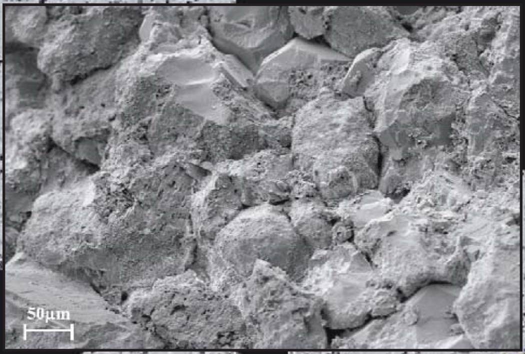
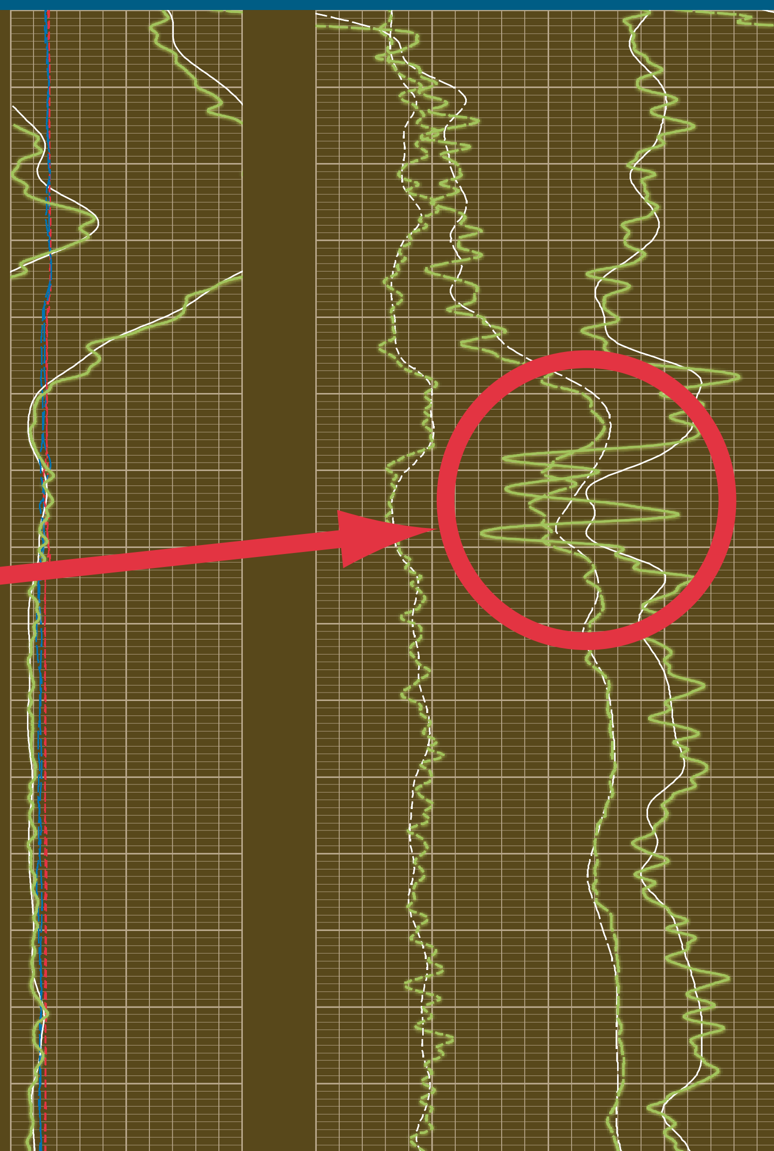
InSite

CWLS Magazine
June 2011 Issue 1 Volume 30

13 CO_2 Rock Physics: A Laboratory Study



18 Drill Cuttings and Rock Properties for the Monteith Formation, Nikanassin Group



InSite

CWLS Magazine **June 2011**

Issue 1 **Volume 30**

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Cover Photos/Graphics credits: Background image – Nisael Solano from the University of Calgary on his work on the Monteith Formation. Inset photos – Helen Yam and Douglas Schmitt from the University of Alberta on their work with CO_2 Rock Physics.

Photos: If you have a photos that the CWLS can use in its next InSite please send a high resolution jpeg format version to bruce.keen@halliburton.com or jefdickson@suncor.com. Include a short description of the photo with your submission.

The 2011 - 2012 CWLS Executive:

Back row (l - r): Jeffrey Dickson, Bruce Keen, Dave Shorey, Gord Lee, Blair Neil
Front row (l - r): Mike Seifert, Tamara Toon, Harold Hovdebo, Maggie Malapad

President's Message

As your incoming CWLS President for 2011-12 I would first like to thank the entire CWLS membership for giving me the opportunity to give something back to our society. The CWLS is an organization that I personally feel has furthered my own career and has had an outstanding track record of contribution to our chosen field of endeavor. I am also sending out a big thank you to the outgoing executive:

Xianfeng Zhang – Secretary
Simon Corti – Treasurer
Brian Glover – Membership Chair

Of course, there are also a number of executive who are staying on with us for 2011, who deserve our gratitude for their contribution to the CWLS over the past year:

Dave Shorey – President now assumes the role of Past President

Maggie Malapad – Chair of Committees is staying on for another term

Bruce Keen and Jeff Dickson – will continue their roles as Publications Chairs and Editors of the InSite magazine

Once again, on behalf of the entire CWLS membership, I'd like to thank all of the above individuals for their hard work and faithful service in 2010. Next, my congratulations to the incoming executive for 2011, who include:

Gord Lee – Vice President
Blair Neil – Treasurer
Tamara Toon – Secretary
Mike Seifert – Membership Chair

Please welcome our new executive members – I think we will make a great team to guide the society through the upcoming year.

I would be remiss in neglecting to mention at this point the importance of the volunteers who make up our executive and various committees – without them this society would not exist. So, to all of you out there who participate in any of the valuable activities offered by your society, please seriously consider serving as a volunteer – we're looking for people year round, not just at election time. Although I know we joke about it, it really won't take that much of your precious time and it really can be fun (not to mention that it offers an excellent opportunity to broaden your contact base in the industry). So get in the spirit and lend a hand – you won't regret becoming more involved in the CWLS.

I would also like to recognize the hard work that the APEGGA staff put in for us in the background, especially our very capable Administrative Assistant, Ashley Pessell. She's there for us every day of the week, all year long and we really appreciate the energy and enthusiasm she brings to our office.

The evening of this past February 23rd saw another iteration of the CWLS Annual General Meeting and it was a very enjoyable evening for the 100+ participants in attendance. We were treated to yet another buffet-style exercise in culinary excellence by the Hotel Palliser staff, after which we had the good fortune to be regaled with tales of deep-sea derring-do by our noteworthy guest speaker, Dr. Joe MacInnis. The significance of the occasion was further enhanced by the induction of three new Honorary Members, Jim Earley, Peter Kubica and John Kovacs. I do not have space in this message to begin to touch on the considerable achievements of these three individuals nor their extensive contributions to the CWLS, but needless to say we should all feel very proud to see them recognized by our society.

On a more somber note, it is with deep regret that we are forced to acknowledge the loss of one of these same recent honorary member inductees. Just a few days after the AGM we were all saddened to hear of the passing of our friend and colleague John R. Kovacs. He had given so much to this society and to our industry. John was a long-time CWLS member, a past President and was known far and wide in the industry as an astute petrophysicist and priceless ally to so many of us. I had not personally known John for very long, but in the few short years since our introduction I quickly came to appreciate him as an invaluable sounding board and a bit of a mentor, not to mention a genuine "character" and good friend. He was brilliant and gregarious and his irrepressible enthusiasm for both petrophysics and people was obvious to all who met him. He will be sorely missed.

It is my duty to remind the membership about the upcoming joint CSPG/CSEG/CWLS "Recovery 2011" GeoConvention to be held at the Telus Convention Center from May 9-11 of this year (as well as the sister Core Conference to follow immediately, on May 12th and 13th at the ERCB Core Research facility). There is still ample time to register for the conference, which only seems to get bigger and better each year. The CWLS will host several excellent technical sessions at the conference and is also offering a number of very topical short courses. To register or for more information just point your internet browser at "www.geoconvention.com".

There is an old adage that says "may you live in interesting times", and as recent world events have unfolded it is apparent that we can count our generation as having been so blessed. There is, of course, no way for us to know the future, but we can be sure that our industry will see more than its share of ups and downs. Of particular interest of late is the fact that it would appear the price of oil and the price of natural gas has for the first time in memory, become almost completely uncoupled from one another. This is no doubt good, in some respects, as buoyant oil prices are keeping us going through a period in which natural gas prices have fallen to ten-year lows. But the WCSB is certainly gas-prone and low prices are already making it very tough for a good number of gas-weighted producers. But for those of us who have been around for any time at all, cyclicity is just business-as-usual in this game, and should be expected.

What we can count on, at least in the medium term, is an increasing global demand for hydrocarbons that should ensure a continued need for formation evaluation expertise, even as the technology involved rapidly evolves to suit emerging trends within the industry. To keep abreast of these shifting technological developments it will become even more important for our members to maintain and develop an up-to-date skill set, and that is precisely where the CWLS intends to create value for its membership. Our goal is the timely dissemination of state-of-the-art technical knowledge and the provision of current training in the relevant technical skills that will assist you, our members, to be the best you can be at what it is that you do best. And let's not forget to try and have some fun while we're at it!

Harold S. Hovdebo
President, CWLS

President's Report from the AGM

It has been a privilege and honor to lead such a special group as the CWLS for a second time. The CWLS has a long and valued history of contribution to the Canadian petroleum industry and I am proud to be a member and a part of such an organization. I would like once again to thank the membership for granting me the opportunity and privilege to serve.

Before I discuss the accomplishments of the CWLS this past year, I feel that it is very important to recognize those who have volunteered their time and efforts in serving the CWLS. I would like to thank the past executive for generously giving their time and commitment in serving our society. In particular, I would also like to give special recognition to those members who have served for a number of years and will not be returning for the 2011-12 executive and whose service was invaluable to this organization. Vern Mathison, Brian Glover, Simon Corti, and Nabil Al-Adani, thank you for your commitment to the CWLS.

In addition to the past executive, the society exists only through the help of the persons who dedicate time and energy to give presentations, organize and contribute to our seminars and serve on our various committees. To all of you that have done so over this past year, thank you for your most valuable contribution.

The life-blood of any professional organization is the membership and its willingness to give its valuable time to serve the organization. Twelve candidates stepped up to the plate and ran for the CWLS executive for 2011-12. Each of these individuals, having won or lost, demonstrated the attitude and commitment to the society that will allow it to successfully grow and positively contribute to the petroleum industry of Canada and beyond. On behalf of the CWLS, I would like to thank each of you for your commitment and dedication.

The CWLS was able to generate $85,000.00 revenue from the convention in 2010. The success of this convention is due in large part to our many volunteers who organize the talks and poster sessions as well as the short courses set up by the CWLS Short Course Committee. We cannot forget to thank the JACC group as well who shoulder most of the organizational burden for the annual conventions.

The 2010/11 CWLS Publications Co-Chairs also produced two excellent magazines for 2010 with more on the way in 2011.

The CWLS Student Awards committee presented the 2010 Thesis Award of $5000 to Nisael Solano and an Abstract Award of $2000.00 went to Helen Yam.

I would like to encourage each of you to continue to invite our young geologists, petrophysicists, exploration managers, field engineers and field managers to join the society and encourage them to become actively involved.

I think most of us would like to remember 2010 as a year of recovery. As we look forward to this coming year, we have a strong executive team in place to take on the challenge of further strengthening and improving our society. I feel I have fulfilled my duties as president by creating value for our members and leaving the society in excellent shape for the next executive to take over.

As I move on to the Past President position, I encourage our members to be active in our society by volunteering their time for the upcoming 2011 GeoConvention. I will also be searching for nominees for the 2011- 2012 executive, so please be encouraged to contact me if you would like to run for any of the executive positions.

I would like to thank the membership once again for granting me the opportunity and privilege to serve. I'm looking forward to seeing you all at our monthly luncheons and workshops.

Very best regards,
Dave Shorey
Outgoing CWLS President

CWLS 2011 to 2012 Executive

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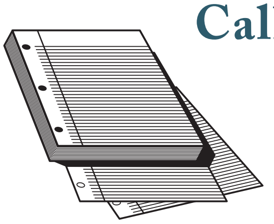
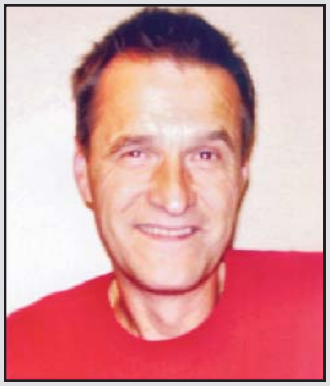


Call for Papers

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:
Bruce Keen - bruce.keen@halliburton.com or
Jeff Dickson - jefdickson@suncor.com



In Memoriam

John Richard Kovacs (1951-2011)

It is with heavy heart that we notify the CWLS membership of the passing of our recent Honorary Member inductee, John Kovacs, who left us on March 18th after a long fight with stomach cancer.

John had a long and illustrious record of achievement in his chosen field, joining Schlumberger Canada Ltd. in 1973 after receiving a Bachelor of Science degree in Mechanical Engineering from the University of Calgary. John distinguished himself at Schlumberger with over thirty years of broad-spectrum responsibilities ranging from wireline field engineer to operations manager and technical sales and marketing. From 2000 to 2006, John was the Unconventional Gas Development Manager, working extensively with Canadian operators pioneering CBM and shale gas resources. The focus was on integrated solutions; combining seismic, special core analysis, log measurements, interpretation development, stress evaluation, stimulation, inflow monitoring and production results. John was the recipient of not one, but two "Wildcatter" awards during his career with Schlumberger.

In early 2007 John joined EOG Resources Canada Inc., a leading unconventional resource operator, as an Exploration Engineer, specializing in unconventional reservoirs. Most recently John was employed as a Senior Petrophysicist with Taqa North, Ltd. where he was a member of a multi-disciplinary geotechnical team working on complex carbonate reservoir characterization before moving into the unconventional reservoir group, focusing on shale resources.

John co-chaired a number of unconventional gas conferences and short courses. One of his major accomplishments came in 2002, when he spearheaded CWLS efforts to put the Society back into a regular technical conference schedule with the CSPG and CSEG. Our participation in the joint annual conference has become a major Society revenue generator. John subsequently co-chaired numerous Canadian Well Logging Society conference sessions and also authored or co-authored a number of new technology and application papers and presentations. In addition to his involvement with the CWLS, John was also a member of SPE, CSUG, and APEGGA. John served as the President of the Canadian Well Logging Society from 2002-2003.

In partial fulfillment of John's last wishes, his loving wife, Susan, and other family members hosted a very well attended celebration of his life in the "McMurray Room" of the Calgary Petroleum Club on Friday March 25, 2011. Several touching speeches were made in tribute to John's life by members of his family, including his sons Jesse and Matt, as well as his professional colleagues, Ken Faurschou and Basim Faraj.

The Canadian Well Logging Society is very proud to salute the many contributions and accomplishments of one of its finest members, John Richard Kovacs.

An Automated Method to Store, Search and Retrieve Wellbore Data

Wednesday, September 8th Luncheon

In September, we were given a presentation by Casey Struyk, who helped to pioneer the Log ASCII Standard (LAS) format. He spoke to us on the concept of standardizing digital wellbore information through the use of metadata, and its application in storing and searching data. There are many problems inherent to the wide variety of methods that companies use to organize their digital data. Struyk champions the idea of not only standardizing wellbore data storage, but indexing it in a way that makes any type of file easily archived. This can be done using metadata: easily accessible tags that store information about a file. These types of tags are already widely used by applications for digital music and photography to allow them to be searched and cataloged. When applied to well data, they could similarly contain information on the log suites and coring runs, and any number of other parameters, all of which would greatly help in cataloguing logging and core data.

Struyk further explained how the task of compiling metadata can be automated in certain structured files. In the case of LAS files for instance, important information is automatically retrieved from the file header and saved as a tag to that file. A test involving 20,000 LAS files determined that this was relatively simple and quite feasible. Challenges arise however, when unstructured files like PDF or TIFF come into play. These files cannot be tagged automatically, and therefore metadata needs to be added manually. It will therefore fall to the responsibility of the venders providing the data to include metadata components with each of their delivered files, and for the client companies to begin asking for this type of information. Standardizing these tagging practices will help them to become more commonplace, and everybody will benefit by making cataloguing, searching and sharing large amounts of diverse wireline and core data much simpler.

Using Wireline Geochemical Data for Shale Gas Reservoir Formation Evaluation

Wednesday, October 13th Luncheon

October's talk was given by Dr. John Quirein from Halliburton on how geochemical data obtained from X-ray diffraction (XRD) can help in the evaluation of shale gas reservoirs. Most established fields have an abundance of core data which can be used to statistically estimate the responses of wells lacking core. The advantage of using XRD bulk mineralogical data is that it can fill in the gaps of information that multiple cores generally do, but it can be converted to geochemical data and combined with other wireline logs to predict core response.

Through core XRD data, a wireline geochemical workflow can be developed to predict mineralogy, kerogen, grain densities, porosity and gas saturation in shales, given the proper mineral model is used. Predicted mineralogy can be used to calculate mineral densities and total organic carbon (TOC), which can then be converted to account for kerogen volume (because XRD does not account for this). This allows for the simultaneous solving of grain density, porosity and gas saturation using the geochemical logs and wireline log data.

Using a case study from the Haynesville shale gas play, Quirein demonstrated a workflow whereby core XRD data was used to establish a mineralogical model to predict mineral weight fractions and TOC, kerogen, bulk mineral volumes and gas porosity from log data. This thorough workflow was validated using core data, and demonstrates that even in areas with minimal coring, meaningful and accurate reservoir characterization is possible.

VSP to Enhance Surface Seismic and Well Monitoring

Wednesday, November 10th Luncheon

Richard Kuzmiski, the Manager of Borehole Services at GEDCO, was our presenter in November. He spoke on how Vertical Seismic Profiling (VSP) can be utilized to enhance surface seismic and well monitoring. VSP surveys are created by placing geophones within the wellbore to record shots from the surface, as opposed to acquiring low-resolution first arrival times as check-shot surveys. VSP data is captured at a finer resolution, which allows it to be used to aid in the processing and interpretation of the surface seismic data. Ultimately, the major benefit of VSP data is that it provides a direct correlation between depth and time, and due to the nature of recording at depth, better signal to noise is a beneficial side-effect. This can even lend itself to fluid mapping and when compared to repeat surveys over time, it can serve as a reservoir monitoring method.

Combining VSP data with three-dimensional seismic acquisition not only expands upon the surface seismic data, but can also be used to optimize horizontal well placement and orientation. By capturing both vertical and horizontal transverse isotropy (VTI and HTI, respectively) information, more accurate velocity models can be created to better understand the geology and fracturing near the wellbore. The resolution contrast between VSP survey information and standard surface seismic allows for subsequent wells to be positioned much better within the reservoir.

Integrated Evaluation of Unconventional Shale Reservoirs

Wednesday, December 8th Luncheon

Characterizing heterogeneity in shale gas reservoirs was the topic presented at December's luncheon by Samuel Fluckiger, from Schlumberger's TerraTek. Heterogeneous reservoirs are composed of laterally and vertically discontinuous lithofacies, and considering each has its own unique properties, this results in a mechanical anisotropy. These are important considerations in unconventional shale gas reservoir analysis, as they directly affect fracturing and subsequent production. It is also important to consider that because variability is something that exists at different measurement scales, from sample, core and log, that scaling relationships must be established as well.

TerraTek identifies multidimensional heterogeneity by focusing first on the log scale measurements and evaluating their variability as a function of depth. This is their heterogeneous rock analysis (HRA) method which categorizes the distinct property regions and then applies these findings as a template for further reservoir characterization. This is compared with core-scale heterogeneity and core-derived strength profiles to determine the optimal sampling strategy for adequate characterization. This establishes an effective log to core relationship in the sense that petrophysical and mechanical properties can be characterized with respect to log response, all of which can be modeled. The application of this model allows for the prediction and propagation of measured properties on the basis of log response alone, improving the strength of estimations further away from the core data source.

Caprock Integrity Assessment: A Case Study of Natural Fracture Characterization in Mudstones of the Clearwater Formation, Alberta, Canada

Wednesday, January 12th Luncheon

Fracture characterization was discussed by Queena Chou at the January luncheon. As a geomechanics geologist at Weatherford, she presented a case study from the Clearwater Formation mudstones that overlay the McMurray Formation, where natural fractures and discontinuities in the caprock were interpreted using imaging logs and core. The mechanical integrity of caprock, the impermeable formation overlying a reservoir, is a very important consideration, especially in the oil sands. Fracture networks within the reservoir caprock can potentially lead to surface breaches under the high pressures built up during steam assisted gravity drainage (SAGD) production.

In this case study, natural fractures were identified using both the acoustic and resistivity image logs, which were then compared and combined into a single data set. This avoided redundancies and allowed for the preservation of details determined using one image logging type and not the other. This combined dataset could then be compared with core over the same interval to confirm fracture origin and character. There were some features that appeared in logs that were not found upon examination of the core, and vice-versa, but given the nature of fracture detection using logs, this was to be expected. Overall, the resistivity and acoustic log data comparisons were very revealing in how well they complemented each other when verified with core. Stereonet plotting of the data from each well also revealed that while fracture orientation was fairly consistent, these overall orientation trends varied widely between individual wells. As a result, correlations of the datasets through linear plotting revealed no dominant spatial or stratigraphic trends.

Chou emphasized that establishing a detailed fracture data set is simply one component in caprock analysis, and it cannot be expected to completely address caprock integrity on its own. Inputting this data in further geomechanical modeling studies however, could shed some light on how these fractures interact and form potential hydraulic pathways. Certainly having a complete borehole fracture dataset, verified through core study, provides a wealth of data to build upon in those next steps.

Jeff Dickson

The 2011 Annual General Meeting

Harold Hovdebo with speaker Joe MacInnis

On February 25th, 2011, CWLS members came together to bid farewell to the outgoing executive and welcome in the newly elected members. The meeting also saw the induction of three new honorary members and the recipient of the President's Award for the best technical presentation of the last year. After dinner, Dr. Joe MacInnis, a world-renowned ocean researcher and explorer, gave a riveting speech on his deep-sea adventures and the value of teamwork.

We would like to thank everyone again for a great turnout that evening.

Outgoing President, Dave Shorey

Above: Brant Bennion accepting the 2010/2011 President's Award for his talk on Tight and Unconventional Gas Reservoir Evaluation and Optimization

Right: Ali Al-Ghamdi receiving his 2010 Thesis Abstract Award for Modeling Petrophysical Parameters in Complex Carbonate Rocks

Right: Helen Yam won the 2010 Thesis Abstract Award for CO_2 Rock Physics

Above: Nisael Solano won the 2010 Master's Thesis Award for Rock Properties Relationship to Gas Production – Upper Monteith Fm, Nikanassin Group

Casey Struyk (left) and Jim Earley (right) being awarded honorary membership

(John Kovacs was unable to attend)

CO_2 Rock Physics: A Laboratory Study

Helen Yam and Douglas R. Schmitt
University of Alberta

Summary

CO_2 in the upper sections of a sedimentary basin can exist in a gas, a liquid or a supercritical fluid phase state. Pore fluids can have a substantial effect on the behavior of seismic waves where seismic methods are widely used for monitoring geological CO_2 sequestration projects. To observe the seismic effects associated with the different phase states of CO_2, ultrasonic pulse transmission experiments were conducted on a Berea sandstone subjected to full CO_2 saturation over a range of pressures and temperatures. Over CO_2 phase transitions the acquired waveforms show significant changes in the arrival time and strength variations.

Introduction

Geological CO_2 sequestration is regarded as an effective method in mitigating the amount of CO_2 released into our atmosphere (Benson and Cole, 2008; Chadwick et al, 2009). Depleted oil and gas reservoirs, saline aquifers, and deep unmineable coal beds together have an estimated storage capacity up to 11,000 gigatons of carbon (IPCC, 2005). Concerns about the safety and the integrity of underground CO_2 containment have enlisted various methodologies for monitoring the behaviour of the injected CO_2, where seismic methods are highly favourable. The presence of a pore fluid has been shown to have a strong impact on the elastic properties of a porous medium (Batzle and Wang, 1992). Seismic methods, particularly time-lapse seismic, are employed in all the current large scale sequestration projects (Sleipner, Weyburn, and In Salah) and in many smaller scale or pilot projects (Frio, SACROC, Nagaoka). Given the possible pressure and temperature conditions at the upper depths of a sedimentary basin, CO_2 can be in a gas, liquid, or supercritical fluid phase state, where each will yield a different effect on seismic waves from the consequent variations in density and fluid compressibility. Therefore to effectively utilize seismic methods for monitoring sequestration projects, the thorough understanding of the elastic properties of CO_2 is essential. Ultrasonic pulse transmission experiments have been conducted on a fully CO_2 saturated Berea sandstone for a variety of temperatures and pressures that are reflective of subsurface conditions for which CO_2 can be a gas, liquid and supercritical fluid. Although realistically the pore space may also contain brine or hydrocarbons, the purpose of full CO_2 saturation is to provide an end member understanding of what extreme behaviours can be expected with CO_2 in the pore space.

CO_2 Phase States and Physical Properties

Based on the empirical thermodynamic model of Span and Wagner (1996), the phase diagrams of CO_2 bulk modulus and density over a temperature range of 0-60 °C and for pressures up to 30 MPa are shown in figure 1a, and 1b. In general within a fluid, the bulk modulus and density are the physical properties that will influence wave propagation; bulk modulus has a direct proportional effect while density has an inverse proportional effect on wave velocities. The accepted critical point of CO_2 is at 30.9782 °C and 7.3773 MPa (Span and Wagner, 1996), and is marked by a red dot in the phase diagrams. Below the critical temperature and pressure, CO_2 can be either a gas or liquid with respect to the possible subsurface conditions. The vapour-liquid boundary is clearly discernible by an abrupt change in all the physical properties. As the critical point is approached the properties of the gas and liquid phases converge and no distinction is apparent thereafter, yielding the supercritical fluid phase. A unique characteristic of supercritical fluid is they have physical behaviors of both a gas and a liquid. As a consequence of this characteristic, any gas or liquid phase transitions gradually into the supercritical phase, in contrast to the gas-liquid transition. Another unique feature of supercritical fluid is in the region close to the critical point, large density variations occur over a small range of pressure and temperature.

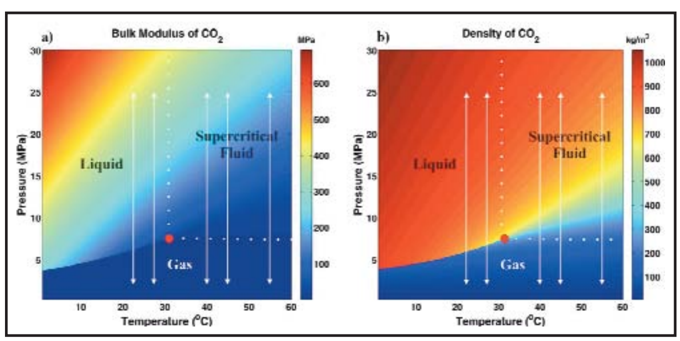


Figure 1: Phase diagrams of CO_2's: (a) bulk modulus (b) and density. The red dot on both phase diagrams marks the critical point of CO_2. The vapor–liquid boundary is clearly discernible from the sudden change in physical properties. The boundaries of the supercritical fluid phase state are marked by the white dotted line. The temperature and pressure conditions applied to the CO_2 during ultrasonic pulse transmission measurements are shown by the white arrows.

CO_2 Rock Physics *continued…*

Porous Medium Sample

A portion of Berea sandstone, predominantly composed of quartz grains, is used as the host sample in this study. From helium porosimetry measurements, the sample has a porosity of 19.0% and from air permeability measurements it has a permeability of ~240 millidarcies. A photograph and a scanning electron microscopy (SEM) image of the sample are shown in figure 2. From mercury porosimetry tests, the pores are mainly 11 microns in size, with a minor component of pores smaller than this.

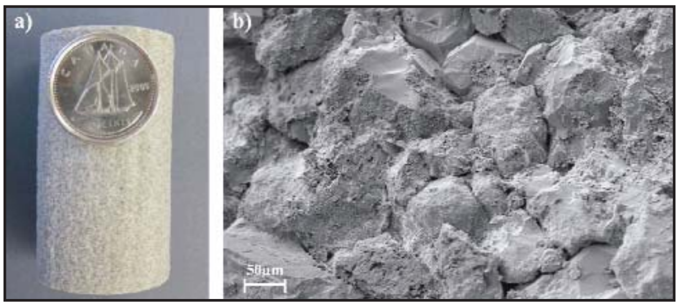


Figure 2: Berea Sandstone a) photograph b) SEM image

Experiment

To determine the elastic properties of the sample, the ultrasonic pulse transmission technique is applied. A cylindrical sample size of 50 mm in length and 25.4 mm in diameter is placed in between a transmitting and a receiving transducer made of P- and S- piezoelectric ceramics with a center frequency of 1 MHz that is mounted on an aluminum buffer cap. The sample-transducer assembly is placed inside a pressure vessel that is filled with hydraulic oil, where the hydraulic oil serves as the hydrostatic pressurizing medium and provides the confining pressure. The sample is placed in a flexible, clear, impervious Tygon® tube to seal it from hydraulic oil contamination. CO_2 is introduced into the vacuumed sample via stainless steel tubing that connects the sample to a CO_2 tank of 99.9% purity, located on the outside of the vessel. The confining and pore fluid systems are independent of each other such that different pressure conditions can be applied irrespectively of each other by using different pumps. The temperature of the experiment is controlled by an electrical resistance tape that is wrapped around the vessel and is measured by a K-type thermocouple located next to the sample inside the vessel.

The transmitted signal is generated by exciting the transmitting transducer with a fast-rising 200V square wave from a JSR-PR35 pulse generator. The propagated signal is recorded by a digital oscilloscope made by National Instrument, at a sampling rate of 10 nanoseconds. The final waveform is a stack of over 500 traces to reduce random noise effects. From the final waveforms the transit time of the signals is deduced, and with the length of the sample, the elastic wave velocities consequently calculated. The general scheme of the experiment is shown in figure 3.

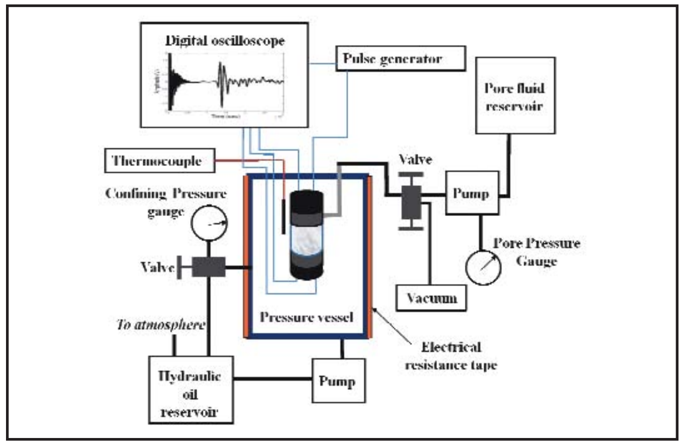


Figure 3: Experimental setup for ultrasonic pulse transmission for CO_2 saturated measurements.

Ultrasonic measurements are conducted on the sample under dry and CO_2 saturated conditions. The dry measurements are completed with the pore space under vacuum (Pp =0 MPa) while the confining pressure (i.e. differential pressure when Pp =0 MPa) varies from 2 MPa to 40 MPa. The resulting P-and S-wave velocities show a significant nonlinear dependence on confining pressure as was expected for the Berea sandstone. This pressure dependency of the elastic wave velocities is attributed to the closing of micro-cracks in the sandstone under pressure. For the CO_2 saturated measurements, five different constant temperature runs are conducted while pore pressure varies from 2 MPa to 25 MPa. The constant temperature runs are completed at 23 °C, 28 °C, 40 °C, 45 °C, and 55 °C. In figure 1, superimposed on the phase diagrams of CO_2 are the different temperatures and pore pressures conditions explored during the series of CO_2 saturated measurements. As pore pressure increases, for the lower temperature runs (23 °C and 28 °C) CO_2 changes from a gas phase to a liquid phase, while for the higher temperature runs (40 °C, 45 °C, and 55 °C) CO_2 changes from a gas phase to the supercritical fluid phase. For each CO_2 measurement run, a constant differential pressure of

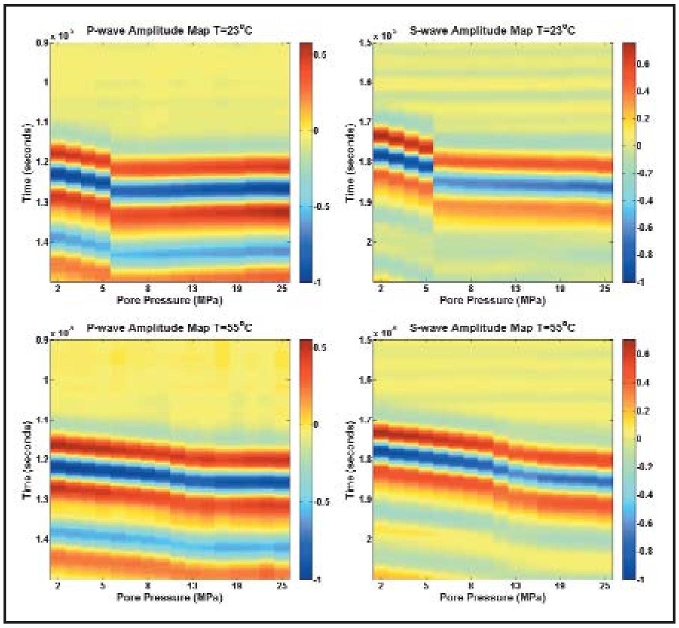


Figure 4: P- and S-wave (left and right, respectively) waveforms collected for T = 23 ˚C and T = 55 ˚C (top and bottom, respectively) constant temperature runs.

15 MPa is maintained by varying the confining pressure accordingly to the pore pressure. As mentioned earlier, the elastic wave velocities of the Berea sandstone exhibits a pressure dependency. By maintaining a constant differential pressure, any resulting variations in elastic wave velocities are solely caused by the pore fluid's behaviour, if it can be assumed that the integrity of the sample has not been altered.

Laboratory results

Figure 4 shows the recorded P- and S-wave waveforms with their amplitudes displayed in color as a function of pore pressure for only the lowest and highest temperature run, T = 23 ˚C and T = 55 ˚C respectively. In general, as pore pressure increases the signals arrive later and in a given plot, two arrival trends can be seen. Furthermore, the waveforms signal strength shows changes near the anticipated phase transition. For the lower temperature run, the elastic wave response to the CO_2 phase transition is sharp and is related to the distinct contrast between the gas to liquid physical properties seen in the bulk modulus and the density phase diagrams of CO_2. The sharp change in the waveforms occurs at a pore pressure close to a CO_2 vapour-pressure of 6.1 MPa at 23 ˚C. In contrast, the elastic wave responses of the higher temperature run to CO_2's phase transition is gentle and less obvious. This is a consequence of the subtle differences between the gas to supercritical fluid physical properties. Furthermore, the change in waveforms trend does not occur until well past the critical pressure

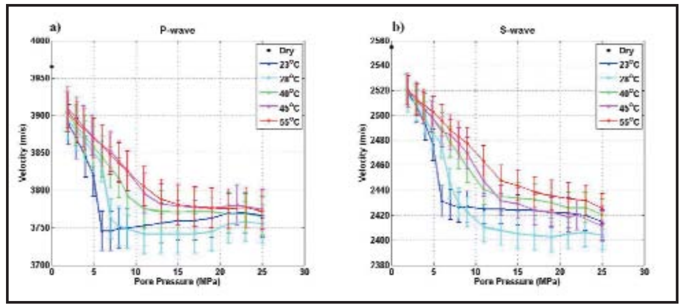


Figure 5: Ultrasonic a) P- wave b) S-wave velocities measured of the sample saturated with CO_2 under various temperatures and pore pressures and when the sample is not saturated (black dot at Pp = 0 MPa). All measurements on the two plots were completed with a differential pressure of 15 MPa.

of CO_2. Referring to the density phase diagram of CO_2, large changes in density do not occur till about 10 MPa at 55 ˚C.

The P- and S-wave velocities of all the waveforms were determined and are displayed in figure 5. On these plots, the velocity of the dry sample at a differential pressure of 15 MPa is shown by the black dot. From these velocity plots the following are observed:

1. Once CO_2 is introduced into the pore space, irrespective of the phase state of the CO_2, the elastic waves traveling through the sample are slower than when the pore space is empty;
2. As pore pressure increases, the elastic wave velocities generally decreases with the exception of the T = 23 ˚C P-waves at high pore pressures;
3. Over the entire 25 MPa pore pressure interval, P-wave velocities changed between 3.6-3.9% while S-wave velocities changed between 3.9-4.4%. The change in wave velocity is greater and sharper for the lower temperature runs than the higher temperature runs;
4. Wave velocity variations with pore pressure are greater within the gaseous phase state than within the liquid or supercritical fluid phase state.

For all S-waves of a given temperature run, as pore pressure increases the wave velocity decreases. This behavior is expected since theoretically changes to S-wave velocities are only due to bulk density changes, which increases with pore pressure. Between temperature runs, the decrease in S-wave velocity with increasing density is less consistent. The integrity of the sample may have changed between the measurement run. For P-waves, as pore pressure increases the wave velocities generally decreases except for the T = 23 ˚C run at high pore pressures.

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CO_2 Rock Physics *continued…*

The decrease in P-wave velocities suggests that the effect of the change in bulk density is greater than the effect of the change in bulk modulus; the two have opposing effects on P-wave velocity and they both increase as pore pressure increases. For the T = 23 °C run at high pore pressures, the increase observed suggests that the change in bulk modulus dominates. Referring to figure 1, in the liquid phase state the T = 23 °C run do undergo a greater change in bulk modulus than the other four temperature runs; therefore the unique behavior observed for the T = 23 °C run at high pore pressures is reasonable.

Conclusions

P- and S-wave laboratory data were acquired for various pressure and temperature conditions on a fully CO_2 saturated Berea sandstone. The results show that elastic waves are sensitive to changes pertaining to the pore space content and CO_2 phase change may be evident from signal variations. The elastic wave velocities show a sharp change when CO_2 transitions from a gas to liquid. However, the elastic wave velocities show a smoother and a more subtle change when CO_2 transitions from a gas to a supercritical fluid. The change observed here is for an extreme end member, and this does not imply that the same results can be attained when there is more than just CO_2 in the pore fluid.

Acknowledgements

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References

Batzle, M. L., and Wang, Z., 1992, Seismic properties of pore fluids, Geophysics, 57, 1396-1408.

Benson, S. M., and Cole, D. R., 2008, CO_2 Sequestration in Deep Sedimentary Formations, Elements, 4, 325-331.

Chadwick, R. A., Arts, R., Bentham, M., Eiken, O., Holloway, S., Kirby, G. A., Pearce, J.M., Williamson, J. P., Zweigel, P., 2009, Review of monitoring issues and technologies associated with the long-term underground storage of carbon dioxide, Geological Society of London Special Publications, 313, 257-275.

IPCC, 2005, Underground geological storage, In: Metz B., Davidson O., de Coninck H. C., Loos M., Meyer L. A. (eds), IPCC Special Report on Carbon dioxide Capture and Storage, prepared by Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Span, R., and Wagner, W., 1996, A new equation of state for carbon dioxide covering the fluid region from the triple-point temperature to 1100 K at pressures up to 800 MPa, J. Phys. Chem. Ref. Data, 25, 1509-1596.

Drill Cuttings and Rock Properties for the Monteith Formation, Nikanassin Group

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Introduction

The issues related to the geologic characterization of hydrocarbon reservoirs have been addressed in many papers and publications in the last decades. For the case of tight sandstone reservoirs, most characterization schemes turn around three major components: the depositional, the petrographic, and the hydraulic rock type. Among these three components, a more dominant effect is usually linked to the petrographic and hydraulic rock types[1], which define the reservoir quality in tight gas formations.

Ideally, the principal input dataset considered on standard workflows for geologic characterization includes: seismic surveys, conventional and special well logs, cores, drill cuttings, and dynamic production tests/performance (Figure 1). However, in most cases we usually have a reduced dataset which is typically restricted to conventional well logs, drill cuttings, production history, very sparsely distributed cores, and some production tests. Due to economic factors, the scarcity of "hard data" is often accentuated for the case of tight gas reservoirs.

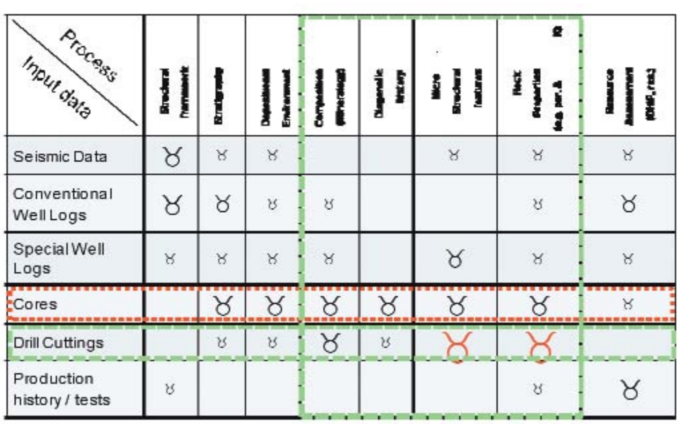

Figure 1: Generalized dataset for geologic characterization of hydrocarbon reservoirs. Size of checkmarks is relative to the contribution inferred for each source of data.

As previously mentioned, the characterization of unconventional gas plays requires a better understanding of petrographic and hydraulic rock types, and the main input data needed for these components are well cores. To overcome this limitation, we assign a more active role to the drill cuttings in the proposed workflow (Figure 2), through the incorporation of two existing

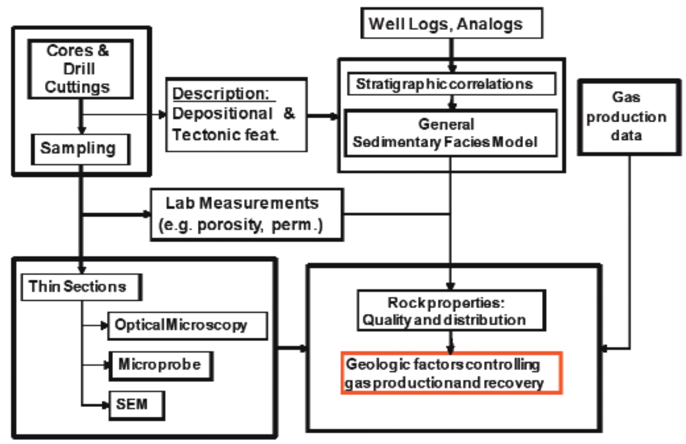

Figure 2: Integrated reservoir characterization workflow targeted to overcome the limited availability of cores, while maximizing the use of drill cuttings samples in the process.

methodologies to get structural features2 and rock properties from drill cuttings3. This article presents a summary of this integrated methodology, and results from its application to Lower Nikanassin strata – a tight gas formation in the Deep Basin of Alberta. Special emphasis is given to the usefulness of drill cuttings samples to evaluate key rock properties in low permeability siliciclastic formations.

Integrated characterization approach

One of the biggest challenges in the reservoir characterization process is the calibration of empirical calculations with rock-derived properties. The workflow applied in this study addresses the limited availability of well cores, and provides reasonable intermediate outputs to evaluate the effects of the depositional, petrographic, and hydraulic rock types on the reservoir quality.

Depositional and tectonic features

Preliminary steps in this workflow include the description of cores and drill cuttings in terms of the sedimentary and tectonic features (Figure 2). Grain size, roundness and sorting are among the sedimentary features described from cores and drill cuttings. Lithology fractions are also visually estimated from each drill cutting sample, and the sandstone fraction is further subdivided according to its lithic content using Folk's classification5. The presence of naturally fractured/faulted zones is readily identifiable at the core scale. However, the identification of specific textures may also assist the assessment of these zones using drill cuttings samples. These textures can be grouped into six major categories[2]:

- Fracture sets with mineral infilling or lining,
- fracture sets with planar, un-mineralized surfaces,
- brecciation and/or fault gouge,
- micro-faulting,
- slickensides, and
- loose mineral crystals.

The data collected is used to prepare vertical logs, and this information is combined with wireline well logs and outcrop analogue models to assist in the definition of stratigraphic boundaries and depositional environments for the analyzed formation within the study area.

Petrography

The application of standard petrography, microprobe and SEM analytical techniques provides valuable insights into the petrographic framework of the rocks. The standard petrography and microprobe analyses are performed on double polished thin sections prepared using available cores, and drill cuttings samples. Thin sections prepared from drill cutting are mounted in multi-sample slides (e.g., 12 samples/slide); this not only reduces the actual amount of sample required and the preparation costs, but is also more convenient for analysis of continuous samples within a given well.

Relative abundance of detrital grains and authigenic minerals is estimated from the thin section slides using a standard petrographic microscope. A combination of Backscattered Electron (BSE) images and Chemical Elemental Maps (CEM) from the microprobe analysis is used to validate the visual estimations of the principal mineral phases. These images also provide a better definition of the detrital framework, and the relative timing of precipitation of authigenic cements. The samples to be analyzed with the microprobe are selected based on their location within key regions drawn as end-points in porosity vs. permeability plots.

The analysis of pore geometry considers the evaluation of five principal pore types: (a) intergranular, (b) dissolution, (c) microporosity, (d) microfractures, and (e) slot-like pores. SEM images gathered from selected samples provide supporting evidence for the interpreted pore geometries.

Hydraulic rock properties

Available routine core analysis data and measurements from drill cutting samples are used to define the hydraulic properties of the rocks. Porosity is calculated from drill cuttings by measuring the differential weight between the samples at 0%, and 100% of water saturation. Average values of water and grain density are used in the calculation of porosity following the saturation method[6]. The permeability is measured on drill cutting samples using the Darcylog apparatus and the "Liquid Pressure Pulse" method[3]. The permeability tests are based on achieving effective fluid flow inside the cutting fragments. To this end, spontaneous imbibition using a viscous liquid is allowed in the samples, and residual gas becomes trapped within the largest pores in the cutting fragments. A pressure pulse is then applied and fluid flow occurs by compressing the gas trapped inside the cuttings.

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Drill cuttings and Rock Properties *continued…*

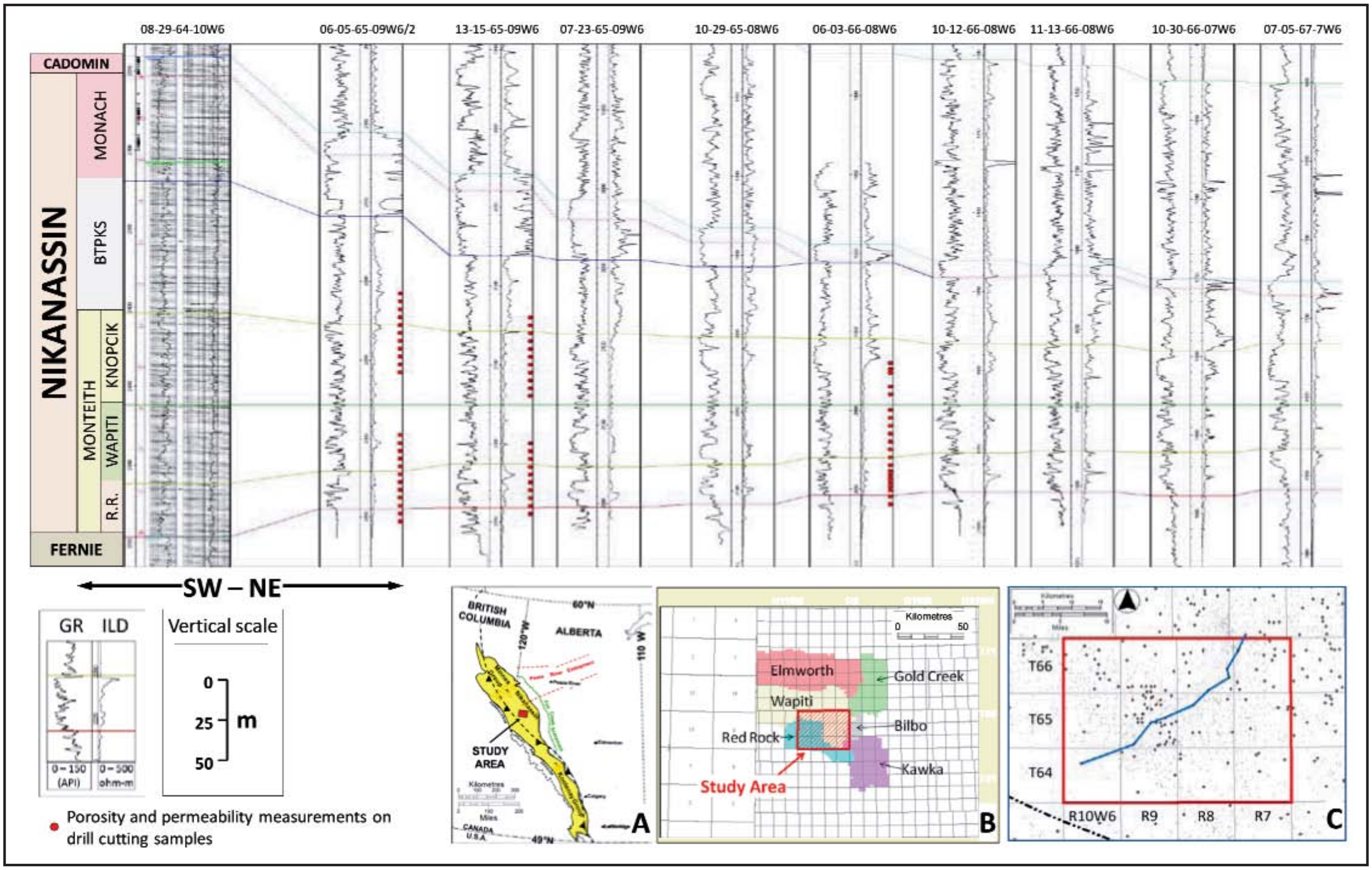

Figure 3: Stratigraphic section and location of the study area, including portions of the Wapiti and Red Rock fields in the Deep Basin of Alberta, Canada. Notice the top of the Nikanassin Group is represented by an erosional surface below the Cadomin Formation. The stratigraphic datum used in this section corresponds to the top of the Wapiti Member within the Monteith Formation, as defined by Miles (2010). Insert A adapted from Leckie et al., 1992. The resistivity in the first well (SW) has a logarithmic scale from 0.2 ohm-m to 200 ohm-m.

Artificial drill cuttings generated from crushed core samples can be used as a quality control of the permeability measurements. Both porosity and permeability measurements are non-destructive tests, so the samples can be cleaned up and restored to its original state after the tests.

The three previously described components (e.g., depositional, petrographic, and hydraulic rock types) are combined to define the quality and distribution of the rock properties for a given stratigraphic interval. Finally, gas production data (when available) is incorporated into the process as a final constraint to define the most favorable combination of geologic factors in the reservoir performance.

Nikanassin strata in the subsurface of the Wapiti and Red Rock areas

The upper portion of the Monteith Formation, the lowermost part of the Nikanassin Group in the Deep Basin of Alberta[4] was selected for the application of this workflow. Nikanassin strata represents the first sedimentary cycle associated with the early stage of the western North American foreland basin during Late Jurassic-Early Cretaceous time[7]. The study area is located in west-central Alberta (Canada), approximately 400 Km NW of Edmonton (inset maps in Figure 3). This area corresponds to the southeast part of the Wapiti field, and northeast portion of the Red Rock fields, between the Townships 64 to 66, Ranges 6 to 10, west of the sixth meridian. As of March, 2010 114 wells have penetrated the entire Nikanassin section in this area.

The Monteith Formation is represented by three coarsening-up sequences: (a) the Red Rock, (b) Wapiti, and (c) Knopcik allomembers, from older to younger. Gas production is generally associated with the Red Rock, and Knopcik members. The stratigraphic section in Figure 3 allows for a quick examination of the internal geometry of these units. In this southwest-northeast oriented cross-section, lateral continuity of sandstone lithologies is relatively more consistent within the Knopcik and Red Rock allomembers; although the net sandstone to gross thickness ratio gradually decreases southwestward in the former. In contrast, individual sandstone bodies within the Wapiti allomember seem to be more disconnected in this direction, as can be inferred from the drastic variations of the electrofacies within this unit among adjacent wells.

Description and interpretation of subsurface cores from the 07-07-065-07 W6M wellbore implies a progradational setting, with a shallow marine to coastal plain facies and tidal flats continuum for the upper half of the Knopcik allomember.

Drill cuttings samples from Nikanassin wells within the study area are available for most wells. The samples are usually stored in individual vials (15 cm^3) representing depth intervals of 5 m, and less often every 2.5 m. Lithological description was performed for over 360 samples from 15 wells, which represents approximately 1,700 m of subsurface rock samples. Porosity and permeability measurements were run in 32% of these samples; In addition, 25% of the samples (144 samples from seven wells) were sub-divided to prepare thin sections, including the correspondent petrographic analysis. Prior to the sub-sampling for the preparation of thin sections, porosity and permeability measurements were performed on each sample.

From the microscopic description of drill cuttings, more abundance of light grey colored fragments are reported from the lower portion of the Monteith Formation (e.g., the Red Rock allomember). This observation implies the dominant presence of sub-litharenites and quartzarenites within the sandstone fraction (Figure 3, images A to C; and Figure 5). Besides the upwards grain size increase accounted for by the three Monteith coarsening-up sequences, there is not substantial variations in grain size ranges among these three allomembers (e.g., lower-very fine to lower-medium sandstone grain size).

Quartz, chert, shale and feldspar fragments are the principal detrital components within the Monteith Formation. In general, lithic content slightly increases upwards within the Monteith Formation. There is a sudden mineralogical change in the sandstone fractions at the Monteith /Beattie Peaks geological boundary. In hand samples and drill cuttings, a color

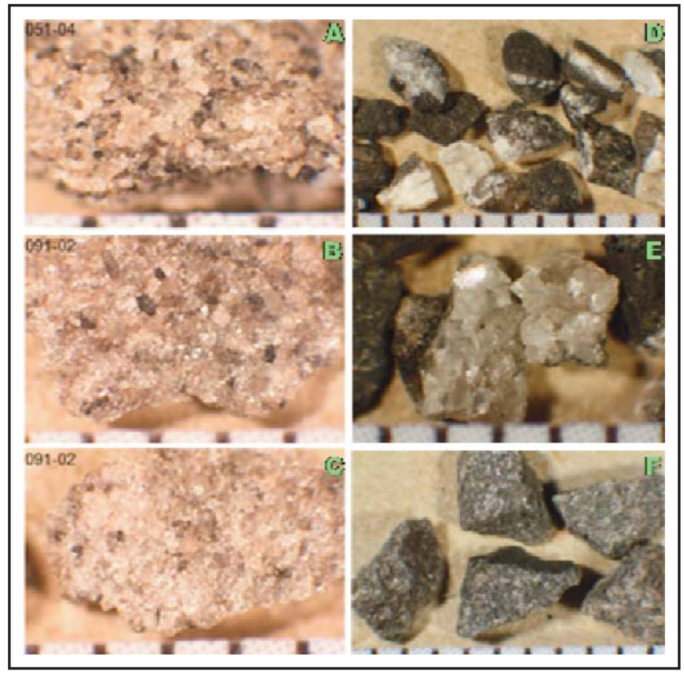

Figure 4: Drill cutting fragments from the Monteith Formation. Pictures A to C show a close-up of litharenite, sublitharenite, and quartzarenite fragments, respectively. Calcite veins are visible running across the fragments in (D), whereas euhedral dolomite crystal growths are attached to the fragments in (E) and angular cutting fragments in (F).Vertical marks at the bottom of each picture are 1mm apart from each other.

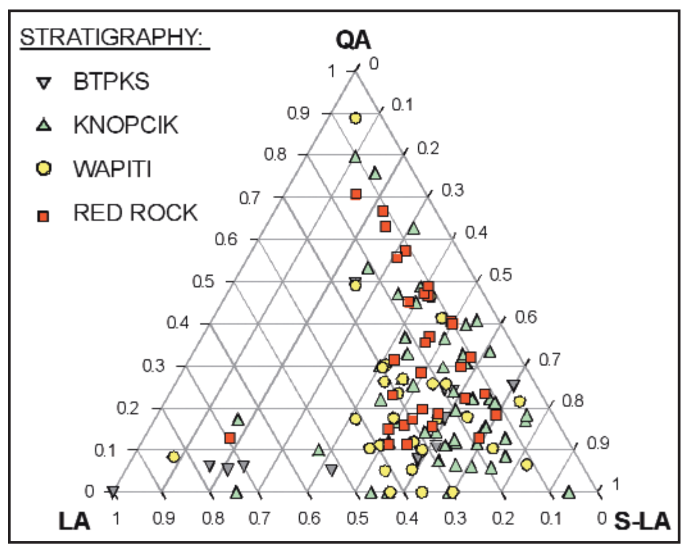

Figure 5: Ternary plot with the distribution of the major lithological groups within the sandstone fractions for the Monteith Formation, and lower portion of Beattie Peaks Formation. LA = litharenite, S-LA = sublitharenite, and QA = quartzarenite.

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Drill cuttings and Rock Properties *continued…*

change accompanies this transition; so the sandstone fractions become medium to dark grey with a salt & pepper appearance at low magnifications (<10x). This observation is consistent with visual estimation of detrital mineral abundance using thin sections prepared from the same drill cutting samples.

Angular fragments are the most widespread tectonic features within the sandstone lithology among the analyzed drill cutting samples (image F in Figure 3). Even though angular faces in these fragments might not represent actual natural fractures, they can be interpreted as pre-existing weakness planes along which the formation can more easily break during hydraulic fracture stimulations. Sub-millimeter, completely healed calcite veins are also common, especially within the siltstone and mudstone sections immediately above the major sandstone intervals. Less common is the presence of euhedral crystals (mostly dolomite), locally restricted to a few fragments from two wells in the NW corner of the study area. These euhedral crystals are likely associated with open natural fractures; thus despite their limited presence among the analyzed samples, their impact in fluid flow enhancement might be significant in these tight sandstones.

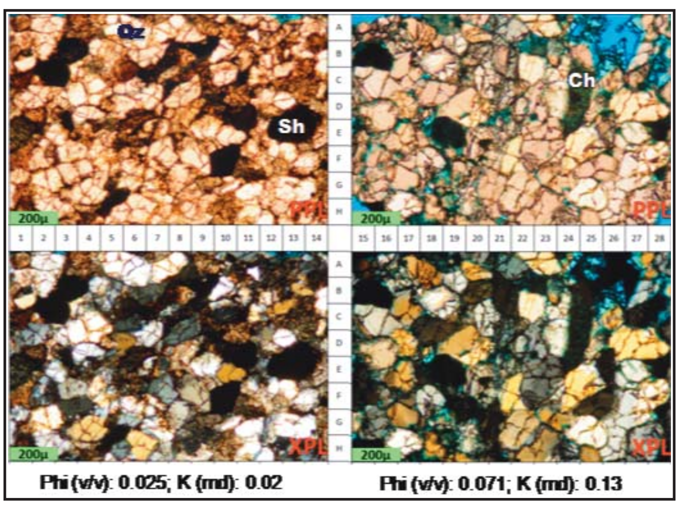

Figure 6: Microphotographs of thin sections under plane polarized (upper) and cross-polarized light (lower) from two different samples representing end-points of porosity and permeability. Blue dyed epoxy was used to highlight the porosity of the samples. Qz = quartz, Sh = shale, and Ch = chert. Thin sections were prepared from drill cutting fragments. Randomly oriented features within individual quartz grains are artifacts associated with the thin section making process. Left and right images are from locations 05-32-065-09W6 (3,287.5-90 m), and 06-03-066-08W6 (3,015-20 m), respectively.

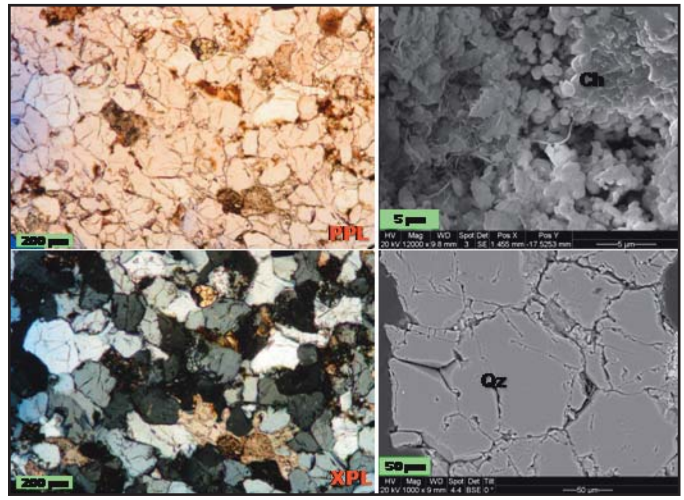

Figure 7: Microphotographs from drill cuttings thin sections (left images, 102/06-05-065-09W6, 3,495-3,500 m); SEM images from core sample (upper right; 07-07-065-07W6, 3,094.9 m) and drill cutting thin section (lower right; 102/06-05-065-09W6, 3,585-90 m). Qz = quartz, and Ch = chert.

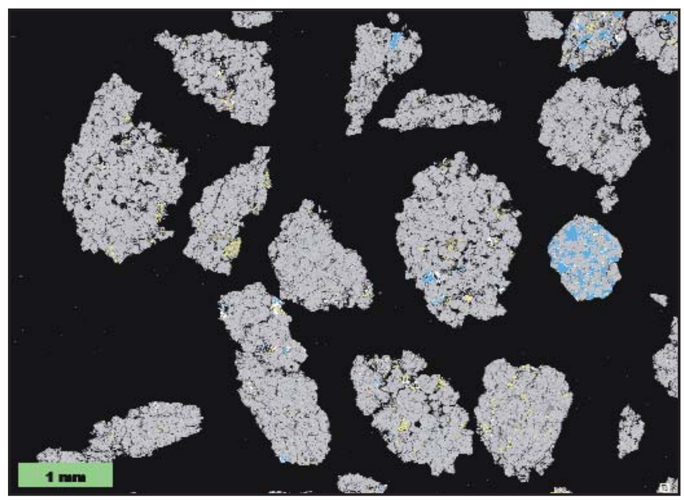

Figure 8: CEM of silica in a thin section prepared from drill cutting samples (05-32-065-09W6; 3,085-90 m). Blue and yellow colored spots indicate the location of dolomite cement, and feldspar fragments, respectively.

The petrographic analysis provides further details regarding the detrital and authigenic mineralogy of potential producing intervals (Figure 6). From this, prospective reservoir rocks comprise very fine to fine grained sub-litharenites and litharenites (occasionally quartzarenites). The principal detrital constituents are quartz, chert, shale, and feldspar fragments. The cementing phase is represented by silica and calcite/dolomite, and minor amounts of clay minerals (Figure 7. Also from this analysis, it was found that the primary intergranular porosity was severely affected by pervasive quartz overgrowth, and variable amounts of carbonate cement (Figure 7 and Figure 8), as well as moderate chemical and mechanical compaction. In contrast, secondary porosity is common and is represented by alteration of feldspars and microporous dissolution within chert fragments.

Distribution of cement types is not the same for the three Monteith allomembers. For instance, silica cement from quartz overgrowths is more dominant within the Red Rock unit, whereas a mixture of carbonate and silica cement is usually present within the Knopcik allomember (Figure 9).

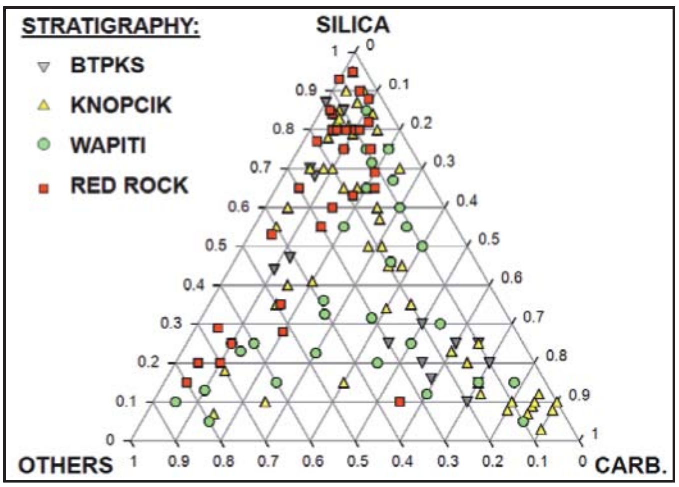

Figure 9: Ternary plot of cement types separated for each allomember within the Monteith Formation. Some data points from the lower portion of the Beattie Peaks are also included. The lower right corner (CARB.) of the plot refers to combinations of calcite/dolomite, with the lower left corner (OTHERS) assigned to authigenic clays, pyrite, pyrobitumen, and other accessory cements.

Porosity values measured on drill cuttings samples range between 2% and 13%, although most values are concentrated between 3% and 10% (Figure 10). The average value is 5.1%, for over 140 analyzed samples, mostly from the Red Rock, Wapiti, and Knopcik allomembers. Average values of porosity are slightly higher within the Red Rock allomember, compared to the overlying Wapiti and Knopcik allomembers (Figure 11). Although microporosity is the dominant pore geometry observed on the three Monteith allomembers, subtle and opposite changes in the contribution from intergranular pores vs. microfractures and slot pores is observed among these three stratigraphic units.

The same set of drill cutting samples was used to run permeability measurements, from which most of the values range between 0.01 md and 2 md. Higher values on this property are

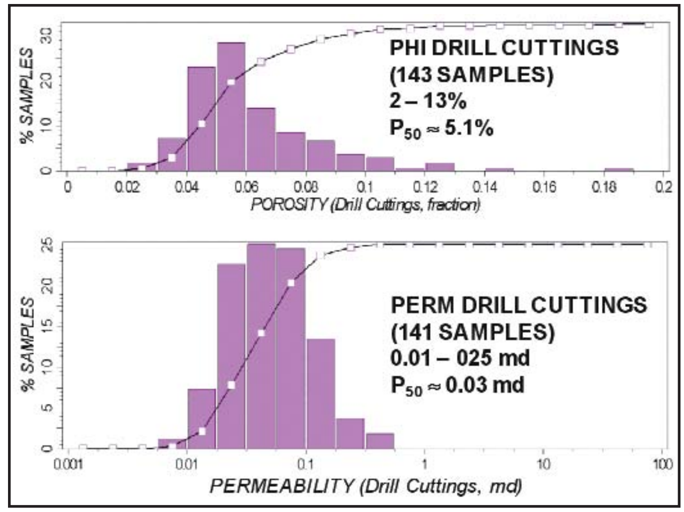

Figure 10: Frequency distribution plots of porosity and permeability from drill cutting samples, Monteith Formation.

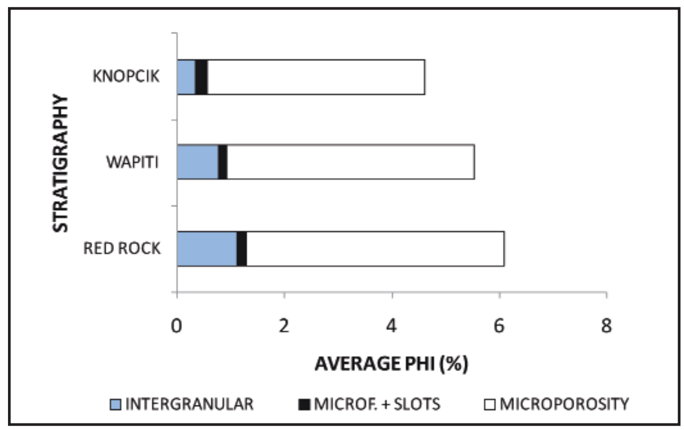

Figure 11: Distribution of porosity types in Monteith allomembers. Bar length represents average values of the product PHITOTAL x PORETYPE from over 140 samples analyzed.

preferentially associated with silica cemented samples, as can be deduced from the ternary plot in 12. This observation is consistent with the presence of sublitharenite and quartzarenites dominated sandstone lithology, especially within the Red Rock allomember (Figure 9). The presence of interlocking quartz overgrowths is thought to favor the development of slot-like pores in quartz-rich sandstones.

The data collected from drill cuttings samples can be presented for each well in a graphic format using standard well log templates. For instance, the example shown in Figure 13 includes a basic wireline log set, results from the lithological description, grain size, cement type, Sneider's rock type[8], structural features, amount of sample, measured porosity and permeability values,

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Drill cuttings and Rock Properties *continued…*

and pore geometry and cement type from thin sections. This allows the correlation of these properties with wireline well logs, and these correlations can be further extrapolated using standard geomodeling tools.

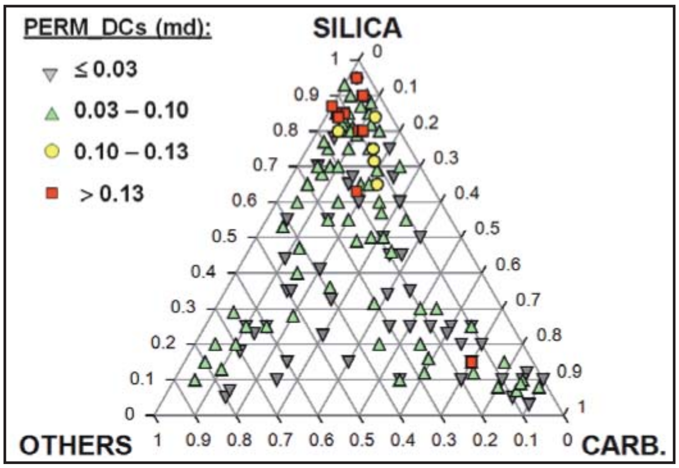

Figure 12: Ternary plot of cement types constrained by permeability values measured on drill cutting samples from the Monteith Formation. See Figure 9 for definition of labels in this ternary plot.

Conclusions

The application of appropriate analytical tecniques to drill cuttings samples can yield valuable insights into the rock properties of tight gas reservoirs. Lithology, structural features, detrital and authigenic mineralogy, along with porosity and permeability measurements are evaluated for the Monteith Formation in the south portion of the Wapiti field, Deep Basin of Alberta.

Subtle yet important differences exist between the Red Rock, Wapiti, and Knopcik intervals, the three allomembers associated with this formation. The most remarkable differences/trends include (a) upwards increase in the amount of lithic fragments and carbonate cement, and (b) downwards increase of the intergranular to microporosity, and silica to carbonate cement ratios.

One of the most important relationships among this datasets is the higher permeability values associated with silica cement in quartz-rich sandstone fragments, especially within the Red Rock allomember. Even though microporosity is by far the dominant pore geometry in this interval (and the overlying in-

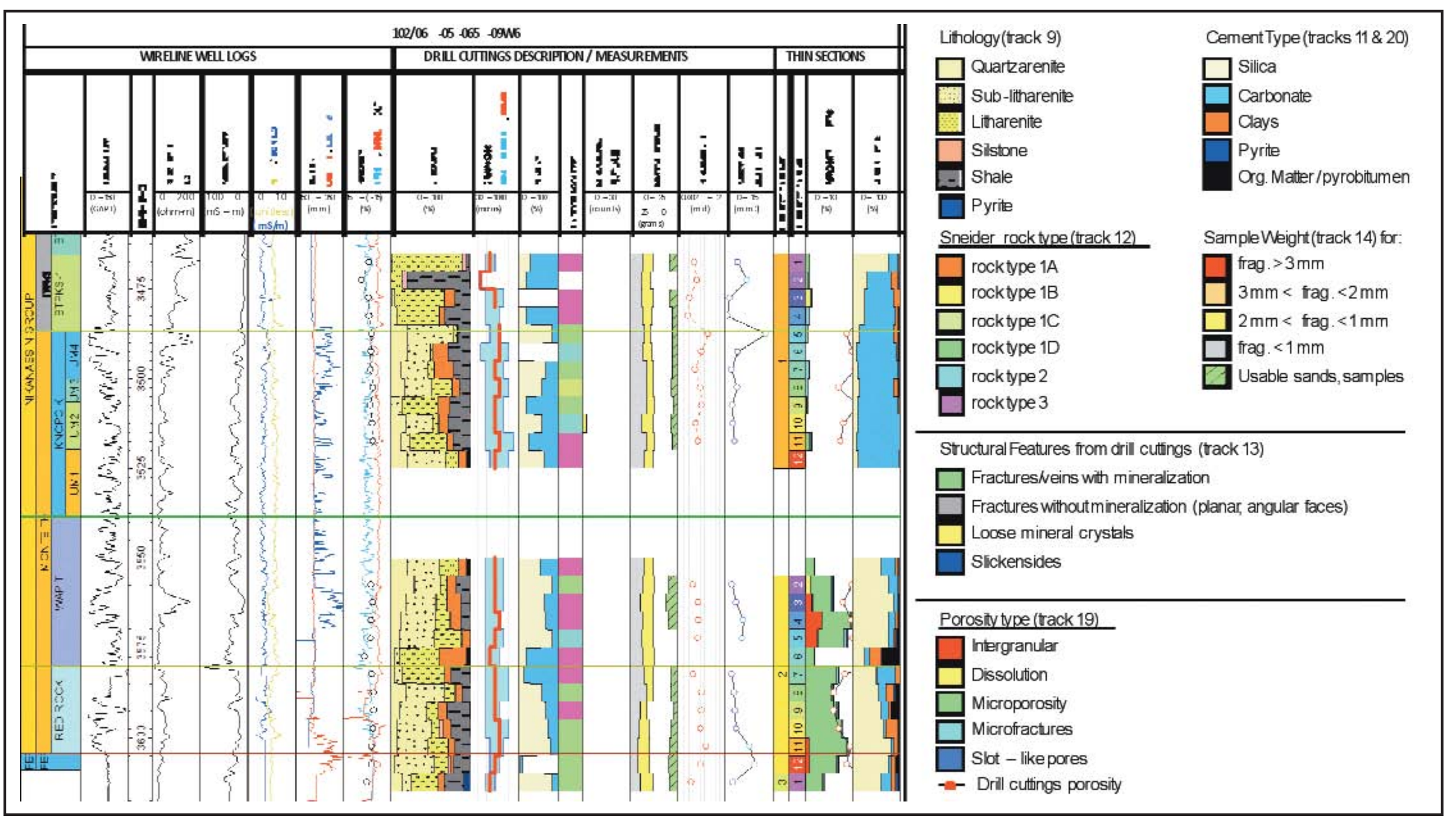

Figure 13: Integration and presentation of the data collected by following the proposed workflow for the evaluation of drill cutting samples.

tervals), relatively primary intergranular porosity contributes significantly to the flow and storage capacity of the rocks.

Acknowledgements

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References

1. Rushing J.A., Newsham K.E., and Blasingame T.A.,2008. Rock Typing - Key to Understanding Productivity in Tight Gas Sands. SPE paper 114164 presented at the SPE Unconventional Reservoirs Conference, Keystone, Colorado, USA, 10-12 February 2008.
2. Hews, J.B., 2009. Structural features that can be identified from drill cuttings. Notes from short course presented by Peter Hews (Hara Consulting Ltd.) in Calgary, Canada.
3. Egerman P., Doerler N., Fleury M., Deflandre J., and Lenormand R., 2006. Petrophysical Measurements from Drill Cuttings: and Added Value for the Reservoir Characterization Process. SPE paper 88684 published in the SPE Reservoir Evaluation and Engineering, August, pp. 303 - 307.
4. Miles B,. 2010. Unraveling the stratigraphic architecture of the Jurassic-Cretaceous Nikanassin Group, northwestern Alberta, Canada. MSc Thesis, University of Calgary, Canada, 2010.
5. Folk R.L., 1974. Petrology of sedimentary rocks. Austin, Hemphill, 182 p.
6. Amyx J.W., Bass D.M., and Whiting R.L., 1960. Petroleum Reservoir Engineering: Physical Properties. McGraw - Hill Book Co. New York.
7. Leckie D.A., and Smith D.G.,1992. Regional setting, evolution, and depositional cycles of the Western Canada foreland basin. Fireland basins and fold belts: AAPG Memoir 55, p. 9-46.
8. Sneider R.M., and King H.R., 1984. Integrated Rock-Log Calibration in the Elmworth Field - Alberta, Canada: Reservoir Rock Detection and Characterization: Part I. American Association of Petroleum Geologists Special Volumes; Volume M 38: "Elmworth: Case Study of a Deep Basin Gas Field", p. 205 - 214 (1984).
9. Solano N., 2010. Reservoir Characterization of the Upper Jurassic-Lower Cretaceous Nikanassin Group. MSc Thesis, University of Calgary, Canada, 2010.

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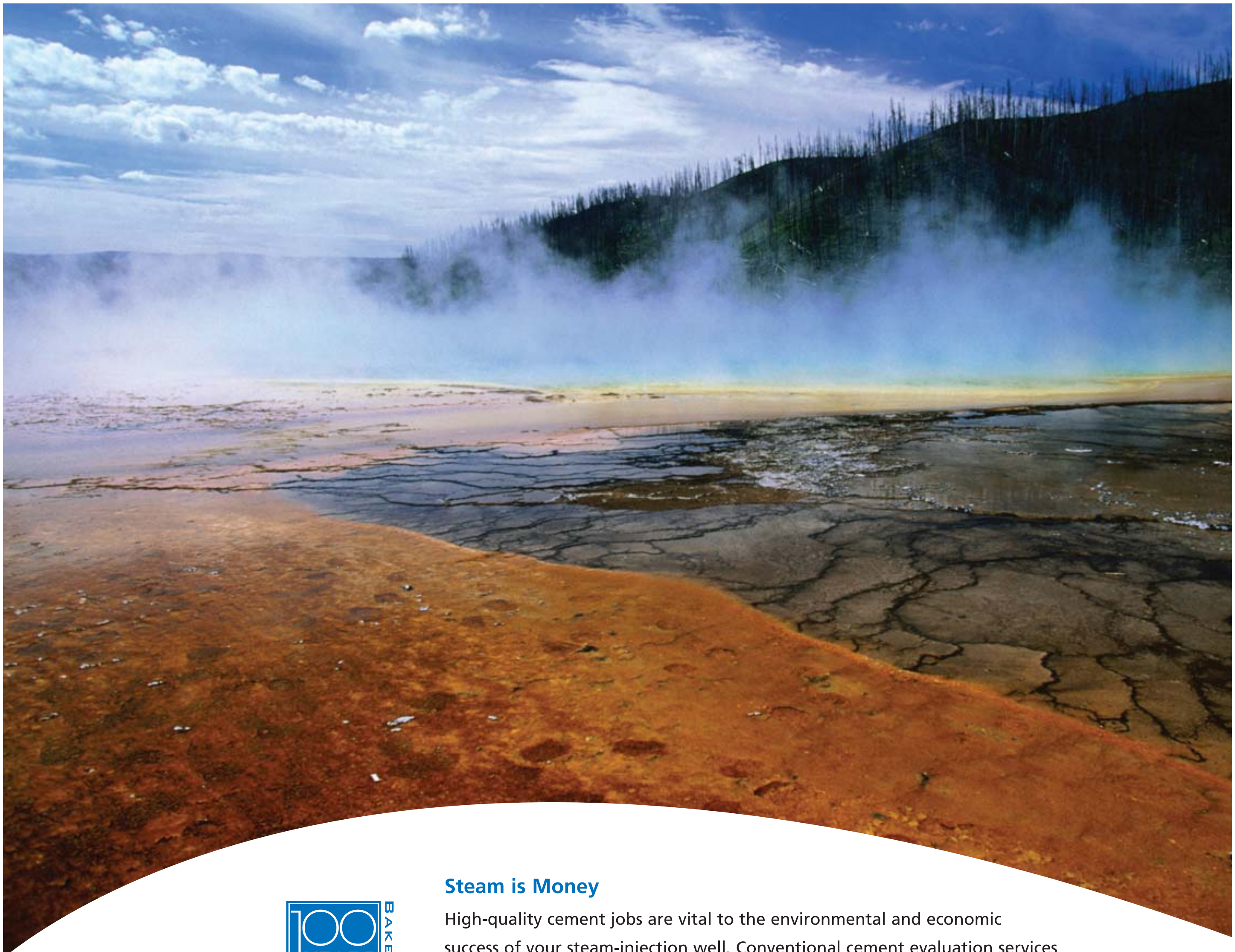

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GeoConvention 2011 Update

Satyaki Ray, P.Geol.

The 2011 Canadian Society of Petroleum Geologists (CSPG), Canadian Society of Exploration Geophysicists (CSEG), and Canadian Well Logging Society (CWLS) Joint Annual GeoConvention, is scheduled for May 9-13, 2011 in Calgary. Serving as a General Co-Chair in the Steering Committee this year, is Satyaki Ray, representing the CWLS, and who served as a Technical Co-chair for the 2009 convention. Simon Corti, a convention Technical Co-Chair, is part of the team which has designed a robust technical program in collaboration with the Technical and Steering Committees this year.

The GeoConvention this year is themed "recovery", which is a hopeful reminder that the recession is now in hind-sight. As world events unfold, there is cautious optimism about continued recovery throughout the petroleum industry. Our convention this year has a Business Recovery session where business leaders will speak about how the economy is recovering and how financial houses and businesses adapt and evolve during these changing times. The technical committee and session chair persons have designed a program this year which aspires to talk about the latest in the world of geoscience. The role of the session chairs has really been elevated to "theme champions". They did a great job of soliciting and reviewing papers along with the Technical Committee and are applauded for their efforts. The general chairs will be happy to see this role and importance continue for session chairs in future conventions.

Two components that the GeoConvention are supporting this year are Earth Science for Society and the Light Up The World Silent Auction. Aileen Lozie is the convention manager coordinating the conference planning and keeping track of the budget this year with the help of the Steering Committee. Carmen Smallwell leads the Sponsorship Committee. We are indebted to all new and previous sponsors who continue to support our convention and without whom it would not be a success. As the convention is built on the kind support of volunteers, we'd like to thank everyone who generously contributed their time this year.

Our committees remain open to tangible ideas which work toward building a successful and strong convention year after year. We hope you are able to attend this year, enhancing your knowledge of geosciences, and leaving with you enjoyable memories as well as the chance to catch up with old friends and make some new ones. We wish to thank everyone and look forward to a great GeoConvention 2011!

UPCOMING EVENTS

June 22, 2011
CWLS Technical Luncheon
Fairmont Pallier Hotel
Lunch at 12:00 noon

September 21, 2011
CWLS Technical Luncheon
Details to be announced

For ticket information, please contact:
Ashley Pessell
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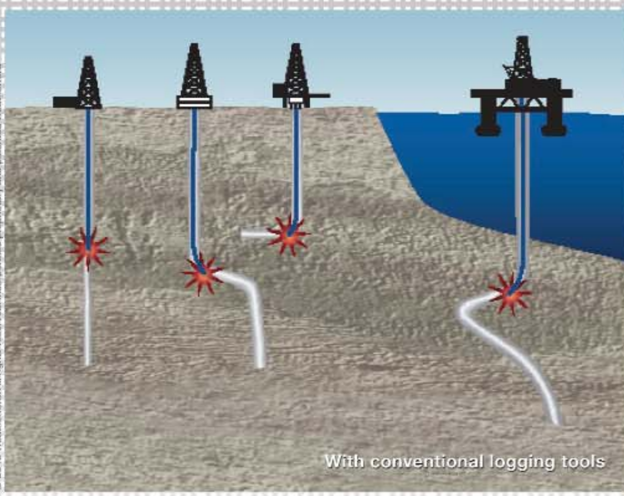

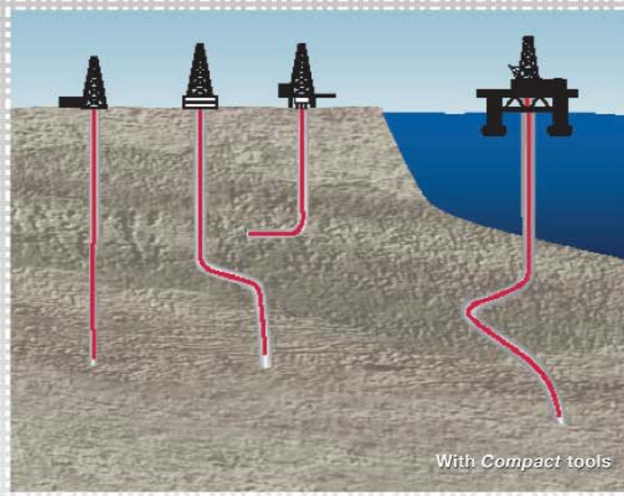

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