatens, M. (2000). Historical Canadian Natural Gas Production and Forecast. National Energy Board, Preliminary Results.

4. Kwon, B., & Pickett, G. (1975). A New Pore Structure Model and Pore Structure Interrelationships. SPWLA 16th Annual Logging Symposium.

5. Pedersen, P., Clarkson, C., Jensen, J., Derder, O., & Freeman, M. (2011). Innovative Methods for Flow Unit and Pore Structure Analysis in Tight Gas Reservoir, Montney Formation, NE BC, Canada. Search and Discovery Article #50439. University of Calgary. Posted July 18, 2011.

6. Pittman, E.D. (1992). Relationship of Porosity and Permeability to Various Parameters Derived from Mercury Injection Capillary Pressure Curves for Sandstone. AAPG Bulletin, (pp.191-198, v.76, No.2).

7. Porras, J., Barbato, R., & Khazen, L. (1999). Reservoir Flow Units: A Comparison between Three Different Models in the Santa Barbara and Pirital Fields, North Monagas Area, Eastern Venezuela Basin. SPE Latin American and Caribbean Petroleum Engineering Conference. Caracas, Venezuela: SPE 53671.

8. Rushing, J.A., Newsham, K.E. & Blasingame, T.A. (2008). Rock Typing-Keys to Understanding Productivity in Tight Gas Sands. Paper SPE 114164 presented at the SPE Unconventional Gas Reservoir Conference, Keystone, Colorado, USA.

9. Tiab, D., & Donaldson, E. (2004). Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties. Oxford: Elsevier.

10. Zaitlin, B., & Moslow, T. (2006). A Review of Deep Basin Gas Reservoirs of the Western Canada Sedimentary Basin. The Mountain Geologista, (pp. 257-262, v.43, No.3).

11. Winland, H.D. (1972). Oil Accumulation in Response to Pore Size Changes, Weyburn Field, Saskatchewan. Amoco Production Research Report No. F72-G-25.

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VISION 2012

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September 19, 2012

McMurray, Dean-Stark and Archie

WHAT AN HONOR! *Our 2012 CWLS President, Gordon Lee had the pleasure of meeting Roy Lindseth (Fellow of the Royal Society of Canada, Honorary Doctorate from the U of C). Roy served on the CWLS executive in 1967 (Treasurer), was the CSEG President in 1971 and 1975, SEG President in 1976, and the APEGGA president in 1978 – 1979. He is the recipient of the Meritorious Service Award, Honorary Membership, and Gold Medal, all from the CSEG. He was also the Geoscience speaker the Ring Workshops on Saturday, March 24th and took the time for this photo at the CSEG AGM on March 26th.*
(Photo credit: Penny Colton.)

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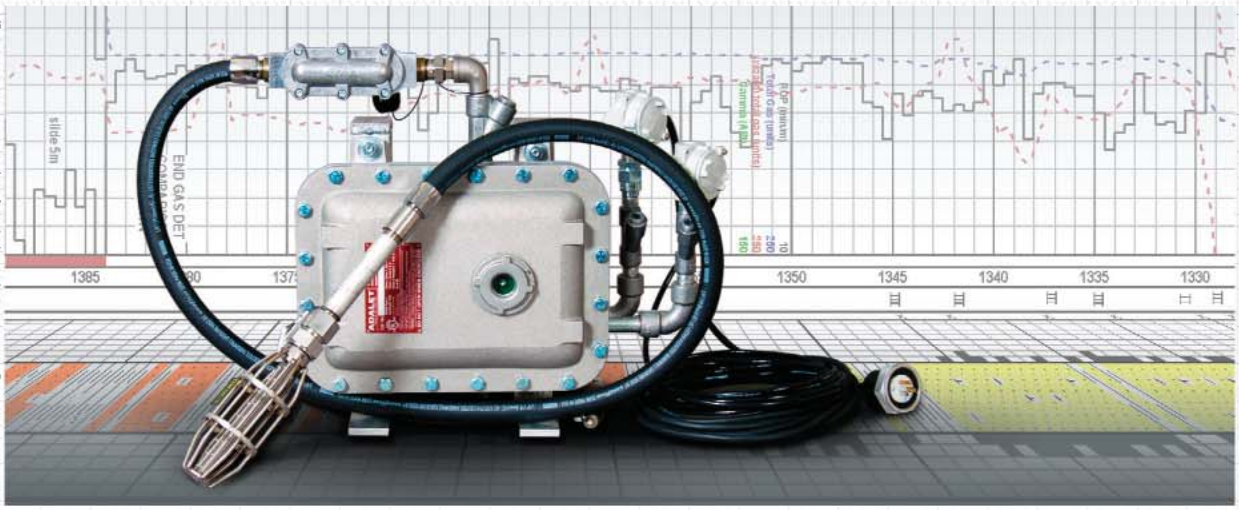

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