# InSite

CWLS Magazine
March 2007 Issue 1 Volume 26

## Inside this issue…

# InSite

**CWLS Magazine** **March 2007**

**Issue 1** **Volume 26**

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The CWLS InSite is printed four times annually which is included as a part of your yearly membership fees.




*The InSite is an informal magazine with technical content. The material is not subject to peer review. The opinions expressed are those of the individual authors.*

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**Cover Photos:** *Mirador da Lua – 50 km south of Luanda just before crossing the Kwanza River, Angola Africa. Photo courtesy of Tim Baumbach*

*Pumping oilwell in the Gold Creek Field, Alberta. Photo courtesy of Robert Bercha*

If you have a photo that the CWLS can use on its next InSite cover please send a high resolution jpeg format version to Tyler.A.Maksymchuk@conocophillips.com or Kelly.S.Skuce@conocophillips.com. Include a short description of the photo with your submission.

**The 2007 - 2008 CWLS Executive:**

*Front row (l - r): Greg Schlachter, Cindy Guan, Jeff Taylor, Kelly Skuce.*
*Back row (l - r): Roy Benteau, Peter Kubica, Vern Mathison, Tyler Maksymchuk, Gordon Uswak.*

# President's Message

Before getting into this month's article, I want to welcome the new members of the CWLS executive:

Roy Benteau – Vice President
Cindy Guan – Secretary
Vern Mathison – Treasurer
Kelly Skuce – Co-Publications
Greg Schlachter – Chair of Committees

And thank the outgoing executives that did a fantastic job all last year:
Gary Drebit – outgoing Treasurer
John Nieto – outgoing Past President
Michael Stadynk – outgoing Membership Chair
Ben Urlwin – outgoing Co-Publications
Dave Ypma – outgoing Secretary

## Boiled Frogs

Have you heard the Boiled Frogs analogy to today's workforce? Maybe. Well if you take a frog and put him in a pot of cold water, he will just sit there quite happy in the pot. Now turn on the stove, just slightly, so that the water heats up, but only very slowly. So slowly that the frog doesn't realize that the water is getting hot. As long as the water is heated very slowly, that frog will just sit there until he is well and truly boiled. If you put another frog in the water during this process, before the first frog is boiled, that second frog will leap out of that water so fast and the first frog will just sit there wondering where the second one went.

So what is the analogy? Well, the frog in the hot water represents the senior worker today, one who has endured the many affects of market forces over time. Restructuring, downsizing, change management, technology with phone and emails 24 hours a day and the expectation that you answer, and so on. This worker is the product of the time when there were many more people than there were jobs. He has adapted. The water that this worker is in has slowly become much hotter over time. The second frog is the newcomer to the workplace. He has an unbiased view and can see the first frog sitting, quite happily, in the hot water. Do you think the second frog will jump in? Probably not. Today, there are more available jobs than skilled workers.

This is what the oil patch is facing today:

- a shortage of skilled workers or an impending shortage
- a missing generation (1986-1999) when the oil prices were very low, there was not much hiring, universities cut back programs, companies reduced spending
- full of frogs in hot water

Many companies are better able to cope with the impending labor shortage, however the oil patch, and particularly their service companies, have a real boom & bust reputation. This has caused universities to reduce courses and caused students to consider other careers. It is becoming a competitive market for labor.

This labor shortage is only forecast to continue and will get worse:

- fertility rates are declining throughout the world and Canada's, at 1.5, is well below the replacement value of 2.2 [the average number of children women aged 15 to 49 will have in their lifetime]
- couples are working longer before starting a family
- people are staying in school and at home longer before getting married
- people are retiring earlier
- immigration is not making up the difference (are highly skilled immigrants standing in line to come to Alberta?)

HR departments are already attempting to accommodate this shortage by proactively making their companies more attractive by offering a better work life balance and flexible benefits to workers; however the things that attract an employee (pay/benefits) are not the same thing that keeps them there. "You can rent their presence, but you cannot buy their passion."

*Continued on page 4…*

## President's Message ... *continued from page 3*

Senior professionals, those boiling frogs, also have a key role to play in attracting and retaining employees. These people can contribute to the job satisfaction of the younger/new employee by training and mentoring. Of course this task should not just be added to their 'regular' job but be recognized as taking time and be allowed to do so. The managers can contribute by giving them responsibility and to listen -. Who are your key people? What makes them exceptional? How are they feeling? What are their aspirations? Listening once a year at performance appraisal time is not enough.

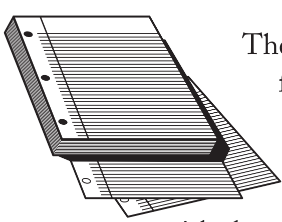
Your role is to act as an agent of change (and start with yourself). This will be a challenge but will be worth it. Keep your sense of humor for when things don't go well, laughter can heal.

"The trouble with the future is that it usually arrives before you are ready for it." Arnold Glasow

*Jeff Taylor, P.Eng.*
*CWLS President*

*Thanks to a talk by Linda Duxbury, Professor at the Carleton University School of Business, for many of the ideas in this article.*

# 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 publications co-chairs Tyler Maksymchuk (Tyler.A.Maksymchuk@conocophillips.com) at (403) 260-6248 or Kelly Skuce (Kelly.S.Skuce@conocophillips.com) at (403) 260-1931

# Editor's Note

Welcome to the CWLS InSite Magazine for 2007. This is my inaugural Editor's note for my two-year term as Publications co-Chair, so please enjoy what looks to be a wonderful year for the CWLS. I would like to welcome the new incoming executive for deciding to run for the various positions available and the entire outgoing executive. The CWLS doesn't run itself without the hard work of the executive to make everything happen. I would also like to welcome all the new and existing members and sponsors of the CWLS, without whom there would be no society. There is currently over 400 new and returning members for 2007 with a possible 200 more left to renew their memberships before April. A very healthy number of members for what was once thought of as a small niche group of professionals! A gentle reminder about this note as well that if your membership is not renewed by April your account becomes inactive and you must once again reapply. So get your memberships renewed now.

This edition of the InSite has local and global talent present in its pages. The first paper comes to us from Geophysicists Ulrich Zimmer and Shawn Maxwell of Pinnacle Technologies Calgary, Alberta explaining how hydraulic fracturing is being measured and detected with their paper Microseismic Monitoring with Borehole Tools on fiber-optic wireline. Our second paper is about determining Gas Coal Content using Mudlogging Methods by William Donovan of Donovan Brothers in Colorado. In addition to these two papers we have our Tech Corner column all the way from Riyadh, Saudi Arabia titled Why we need Well Logging and LWD by Mr. Al-Anazi. Many Thanks to Mr. Al-Anazi for his contributions in this issue and the past.

As always is the mantra of the Editor's note in the InSite, the magazine is continually looking for more papers and material to publish. If you have a short paper, new technology and or analysis method you wish to discuss or just an anecdote you wish to share with the members, please forward it to either of the two Publication co-Chairs. Contact information can be found in the magazine as well as on the CWLS website (www.cwls.org).

Without further ado please enjoy the current issue of the CWLS InSite.

*Kelly Skuce*
*Tyler Maksymchuk*

# As the Winch Turns

One of old rig sayings that seems to have disappeared is: "I wasn't scared but I passed four guys that were." Now if you have ever seen a drilling rig on fire you will realize that it is not really that funny. The urge to run can be totally understood. It is the fact that most people stop and do their jobs that seems counter intuitive. There are exceptions of course. One company man told me about taking a kick. He was standing in the manifold shack watching the pressure gauge and when he turned to give instructions, the only one behind him was his dog.

Which leads me to an obvious conclusion: that when the chips are really down only two groups can be counted on. The first are the well trained, experienced crews that have seen and done it all. Nothing will faze them, because it has happened before and most likely been worse. The second is the green, "has no idea what is going on" new guy.

The perfect example was my first job, while training, and yes the derrick was made out of steel. We were drilling south of Grande Prairie in the foothills with S and T Drilling Rig number three. It was November of 1978, a year after it had been severely damaged at Lodgepole during a blow out. The program called for air drilling as deep as possible, which meant keeping a small fire going at the end of the blooey line to burn off any gas that came to surface. When we drilled into, if my memory serves, the Bluesky we had fluid filling the flare pit and flowing back into the sump.

The company man, not the sharpest knife in the drawer, immediately took stock and announced that it had to be salt water because the fire was out. But since we could smell gas he thought it best to fire a flare through the gas to burn it off. The only flare we had was a little spring pencil flare gun. It would perhaps reach 30 feet on a really good day, and lots of luck, with a strong tail wind. His first shot flew out and bounced on the ground well short, so he ran closer and fired again. The second shot was still too short so he moved really close. I was standing back beside my shack trying to figure out what was going on when he fired his third shot. It seemed to only go about 10 feet when there was a big whomp that blew him flat and every thing was on fire.

I still was not worried. After all they might do this every other day just for fun; although it seemed to be a rather noisy way to restart the fire. What he had taken to be salt water was really condensate. The flare pit, the back side of the lease and the sump were all on fire. There was a mad scramble to get water on the back side of the rig to keep it from catching fire. I was starting to figure out that maybe this wasn't standard operating procedure when I saw the tool pusher headed for the mud tanks at a dead run. Even though he was in rubber boots his pace was impressive.

If it happened today I would probably stand my ground, but there is no way I would be as unconcerned. Although that day I really started to wonder when I heard the tool pusher say, "Oh Please Mommy, not again" as he rushed by.

*Dave*

# Correction Notice:

Please be advised that at the request of the authors of the paper entitled "Petrophysical Analysis in Reservoir Characterization" March 2006 InSite we have added a third author to this publication.

His name is Dr. Eladj Said and his bio and updated photo can be found in the issue at the website link. www.cwls.org/docs/insite/insite_2006_03.pdf

# Outgoing President's Message

As the new CWLS Past-President, this will be my last message in our InSite.

It was a pleasure and a privilege to be the president of the society for the past year. I am very pleased with the achievements of our executive. Our society is in great financial position mainly due to a highly successful joint symposium that brought us substantial revenue. We had great attendance at our monthly lunch meetings which speaks of the quality of our speakers and their presentations. We have made improvements to the website functionality and we formalized student award funding. Individual and corporate memberships were reviewed and updated. We have also reviewed and modified the bylaws of our society to better reflect present needs and circumstances. My thanks go to the members of the past executive for their contributions.

I would like to take this opportunity to thank Jeff Taylor (our past VP) for organizing a very successful AGM on February 13th at the Calgary Zoo. This was a refreshing change for the venue, and highly fitting with the presentation by Brian Keating. In spite of a very cold evening we had over 160 attendees. Additional thanks to David Ypma (past secretary) for organizing the printing of programs, reports and sponsor recognition.

The AGM business meeting proceeded smoothly and efficiently. It was my pleasure to present Distinguished Service Awards to Taras Dziuba and Case Struyk. Both are long time members who made major contributions to our society. Hugh Reid became our new honorary member, recognizing his contributions to our society as well as his role in advancement of the science of well testing. The President's Award for the best technical lunch presentation of the year was awarded to Laurie Bellman for her talk on Oilsands Reservoir Characterization. I was pleased to be able to announce that our bylaw revisions were approved by the society members. This update was long overdue and the executive worked hard to review the proposals and meet the deadline for the vote. I would like to thank David Greenwood for leading the revisions committee. Our business meeting also included a vote on the motion to establish a Students Award Foundation with a starting capital of $100,000. I was very pleased that this motion was approved. The Student Awards Foundation will become a Trust Fund to finance future student awards.

My thanks also go to the past President John Nieto for organizing the election ballot.

Congratulations to our new executive, and also thanks to all those society members who were in the running but did not get elected. Please, run again next year, I will be looking for the candidates!

After the conclusion of the AGM business we all had a delicious dinner, and a very interesting and entertaining presentation by Brian Keating. His talk and his short visual clips from the zoo and from his trips were outstanding.

Our new President Jeff Taylor needs little introducing. He was the CWLS VP for the last year, responsible for organizing our monthly lunch meeting. He is a long time society member and presently Manager of Formation Evaluation at Nexen.

I congratulate Jeff and his newly elected executive and wish them all the best in 2007.

*Yours Peter Kubica*
*CWLS Past President*

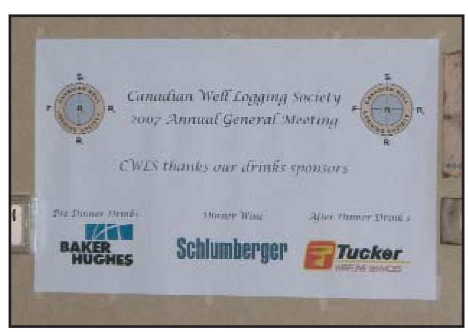
*2007 CWLS AGM Attendees. Photo courtesy of Tyler Maksymchuk*

*Keynote speaker Brian Keating.
Photo courtesy of Tyler Maksymchuk*

# 2007 CWLS AGM

*2007 President's Award recipient –
Laurie Weston Bellman.
Photo courtesy of Tyler Maksymchuk*

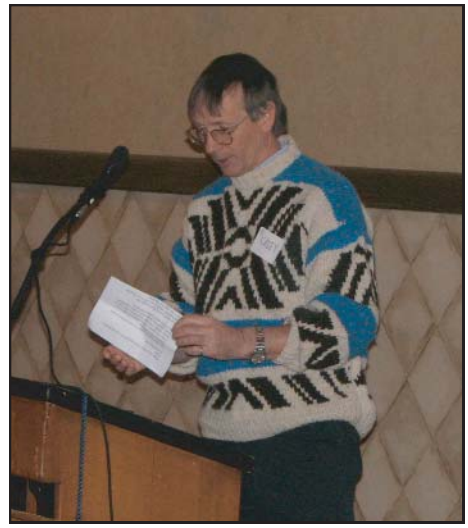
*Buffet Table.
Photo courtesy of Tyler Maksymchuk*




*Drink Sponsors.
Photo courtesy of
Tyler Maksymchuk*

*Honourary member award recipient Hugh Reid. Photo courtesy of Tyler Maksymchuk*

*Past President Peter Kubica commencing 2007 CWLS AGM. Photo courtesy of Tyler Maksymchuk*



*Distinguished service award recipient Casey Struyk. Photo courtesy of Tyler Maksymchuk*

*Distinguished service award recipient Taras Dziuba. Photo courtesy of Tyler Maksymchuk*

# 2007 CWLS AGM

*Socializing prior to AGM and presentation. Photo courtesy of Tyler Maksymchuk*

*John Nieto sharing some conversation with Distinguished service award recipient Taras Dziuba. Photo courtesy of Tyler Maksymchuk*

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# New Members

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Erik Bartsch, Shell
Steve Whittaker, Canada Capital Energy Corporation
Adel Vatandoost, University of Tasmania
Sun Deming, Fugro-Jason Canada
Rochelle Mack
John Lucic, Nexen Inc
Rudi Meyer, Memorial University of Newfoundland
Lindsay Dunn, Compton Petroleum
Jordan Gao
Charles Fensky
Barbara Lane, Talisman Energy Inc
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Heather Leslie-Young, Canadian Sub-Surface Energy Services Inc.
Muhammad Khan
Ruslan Nutrobkin, Conquest Energy Services Inc.
Samantha Halbauer, Kereco Energy Ltd
Andrew Tarka

# Microseismic Monitoring with Borehole Tools on Fiber-Optic Wireline

*Ulrich Zimmer and Shawn Maxwell,*
*Pinnacle Technologies, Calgary*

Microseismic monitoring with borehole tools is now widely used in hydraulic fracturing and reservoir monitoring to determine the extent of fracture networks and stress changes. This logging method uses the elastic waves that are associated with fracture and sliding processes in the rock to locate the point of origin of these dislocations. If new fractures are created, microseismic monitoring helps to visualize the azimuth, width, height and half-length as well as inner structure of the fracture network which is important information for the optimization of the reservoir stimulation program. Microseismic monitoring provides information about a large area around a borehole and is not limited to its immediate vicinity. The coverage can be increased even more by adding additional observation wells and sensors.

## Overview

Microseismic events can be considered as tiny earthquakes caused by breaking or sliding rock. Such events are induced in the rock when the stress field is changed due to oil/gas production, fluid or steam injection etc. The harder the rock and the greater the stress changes the larger the induced microseismic event will be. In turn, soft formations or low treatment pressures create much smaller events.

The breaking or sliding of rock masses creates elastic waves in the ground that can be picked up by geophones. Using recordings on multiple geophones the three-dimensional location of the event can be calculated. Due to the small size of the signal it is preferable to have the geophones in close proximity to the original event location which usually requires the geophones to be installed in boreholes. Although in theory it is possible to locate a microseismic event using a single 3-component geophone, natural noise and borehole effects make it necessary to deploy an array of geophones. More geophones also mean redundancy and a broader statistical base when calculating the location of the microseismic event.

## Data Acquisition

As a company standard, a toolstring comprised of 12, 3-component geophone tools with a tool spacing of approximately 10 m is used. However, the tool spacing can be varied depending on the specific target of the monitoring. The microseismic tools can be installed in boreholes with an inner diameter between 3.75 in. and 12 in.. The geophone signal is typically sampled at a frequency of 4 kHz. Since these borehole tools are operated on a fibreoptic wireline, the number of tools can be increased up to 24 without any decrease in the sampling frequency. This is a configuration which is currently well beyond any conventional wireline tool. Toolstrings of many more tools are possible when decreasing the sampling frequency accordingly. This is a configuration that is used for VSP data acquisition.

The toolstring is assembled by lowering a tool just into the wellbore, connecting the tool to a rigid or flexible spacer, lowering the spacer just into the wellbore and connecting the next tool. In this way a toolstring of more than a 100 m in length can be assembled quite easily. Once the toolstring is completely assembled it is lowered down to the reservoir formation. At target depth each tool is clamped mechanically to the borehole walls. Although it is possible to use these tools in open holes, it is preferable to work in cased holes to ensure good elastic coupling and easy retrievability of the toolstring.

Usually the microeismic toolstring is installed in a vertical (or nearly vertical) offset well. Although a little bit more elaborate in installation, processing and interpretation, the microseismic tools can also can be installed in horizontal boreholes using a tractor system. In some settings this option might be the preferable installation to get the tools close enough to the area of interest. For an event to be detected, its signal has to be larger than the ambient noise. The further away an event occurs the larger it has to be to be detected at the observation well. To increase the covered area a second toolstring can be installed, e.g. in a long horizontal well. Events which are recorded on both toolstrings can also be located with a higher accuracy than events recorded only on a single toolstring. Although a single or dual array (i.e. 1 or 2 observation wells) is sufficient for most hydraulic fracture settings, large scale reservoir monitoring usually requires additional observation wells and toolstrings. In theory there is no specific limit to the maximum number of tools in such an array. But practical concerns like data transfer and processing times introduce certain limitations.

If no suitable offset well for the installation of the microseismic tools is available, the tools can also be installed in the treatment well itself as long as the fracture treatment does not use any abrasive proppants which would damage the wireline. For this acquisition geometry the fluid movements during the treatment mask the signals from the microseismic events com-

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## Microseismic Monitoring … *continued from page 12*

pletely. Only during the shut-in or flow-back phase is the surrounding sufficiently quiet to allow the recording of the microseismic events.

The latest development is the combination of microseismic sensors and tiltmeter tools in a single "Hybrid" borehole toolstring. Tiltmeters can be installed as borehole tools or as 'surface' tools in very shallow boreholes. They measure directly the deformation caused by stress changes in the monitored area. The interpretation of the results requires little additional information which produces very stable results. Since microseismic and tiltmeter sensors record different signals from the same fracture network, they can complement each other and provide an even better picture of the fracture than each method by itself.

The maximum distance for a detectable microseismic event, i.e. area of microseismic coverage, depends predominantly on the ambient noise level, the size of the event and the attenuation of the rock. In northern Alberta typical maximum viewing distances are around 800 m. In the Barnett shale, Texas, where the treatment pressure is higher and consequently the events are larger, viewing distances of close to 2 km have been achieved. Elevated ambient noise is often a limiting factor. Sometimes this is a problem when the fracture treatment equipment and the microseismic tools operate from the same pad.

### Data Processing

Once the tools are clamped in, their orientation has to be determined. Usually, this is done by setting off a perforation shot or stringshot at a known location in a nearby borehole. From the recorded signal the absolute orientation of the microseismic tools can be calculated. After the tool orientation is determined the system is ready for data acquisition and real-time analysis of the incoming signals. If the project does not require real-time analysis the tool orientation can also be determined after the treatment but before the toolstring is moved.

In addition to tool orientation, the perforation shots or stringshots serve the additional purpose of calibrating the velocity model. To translate the measured traveltime differences at the tools into spatial coordinates it is necessary to provide a compressional (p-) and shear (s-) wave velocity model for the area between the tools and the event location. Often it is not adequate to just assume constant velocities (i.e. constant P-wave velocity and constant S-wave velocity) in the area of interest. If the area is not too big and the geology not too complicated, then it is often sufficient to use a 2 dimensional velocity (model with dipping layers if necessary). Log information is essential for setting up the initial velocity model. A Gamma-ray log helps to determine the layer tops. A sonic- and shear wave log is very helpful in determining formation velocities even if it is from a wellbore in the general vicinity.

Once the basic velocity model is set up from logs or any other additional information, the velocities are fine tuned using the location of the perforation shots as guidelines. Since the locations of the perforation shots are known, their corresponding microseismic events have to locate close to that known location. Within the margins of uncertainty the velocity model is changed putting the perfshot events close to their known location. Strictly, this calibration of the velocity model is only valid in the vicinity of the calibration events.

During the data acquisition the event locations can be plotted almost in real time. The analysis can be done either on site or more often now via satellite transmission from the site using any high-speed internet connection. Depending on the number of microseismic events, the real-time results might have fewer events on the map than the final results. But these results can still help to provide a first impression of the created fracture

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## Microseismic Monitoring *… continued from page 13*

network. This is of special importance when critical geological features like water-bearing formations, faults, etc. have to be avoided by the fracture network. The real-time results indicate when the fracture network comes close to these features and the appropriate changes in the pumping schedule can be made.

An important tool to avoid errors in the interpretation of the microseismic event distribution is the quality control (QC) report. This document contains numerous figures showing for each event location error margins, signal/noise levels, location confidence, traveltime residuals, hodogram residuals, velocity model sensitivity, event magnitudes etc. Since the accuracy of the event locations can vary, it is important to base the interpretation only on events with acceptable location confidence. From the standard event map this is not directly obvious as all event locations are treated equally. Besides other advantages, the QC-report is an important tool to avoid interpretations based on low confidence event locations.

### Example 1: Hydraulic Fracturing, Alberta, Canada

The first example shows the monitoring results from two openhole hydraulic fracture treatments in Alberta. Both treatments were monitored from the same observation well. The two treatment wells were close to each other with no significant change in geology between the two wells. More than 150 events were recorded in each of the treatments but their distribution is rather different.

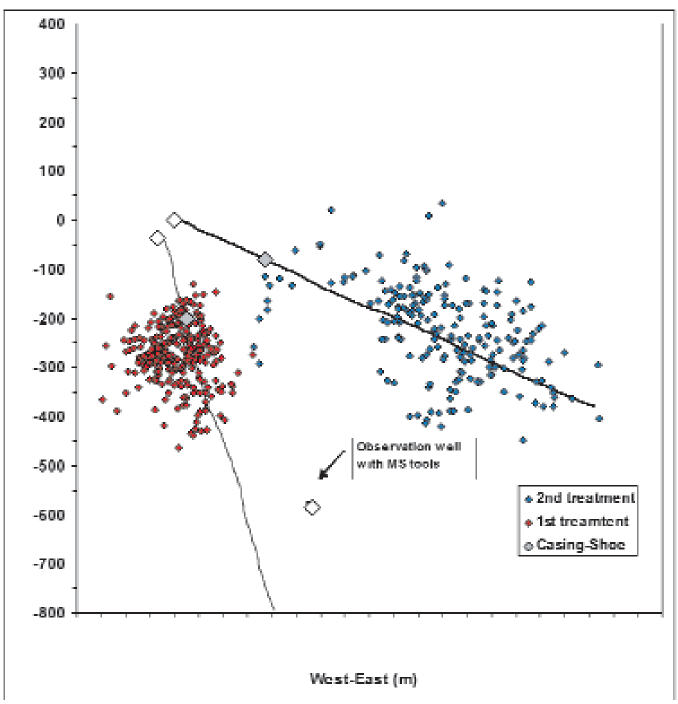



*Figure 1: Microseismic monitoring results from two hydraulic fracture treatments in northern Alberta, Canada.*

The first treatment resulted in a fairly small event cloud starting at the casing shoe and covering only 250 m of the 700 m long open hole trajectory. These results clearly suggest that only a small part of the trajectory was stimulated. Based on these results the fracture design was changed for the second treatment a few weeks later.

The results from the 2nd treatment show a much more spread out event cloud along the horizontal wellbore trajectory. Even in this case it appears that the majority of events focus in a certain area along the wellbore. But in contrast to the 1st treatment additional events prove the extension of the fracture network almost over the entire length of the wellbore. In addition, production data from both wells proved a much more effective stimulation in the 2nd treatment.

Considering the costs of drilling long horizontal wells it is certainly desirable to maximize the drainage area for each of the wellbores. These examples show how microseismic monitoring can effectively be employed to determine and improve the fracture design and optimize the drainage pattern.

### Example 2: Reservoir Monitoring, Heavy Oil Example

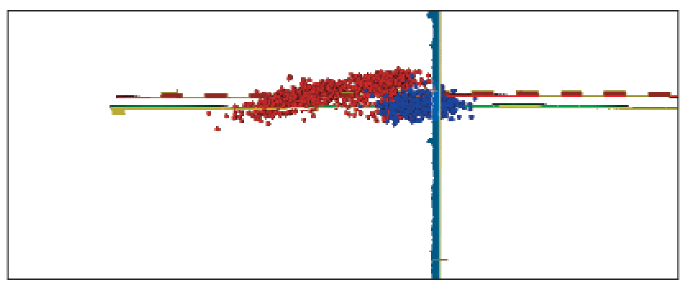


*Figure 2: Cross-section view of microseismic activity recorded during initial steam injection of a SAGD well pair.*

The second example is from a 6 week long monitoring of a SAGD well pair. During this time numerous microseismic events were recorded and located. Compared to the average event from a hydraulic fracture treatment the events in this reservoir monitoring case were generally much smaller. Due to the small event signal the viewing distance from the single observation well covered only a part of monitored well pair.

*Continued on page 15…*

## Microseismic Monitoring *... continued from page 14*

Even with the limited range of coverage the events could be grouped into two distinct clusters. The first cluster (red symbols in Figure 2) is believed to be related to fracture movement in the reservoir from the steam injection, while the second cluster (blue events in Figure 2) may be associated with casing deformation as suggested by the wave radiation pattern. Although in this case the target formation is comparably soft and the induced stress changes due to the steam injection are rather low, a large number of microseismic events were created revealing significant stress changes within the reservoir.

### Summary

Microseismic Monitoring has seen a rapid increase in applications for the oil and gas industry in recent years. Although this method has limitations, most notably its viewing distance in the presence of ambient noise, it has been successfully applied to many different geometries. New tools for use in horizontal and treatment wells are becoming available now which will increase the installation options considerably. In its basic version the results, i.e. dots on the map, appear easy to understand and interpret. But since each microseismic 'dot' is individually processed it is important to check different quality control (QC) parameters to avoid a wrong interpretation of the event cloud.

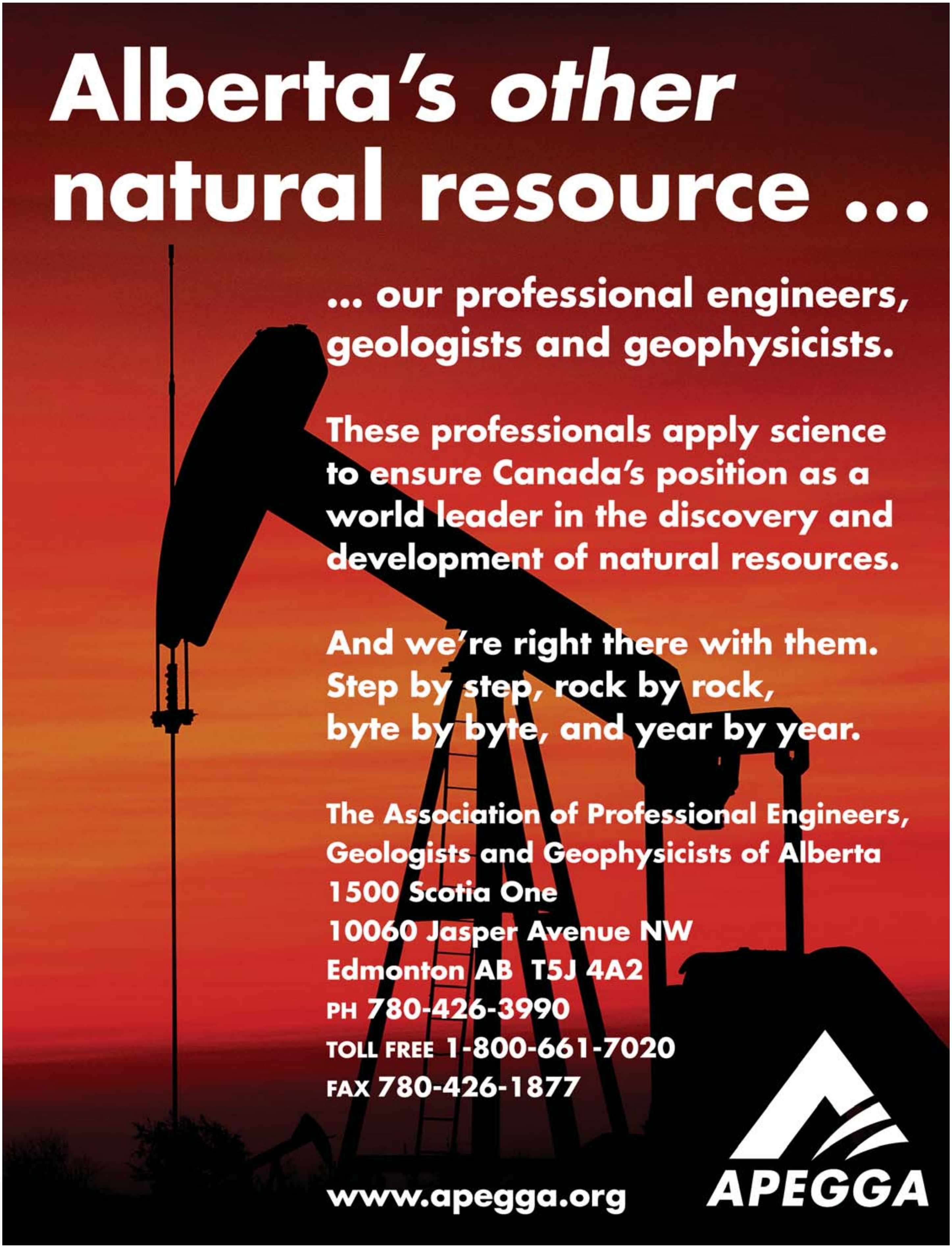
Future developments will see improvements in the combination of microseismic monitoring with other methods (e.g. tiltmeter mapping), as well as an increased emphasize on the remote operation and processing of any site through satellite communication.

### About the Authors

**Ulrich Zimmer** is a Senior Geophysicist at Pinnacle Technologies, and is based in Pinnacle's Calgary office. Ulrich's responsibilities include Acquisition, processing and interpretation of microseismic data for hydraulic fracture treatments and reservoir monitoring as well as development of quality control tools. Ulrich has spent the last eleven years between Germany and Western Canada working and completing his education. He enjoys skiing, climbing, sea kayaking, traveling, Western Canadian history, and lost goldmine stories.

**Shawn Maxwell** is Chief Geophysicist of Pinnacle Technologies, and is based in Pinnacle's Calgary office. Shawn's responsibilities include technical direction of Pinnacle's microseismic monitoring services for hydraulic fracture diagnostics and reservoir monitoring. Shawn has over 20 years experience in a broad range of microseismic monitoring applications, including mapping hydraulic fractures, fracture networks, steam floods, gas floods, water floods, casing failures, reservoir compaction, gas storage and sequestration, excavation damage around underground tunnels, and mining induced seismicity and rockbursts. Shawn has been active in projects throughout North America, Europe, Africa, and the Middle East. Shawn's expertise includes velocity tomography of active and passive seismicity, seismic raytracing, synthetic seismograms, source characterization, data acquisition, processing and interpretation. Prior to joining Pinnacle, Shawn spearheaded ESG's entry into the oil and gas industry, after serving as a Lecturer in Applied Seismology at Keele University. Shawn has authored numerous publications in journals and professional abstracts.

*Winter drilling operations in the Gold Creek Area, Alberta, Canada. Photo courtesy of Robert Bercha*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# SASKATCHEWAN INDUSTRY AND RESOURCES NEW ELECTRONIC SUBMISSION REQUIREMENTS FOR WELL LOGS

**Effective April 1, 2007**, *The Oil and Gas Conservation Regulations, 1985* will be changed to require submission of all geophysical well logs in electronic format (both LAS and TIFF). During a six month period (April 1 to October 31, 2007), Saskatchewan Industry and Resources (SIR) will require the submission of one hardcopy of each log, in addition to copies of the electronic format logs (as outlined below), for each different log run on a well.

**The Operator will be required to submit to SIR:**

- One LAS copy of all logs run

  **and**
- One TIFF copy of all logs run

  **or**
- Three (3) paper copies of all logs run (if not producible in either LAS or TIFF format)

Exceptions to the above:

- Three (3) copies of Directional Surveys shall be submitted in paper format.
- Three (3) copies of Geological Strip logs shall be submitted in paper format.

**Electronic Log Submission Standards:**

- LAS format means LAS (ver. 2) format; and
- TIFF format means in accordance with the Canadian Well Logging Society standards as proposed September 28, 2004.
- These standards will be reviewed and, if required, updated from time to time, as necessary.

**Key Points:**

- All other well data (e.g., forms, reports, analyses, survey plans, licences) shall continue to be submitted in paper format.
- The log files can be submitted on CD or DVD.
- The logs will be marked "received and approved" only when SIR personnel have viewed and verified that all required logs have been submitted in acceptable formats and are not corrupt in any way.
- As with all submitted well data, the logs must be labeled with the official well name, location and licence number (Sec. 89.2 of the *The Oil and Gas Conservation Regulations, 1985*).

**For further information or questions, contact R. Troyer by phone: (306) 787-2562 or e-mail: btroyer@ir.gov.sk.ca**

Saskatchewan Industry and Resources

# Determining Coal Gas Content Using Mudlogging Methods

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## Abstract

Mudlogs offer a method of determining the gas content in coals (SCF/TON). This paper will discuss the following: 1) the theory used to support measuring a coal's gas content by mudlogging methods; 2) the methodology and equipment used to determine gas content of coals drilled with mud or air; 3) examples, results compared to canister desorption and computations used determine a coal's gas content, and 4) the sources of error and the degree of uncertainty in the measurements.

Coal whole core desorption data indicates a preponderance of gas will desorb from coal drill cuttings as they are drilled and circulated to the surface. Calculations to determine drill cutting size and desorption times required to desorb small drill cuttings will be presented.

How to determine the amount of coal gas freed using mudlog data will be presented. Two methods to determine mudlog response to gas from coal will be reviewed. The advantages and disadvantages of both techniques will be discussed

Examples of air drilled and mud drilled mudlog gas content data will be compared to canister desorption data. An analysis of the sources of error and the common pitfalls of determining gas content from mudlogs will be discussed.

## Theory

Whole core desorption is the currently accepted procedure for determining the gas content of coals. Whole core desorption has certain limitations. Some of these limitations are: the coring operation is expensive and time consuming, the coring operation often fails to cut the target coal or the coal cut is not recovered, and gas content calculations are uncertain. Determination of "lost gas" in whole core desorption measurements illustrates the uncertainty in calculating a coal's gas content by whole desorption methods. The determination of "lost gas", that is the amount of gas which escapes prior to the controlled measurement of the gas at the surface must be estimated to determine total gas content. Three different methodologies are used to determine the "lost gas" volume. These methods are the Direct Method[1], Smith and Williams Method[2] and the Amoco Method[3]. The degree of uncertainty of whole core desorption is considerable as indicated by the following: "For GRI cooperative research wells, the Smith and Williams total gas content estimates average 27.3% less than the Direct Method"[4] and "For GRI cooperative research wells, we found that the Amoco Method total gas content estimates averaged 21% greater than the Direct Method"[5]. Other factors such as timing of the start of desorption, the temperature variation while desorption occurs and the pressure profile of desorption also add to the uncertainty of the procedure. Other methods of estimating the gas content in coal are even less reliable than whole core gas desorption, therefore whole core gas desorption is still the benchmark by which other methods are judged.

The rationale for using mudlogging techniques to determine a coal's gas content is derived directly from desorption theory. Drill cuttings can be viewed as very very small whole cores. The maximum height of the drill cuttings can be determined by knowing a drill bit's cutting configuration, its rotational speed and its penetration rate. The time it takes to desorb gas from a cylindrical whole core is determined by desorption data and an analogous process occurs when drill cuttings desorb gas. It will be demonstrated that due to the small size of the drill cuttings that much of the gas in the drill cuttings is desorbed and liberated while being circulated out of the hole and passing through the gas trap.

For methane to desorb from a coal it must leave the sorbed site and travel to a permeable boundary. For drill cuttings the permeable boundary is the drill cutting's surface, for whole cores the permeable boundary is the core's surface and for a well the permeable boundary is the cavitation chamber, a natural fracture, a propped fracture and/or a wellbore. The height of coal drill cuttings can be determined. Height of a coal drill cutting is the vertical distance between successive drill bit cutter contacts. The length and width of the drill cuttings are not known, but most likely are less than the drill cutting's height. One dimension of the drill cuttings is known, if the time to desorb per distance can be estimated, then the time to desorb a drill cutting can be determined. Knowing three factors; the penetration rate, bit rotation and the number of cutters can be used to determine the height of a drill cutting. The following formula determines drill cutting height.

*Continued on page 20…*

## Determining Coal Gas Content *… continued from page 19*

(1)CH = 12.0 /(PR * ROT * CUT)
CH = drill cutting height (inches)
PR = penetration rate (minutes per foot)
ROT = bit rotation (revolutions per minute)
CUT = number of cutters impinging per revolution (cutters per revolution)

For example, from the following data:
PR = 0.5 min per foot
ROT = 80 revolutions per minute
CUT = 3 cutters per revolution

A drill cutting height of 0.10 inches is calculated (CH = 0.10 inches) Note the bit rotation is the kelly rotation for conventional drilling. Adjustments to the kelly rotational speed must be made if a mud motor is being used to drill. Also note the most common bit used to drill coal wells is a tri-cone bit. Each cone impinges on the bottom of the hole once per revolution, that is 3 cutters per revolution. PDC bits and "fish tail" bits have different cutter configurations and therefore different cutters per revolution. This simple formula is a first order estimation of the process. Verification by sieve analysis indicated that about 80% of drill cuttings are less than 0.04 inches in diameter, which is considerably smaller than the drill cutting height calculated.[6,7]. Both papers indicated that about 80% of drill cuttings are less than 0.04 inches in diameter, which is considerably smaller than the drill cutting height calculated.

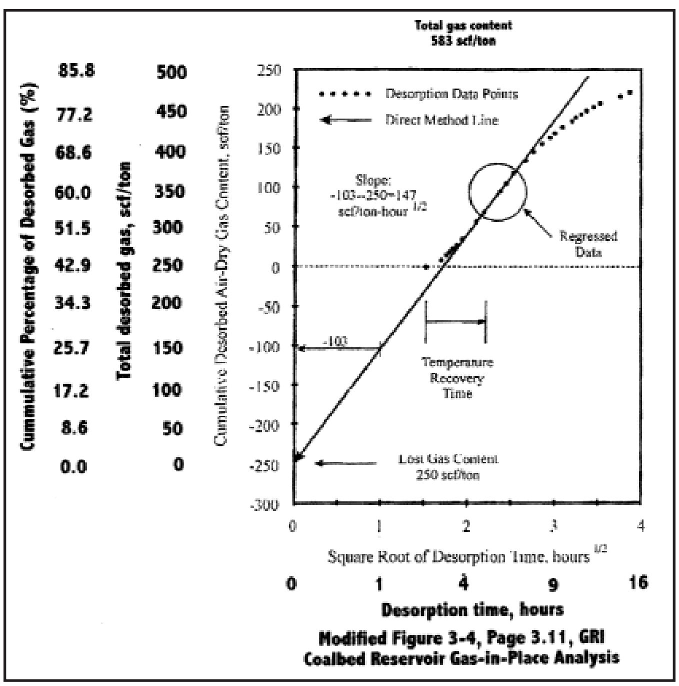


*Figure 1: Cumulative Desorbed Air-Dry Gas Content vs. Square Root of Desorption.*

Corrections can be made for "bit bounce", "torque", "bit whirl", "jetting" and "overpressure sprawling".

For the mudlogging coal gas content technique to be valid it must be demonstrated that the coal drill cuttings can be desorbed before they are sampled at the gas trap. Any desorption data that is representative of the coal in the area can be used to determine the desorption rate. It is assumed that drill cuttings are essentially small whole cores that are desorbing like actual whole cores. Two examples of whole core desorption are presented. The desorption data presented here is from the GRI Report Number GRI-97/0263 "Coalbed Reservoir Gas-in Place Analysis" by M. Mavor and C. Nelson. Desorption data is often analyzed in graphical form. A plot of time or the square root of time is on the x-axis, while cumulative desorbed gas is presented on the y-axis. Figure 1 is a modified version of a standard presentation. Gas content is presented as total cumulative gas content and zero time presented is the time at which the desorption starts. It was assumed desorption starts when the reservoir pressure equaled the drilling mud's hydrostatic pressure. It can be seen that coals typically start to desorb gas rapidly and then reach an asymptote. In this example the core desorbed 250 SCF/TON in the first 2 hours and only desorbed 150 SCF/TON in the next 5 hours. Of the total 583 SCF/TON desorbed 80% desorbed in the first sixteen hours. Figure 2 presents the same data as Figure 1 on a linear time scale.

This data is from a 1 foot long, 4 inch diameter core of the Fruitland Coal in La Plata County, Colorado. The purpose of reviewing desorption data is to determine desorption velocity. That is the speed at which desorbed gas travels to the surface

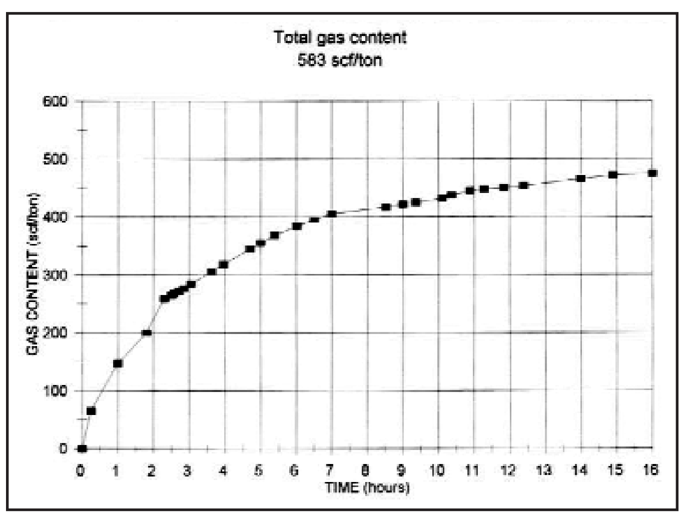


*Figure 2: Gas Content vs. Time.*

*Continued on page 21…*

## Determining Coal Gas Content *… continued from page 20*

of the core. Desorption is a concentration driven mechanism, not a pressure driven mechanism so the direct comparison of desorption to flow is not rigorous. However dropping the pressure in coals does cause gas to flow regardless of the theoretical mechanism that causes this flow. For purposes of calculation the 16 hour desorption data is used. In sixteen hours 470 SCF/TON was desorbed or about 80 percent of the 583 SCF/TON were desorbed. It took about three months to desorb all the gas from the core. If it is assumed that desorption rate is directly proportional to the length of travel, then for 80% of the gas content of a 0.1 inch diameter drill cutting takes about 24 minutes. The radius of a 4 inch diameter core is 40 times larger than the radius of a 0.1 inch diameter drill cutting, therefore it takes a drill cutting 40 times less than 16 hours for a core to desorb. 1/40 of 16 hours is 0.4 hours or 24 minutes.

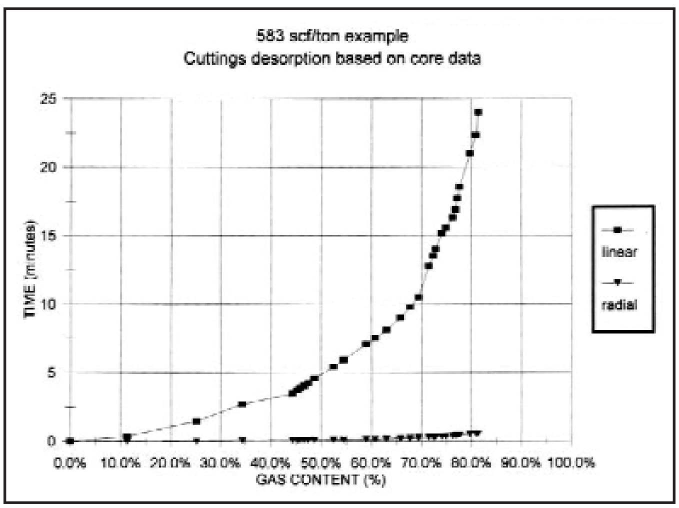


*Figure 3: Time vs. Gas Content.*

Diffusivity and sorbtion theory, not desorption theory indicates the rate of gas sorbtion is a function of the radii squared. If this were the case, it would take 1600 time longer to desorb a 2.00 inch radii whole core than a 0.05 inch radii drill cutting. If this is correct then a coal drill cutting should desorb in less than a minute. A plot of the time to desorb using both the linear and square of the radius are presented in figure 3. Figure 3 data is based upon the 583 SCF/TON core data.

Figures 4, 5 and 6 present a similar analyses of whole core desorption data for a sample with gas content of 229 SCF/TON. The desorption is slightly slower in this case. Again linear drill cuttings desorption is considerably slower than radial drill cuttings desorption theory suggests. Also enclosed, as figure 7 is a full-scale graphical presentation of the whole core diameter and a drill cutting diameter for reference.

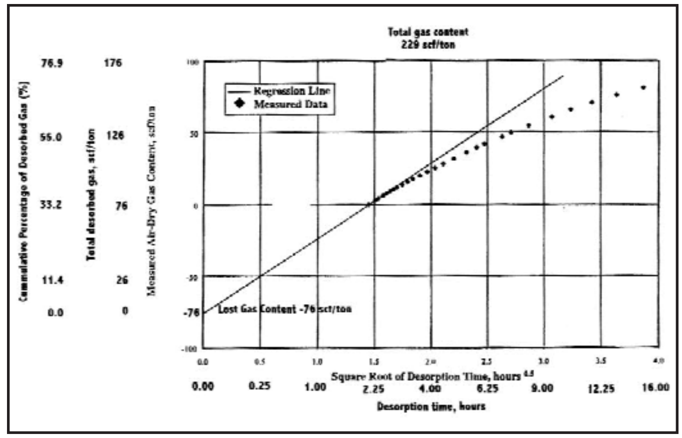


*Figure 4: Measured Air-Dry Gas Content vs. Square Root of Desorption.*

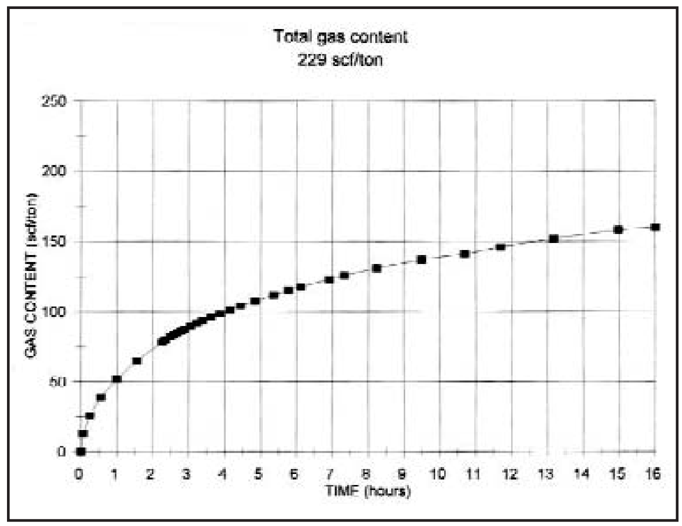


*Figure 5: Gas Content vs. Time.*

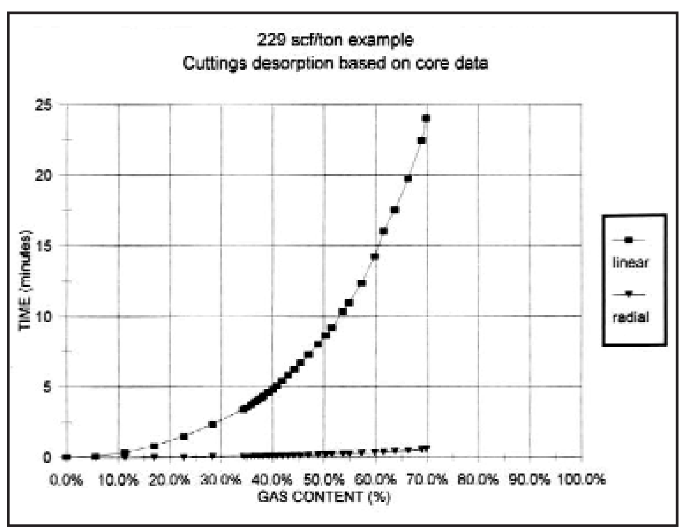


*Figure 6: Time vs. Gas Content*

*Continued on page 22…*

## Determining Coal Gas Content *… continued from page 21*

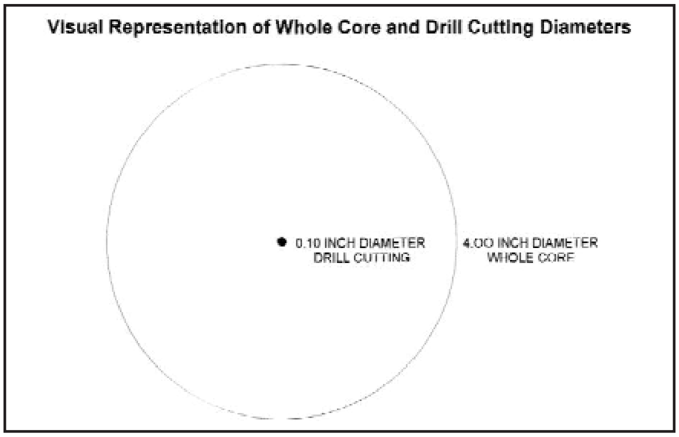


*Figure 7: Comparison of Whole core dimension vs. Drill Cutting Diameters.*

Most likely core desorption over the distances pertinent to this discussion are more linear than radial. The linear relationship is also the slowest and therefore gives the longest desorption times. Therefore the times presented to desorb 70% to 80% of the drill cuttings gas is about 20 minutes. To desorb 50% of a drill cutting's gas takes about 6 minutes. If rig pump circulation rates are typically 1 minute to 2 minutes per hundred feet and coals are encountered between 1,000 to 2,000 feet then the time to desorb is about 10 to 40 minutes. If the drill cuttings are smaller due to naturally fracturing, lack of cohesion, water sensitivity, water solubility or abrasion with the drill pipe and annulus then more gas from the drill cutting would be desorbed in the time frame of interest. Data from published drill cutting analysis indicates drill cuttings are indeed smaller than the calculated height presented here. Finally the mudlogging gas trap shears the drill cuttings and creates a partial vacuum which hastens desorption to some extent. From experience, little correction of mudlog gas content data is required for partial desorption due to drill cutting size, except in extreme cases. Good agreement exists between whole core gas and mudlogging gas content data.

## Methodology

The above discussion presents the theoretical foundation for determining gas content from mudlogs. To reiterate, drill cuttings are sufficiently small to desorb about 80% of their gas content in the time required to circulate them to the surface. Other factors, such as smaller drill cutting height hasten the desorption process. To calculate a coal's gas content the weight of the coal in tons and the gas in the coal in standard cubic feet must be determined. To determine a coal's gas content the volume and weight of coal drilled per minute and the amount of gas liberated per minute from that volume must be determined. The next paragraph discusses how the denominator (TONS) is determined and following paragraph discusses how the numerator (SCF) is determined.

The volume of coal drilled per minute is assumed to be one foot of hole drilled multiplied by the area of the bit's face divided by the penetration rate. The weight in tons of that volume is determined by using the density of the coal. The density of coal can be estimated by density logs, core or drill cutting density determination or by using density from analogous coals.

The amount of gas is determined by relating the size of the mudlogging show to standard cubic feet of methane gas (SCF). First the mudlogging unit's response to both methane and acetylene over a wide range of gas concentrations must be carefully determined. Second, the use of Gas Referencing© [8] or calibration by carbide lagging is necessary to relate the size of the methane gas show in units to SCF. If calcium carbide is used to generate acetylene gas the amount of calcium carbide per units of acetylene must be determined. Prior and after coals are drilled carbide lags are performed to determine the gas traps response to acetylene and methane. Gas Referencing© continuously injects a known volume of acetylene into the mud pumps and can be considered a continuous carbide lag. Now a functional relationship exists between the mudlogging unit and gas trap response to acetylene and methane. If a coal is drilled and methane gas is liberated then the amount of gas liberated can be calculated in SCF per minute. Typically, 1% methane in air is 100 units or 10,000 ppm's, however a unit of gas should be defined.

Both the weight of the coal and the amount of gas liberated per volume of coal drilled are known, therefore gas content in SCF/TON can be determined. Note only combustible gases, typically methane, are measured. Mudlogging units do typically not measure carbon dioxide, nitrogen, hydrogen sulfide and other non-combustible gases. If these gases are measured they can be added to the combustible gas content of the coal. Whole core desorption measures all gases desorbed, mudlog desorption typically only measures combustible gas desorbed. If poor agreement exists between the two methods a gas analysis of desorbed whole core gas is recommended. Also, it is extremely important to have a properly functioning gas trap, consistent and multiple carbide lag information, and well calibrated instrumentation. A typical mudlogging service does not provide the instrumentation or quality control needed for the computations outlined.

*Continued on page 23…*

## Determining Coal Gas Content *… continued from page 22*

In air drilled wells carbide lagging is impractical and not necessary to determine SCF. The compressor volume must be accurately known to determine a dilution factor. After the dilution factor is determined the computations for air and mud drilled holes are the same.

1119/98 21:02 WSD
ABRIDGED FORM

**WELL DATA**

OPERATOR:
WELL NAME: EXAMPLE
LOCATION:
COUNTY:
STATE WYOMING
DATE:

**INSTRUMENT CALIBRATION DATA**

| GAS | KNOWN % GAS IN AIR | RESPONSE IN UNITS |
|---|---|---|
| CH4 | 2.5 | 250 |
| C2H4 | 1.15 | 230 |

**CARBIDE LAG DATA**

| LAG NUMBER | DEPTH (FEET) | SHOW (UNITS) | MW (#/GAL) | VIS (MARSH) | CARBIDE AMOUNT | ENTER UNITS (CUPS OR OZ OR GMS) |
|---|---|---|---|---|---|---|
| 1 | 1,202 | 45 | 9.5 | 42 | 4.00 | OZ |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |

| LAG NUMBER | OZ | CUPS | GMS | SHOW UNITS | SCF C2H4/ UNIT | SCF CH4/ UNIT |
|---|---|---|---|---|---|---|
| 1 | 4.00 | 0.45 | 113 | 45 | 0.02556 | 0.05111 |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |

**CONSTANTS AND CONVERSION FACTORS**

BIT DIAMETER = 17.500 INCHES
HOLE AREA = 1.6703 SQUARE FEET
1 CUP = 250 GRAMS = 8.8183 OZ
18 OZ CARB = 4.8 SCF C2H4
SCF CH4/UNIT USED = 0.05111

**SHOW DATA AND YIELD CALCULATIONS**

| COAL (SCF/TON) | DEPTH (FEET) | DRILLING RATE (MIN/FT) | TOTAL GAS (UNITS/MIN) | COAL DENSITY (GMS/CC) | COAL DENSITY (TONS/FT^3) | DRILLED (TONS/MIN) | DRILLED (SCF/MIN) | YIELD |
|---|---|---|---|---|---|---|---|---|
| 1 | 1,348 | 2.500 | 300 | 1.700 | 0.05308 | 0.03545 | 15.333 | 432 |

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coal yield mud xls

*Figure 8: Example from well in Wyoming.*

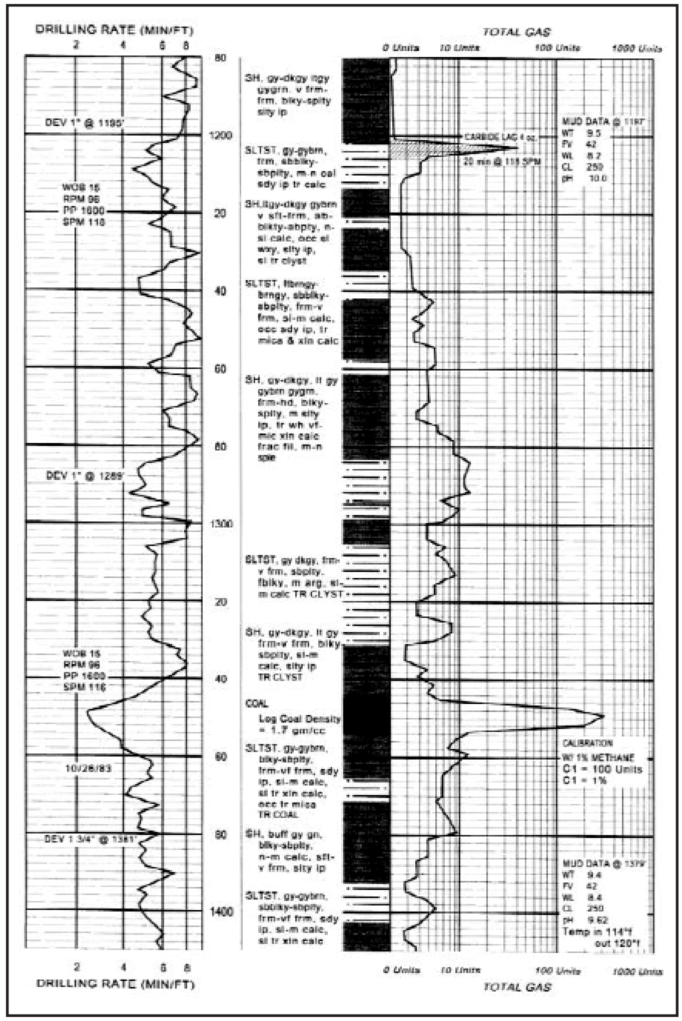


*Figure 9: Striplog and mudlog from well in Wyoming.*

## Example and Computations

The following example and calculations are from a well in Wyoming. Whole core canister desorption data is available from a well in this area. All data presented here is from public sources, appears to be reasonable and is assumed to be correct.

Figure 8 is an abridged worksheet outlining the computational method used to determine a coal's gas content. Figure 9 is the mudlog, which is the basis of the computations. Mudlogging personnel can determine all information needed except the coal density. Prior to drilling the coal the mudlogging unit's response to both acetylene and methane must be determined. Also the gas trap's sensitivity to acetylene must be determined.

## Mud Drilled Example

### Instrument Calibration

Instrument calibrations must be performed using varying mole percents of both methane and acetylene. The range of calibration should be in the range of anticipated results. Catalytic bead sensors are used in this example and are the most common mudlogging sensor. However, catalytic bead sensors may not be the most suitable type of sensor for this application. Generally, catalytic bead type sensors are about twice as sensitive to acetylene as methane. This relationship can only be determined experimentally. A minimum of a pre and post well calibration should be run. Instrument calibration and carbide lag data are the bulwark of this method. If the instrument calibration is not

*Continued on page 24…*

## Determining Coal Gas Content ... *continued from page 23*

done or done improperly, then the calculated results are questionable. Catalytic beads degrade with time, degrade when detecting combustible gases, are subject to poisoning and do not have a linear response to methane. These three factors make instrument calibration unique and imperative. Computerized mudlogging units often linearize the gas readings and allow for rapid computation of the gas response. In Figure 8, a single point calibration is presented. Twice as much methane as acetylene is required to give the same mudlogging instrument response. The instrument response data and the carbide lag data establish a relationship between methane gas and instrument response.

**Carbide Lag Data**

After the instrument is calibrated and while drilling, the calcium carbide lag response is determined. Calcium carbide reacts with water based drilling mud to produce acetylene. As discussed above, typical mudlogging units respond to combustible gases. Acetylene is a combustible gas. The mudlogging industry typically uses calcium carbide to determine and report lag time. Important information can be gathered from calcium carbide lags if the amount of calcium carbide introduced into the drill string during a connection is measured. The amount of carbide used and the response in units is recorded on Figure 9 and Figure 8. Figure 9 is the mudlog used in this example. At 1,202 feet during a connection four ounces of calcium carbide gave a peak response of 45 units. This information is recorded under Carbide Lag Data in Figure 8.

**Gas Referencing©**

Gas Referencing© can be used as an alternative to carbide lagging. If Gas Referencing© is used, then the relationship between calcium carbide and acetylene need not be established. Gas Referencing© is essentially a continuous carbide lag. A small precise amount of acetylene is injected into the mud pumps and monitored continuously with the mudlogging unit. If any variation in trap efficiency or calibration occurs they will be detected using Gas Referencing©.

*Continued on page 25…*

## Determining Coal Gas Content

*… continued from page 24*

**Constants and Conversion Factors**

The amount of SCF of acetylene per ounce of calcium carbide can be determined by testing. In this example under “Constants and Conversion Factors” 16 ounces of calcium carbide yields 4.6 SCF of acetylene. The units per ounces of calcium carbide is known and the SCF of acetylene per ounce is known, so the SCF of acetylene per unit can be calculated. 0.02556 SCF of acetylene per unit is the result of this computation. Now the relationship between acetylene and methane can be used to determine the amount of methane gas detected per unit response on the mudlogging instrument. In this example 0.05111 SCF of methane is present for every unit of mudlogging instrument response. Now that a relationship is established between the amount of methane and the mudlogging instrument’s response is known, the amount of methane gas in any coal drilled can be determined.

Typical commercial mudlogging services either do not measure the amount of calcium carbide used or fail to report this critical information. This information can also be used as a quality control tool and is a good check on the quality of service provided. This data can also be used to compare different mudlogging equipment. If this data is not provided then a coal’s gas content can not be determined. Also some judgement is required to determine the number of carbide lags required for adequate coal gas content determinations. The quality and age of the carbide affects the response, therefore it is imperative to use carbide that has been recently tested. Also, any spilling of calcium carbide or venting of acetylene during “dropping carbide” during a connection must be noted. Sealed water tight bags are recommended. Consistent carbide lag response give more confidence in the data.

**Show Data and Yield Calculations**

A review of Figure 9 indicates a coal was drilled at 1,348. The coal is about 6 to 10 feet thick. The fastest drilling was 2.5 minutes per foot and this drilling break had a 300 unit mudlog show. Other pertinent information is that the hole size is 17.5 inches in diameter and the coal density is 1.7 gms/cc. For computational purposes the mudlog show is reported as 300 units per minute. If 300 units is multiplied by the conversion factor of 0.05111 SCF CH4/unit, then the SCF/minute of methane liberated can be determined. The result of this computation is 15.333 SCF/MIN of methane gas liberated. An integrated gas response in units over time can be performed if higher precision is required. The volume in cubic feet of coal per minute can be determined by dividing the hole area in square feet by the drilling rate in minutes per foot. The coal density in gms/cc can be converted to tons/cubic feet. If the coal density in tons per cubic feet is multiplied by the cubic feet of coal drilled per minute, then the product is the tons of coal per minute drilled. Both the SCF per minute of liberated methane gas and the TONs per minute of coal drilled is known. Dividing 15.333 SCF/MIN by 0.03545 TONS/MIN yields a gas content of 432 SCF/TON. 432 SCF/TON compare favorably with published canister desorption data of from 450 to 525 SCF/TON in the area.

## Air Drilled Example

The process for calculating a coal’s gas content while air drilling involves considerably easier computations. The process involves accurately determining the air compressor dilution factor. The

1/26/99 12:00WSD
ABRIDGED FORM

**WELL DATA**

OPERATOR: EXAMPLE OF COMPUTATIONS
WELL:
FIELD:
LOCATION:
COUNTY:
STATE:
DATE LOGGED

**COMPRESSOR IN FORMATION**

| | |
|---|---|
| RATED FLOW | 2000 SCFM |
| DERATING | 0.23 |
| ACTUAL FLOW | 1540 SCFM |

**BIT IN FORMATION**

BIT SIZE 7.875 INCHES
RPM 60 REVOLUTIONS PER MINUTE
CUTS PER REV 3

**ZONE IN FORMATION**

| | | MAX | MIN |
|---|---|---|---|
| TOP OF ZONE | 1500 FEET | | |
| THICKNESS | 5 FEET | 8 | 6 |
| PENETRATION RATE | 0.25 MIN/FT | 0.2 | 0.4 |
| GAS BEFORE | 5 UNITS | 5 | 5 |
| GAS DURING | 60 UNITS | 50 | 70 |
| GAS AFTER | 10 UNITS | 10 | 10 |
| DENSITY | 1.400 gm/cc | 1.460 | 1.340 |
| CALIPER | 8.125 INCHES | 8.375 | 8.000 |

**COMPUTATIONS**

HOLE GAS CONTENT ((UNITS/10000)*SCFPM)/(1-(UNITS/10000))
9.30 SCF METHANE/MINUTE
LESS BACKGROUND GAS
8.52 SCF METHANE/MINUTE
HOLE VOLUME (D/24)^2*PI*1
0.33824 FT^3/FT
CALIPER HOLE VOLUME
0.36006 FT^3
HOLE VOLUME PER MINUTE (HV/MIN)
MINUTE
1.35297 FT^3/MIN
CALIPER HOLE VOLUME PER
1.44024
TONS PER MINUTE (DEN*HV/MIN* 0.31214)
0.05912
CALIPER TONS PER MINUTE
0.06294

**COAL GAS CONTENT**

COMPRESSOR DERATED COAL GAS CONTENT
157 SCF/TON
CORRECTED FOR BACKGROUND GAS ONLY
144
CORRECTED FOR HOLE SIZE ONLY
148
CORRECTED FOR BACKGROUND GAS AND HOLE SIZE
135
CORRECTION FOR CUTTING SIZE 125% CUTTING HEIGHT 0.2000 INCHES
169
BEST ESTIMATE
157 SCF/TON

SEE DISCUSSION, THIS MATERIAL IS COPYRIGHTED BY DONOVAN BROTHERS INC. 1997

*Figure 10: Example from well inWyoming.*

*Continued on page 26…*

## Determining Coal Gas Content … *continued from page 25*

methane gas from a coal is liberated during the drilling process and is diluted by the air that is used to circulate out the coal drill cuttings. The mudlogging equipment measures the percent or units of methane in air. If the dilution factor of the air compression is known then the SCF of methane circulated from the well bore by the air can be calculated. Again the tons of coal drilled are determined by the hole volume and the density of the coal.

**Compressor Information**

Figure 10 is a worksheet used to determine a coal's gas content while air drilling. The section labeled "Compressor Information" is determined either by measuring the airflow rate or using the air compressor data provided by the air compressor supplier. If any doubts exist about the reliability of the data supplied the airflow rate should be measured. This simple procedure can eliminate a potential source of error. If a compressor deration factor is supplied it is necessary to determine if the factor is an adjustment due to barometric pressure changes with altitude or an adjustment due to loss of horse power caused by altitude. Other factors also influence deration and may be significant.

**Bit and Zone Information**

After a coal is drilled and logged the "Bit Information" and "Zone Information" portion of Figure 10 can be completed. The minimum required information to calculate gas content is compressor flow rate, bit size, drilling rate, gas show and coal density. Again accurate information is the key to this procedure!

**Computations**

Again, the gas "unit" must be converted to the methane fraction in the air. One hundred units is one percent methane in an air mixture or one ten thousandth's methane in an air mixture. The total flow out of the well bore is the methane volume plus the air volume. The mudlogging unit is calibrated in units, which are the methane fraction per total volume. The following formula relates a methane unit to a methane volume.

(2)UNIT/10000 = MV/(MV+CV)
MV = methane volume in SCF
CV = compressed air volume in SCF
UNIT = mudlog gas show in units

Rearranging the terms to solving for methane volume in SCF yields the following equation.

(3)MV = ((UNIT/10,000)*CV)/(1-(UNIT/10000))
MV = methane volume in SCF
CV = compressed air volume in SCF
UNIT = mudlog gas show in units

The first calculation in the "Computations" section of Figure 10 employs equation 3 to calculate the amount of methane liberated per minute. In this example 9.30 SCF of methane are liberated per minute. As discussed before integrated units per minute value can be used.

The remaining computations in Figure 10 determine the tons per minute of coal drilled. The first step in this process is to calculate the hole volume using the bit size. In this example a 7.875 inch diameter bit, drills 0.33824 cubic feet of coal per

*Continued on page 27…*

## Determining Coal Gas Content *... continued from page 26*

foot. To determine the hole volume per minute drilled, the hole volume is divided by the penetration rate measured in minutes per foot. That is 0.33824 cubic feet per foot divided by 0.25 minutes per foot. The result of this computation is 1.352 cubic feet of coal drilled per minute. The coal density as measured by the open hole logs is 1.4 grams per cc or 0.05912 tons per cubic feet of coal. One gram per cubic centimeter is equivalent to 0.031214 tons per cubic feet.

### Coal Gas Content

9.30 SCF of methane are liberated per minute and 0.05912 tons of coal are drilled per minute. That is 9.30 SCF per 0.05912 TONs or a gas content of 157 SCF/TON.

As discussed previously, some sources of errors need to be acknowledged or accounted for. Figure 10 outlines some common corrections. These corrections are a correction for background gas, hole size during drilling, and correction for not total desorption. In air drilled holes the circulation time is faster and the mudlogging data appears to be slightly lower than desorption data would suggest. One solution to this difficulty would be to desorb air drilled cuttings and add this amount of gas to the gas content determined by mudlogging. One major source of error is determining the air compressor's output. When in doubt direct measurement with a flow meter is recommended. It should be noted that mudlogging shows in air drilled holes are considerably lower than mud drilled holes due to air dilution.

## Source of Errors

The source of error affecting the determination of gas content by mudlogging comes from three sources. The three sources are that 1) the theoretical model does not adequately describe the process, 2) the theoretical model fails to account for some physical processes that influence the measurement and 3) error in measurement. The sources of potential errors have been mentioned in the above sections. The errors will be enumerated, discussed in more detail and suggestions for reducing the error will be provided.

### Theoretical Model Error

An important assumption of mudlogging determination of coal gas content is that a preponderance of gas is desorbed from the coal while it is drilled and circulated from the hole. Height is the one dimension of a drill cutting that can be determined with a fair degree of accuracy. A formula has been presented to determine drill cutting height. The smaller the drill cutting size the more likely that the gas will be liberated. Increasing the bit rotating speed, reducing the weight on the bit and using a bit with multiple cutters such as a PDC bit can reduce drill cutting height. It is assumed that reducing the weight on bit will reduce the penetration rate. This maximum height may be reduced further by natural fracturing, lack of cohesion, water sensitivity, water solubility, and drill pipe abrasion. Sieve analysis of coal drill cuttings may be useful, if results are unsatisfactory.

It is beyond the scope of this paper to discuss the type and degrees of error in whole core canister desorption techniques. An a priori assumption when comparing results is that canister desorption accurately measures the gas content of coals. "Lost gas" may be estimated by using mudlogging gas determinations, but the subject is beyond the scope of this presentation.

### Physical Process Errors

Some errors may result from not accounting for drilling difficulties. It is assumed the hole is in gauge, full circulation exists, no holes are in the drill pipe, the mud pump is good, drilling is overbalanced, "bottoms up" times are relatively slow and gas is only coming from the zone being drilled. The weight on bit, revolutions per minute and the mud pump strokes per minute should be constant and accurately recorded. Often the amount of error can be determined or a range of reasonable results can be determined. Note most of the difficulty mentioned above can be ameliorated by good drilling techniques. Poor drilling techniques cause major problems with mudlogging whether it is used to determine the gas content of coals or conventional evaluation

If a caliper log is available hole gauge in the coal zones should be checked. Determining the magnitude of the possible error by calculating a coal's gas content with the enlarged hole volume is advised. When the hole enlargement occurred is the critical question. Only MWD instrumentation may accurately determine when enlargement occurred. Drill cutting sieve analysis, a careful review of the caliper log relative to drill collar depth, tight hole problems after trips and drilling problems may offer insight into when hole enlargement occurred. Casing the hole, fast drilling, mud motors and good mud often minimize hole enlargement. Hole size enlargement is usually not a major problem when the target is the coal because the well reaches total depth shortly after the coals are drilled.

Full circulation, a good drill string, good pumps and drilling over balanced are some of the good drilling practices, which are needed for successfully determining a coal's gas content. No ef-

*Continued on page 28...*

## Determining Coal Gas Content ... *continued from page 27*

fective mudlogging can occur when these difficulties occur. Constant monitoring of the rig and stopping to fix problems is the only solution to these difficulties. Making the drilling contractor aware that poor drilling practices will not be tolerated, having pre drilling meetings and contractually obligating the contractor to meet minimum standards is recommended. The drilling practices mentioned above affect carbide lag response and lag times.

Another source of potential error is determining the amount of gas liberated from the coal being drilled. If a large background gas is being consistently measured then the background gas should be subtracted from the gas show. The background gas tends to increase after each coal in a multiple coal seam project. Under balanced drilling such as air drilling and drilling with light mud increases the possibility of high background gas readings. High background gas indicates the coal zones are permeable and the time for the background gas to fall off may be a qualitative indicator of coal permeability. If gas backgrounds are high and erratic a simple solution is to circulate the hole to reduce the gas or slightly increase the mud weight. From solely anecdotal experience it appears that high mud weight decreases the amount of gas measured more than can be explained by theory.

Although constant bit weight, rotary table speed and mud pump strokes are not directly used in the computations. They affect the results of determining a coal's gas content. Keeping these factors constant helps assure lagging and drilling rates are more easily measured and the response to acetylene and methane is not changed. Typically rig functions are not recorded continuously and if problems with the computations arise it is imperative to know that the values recorded are constant and accurate.

Air drilling results tend to be slightly lower than would be anticipated. The circulation rate is fast and more desorption time occurs with longer circulation times. The lack of time is partially offset by the fact that there is little hydrostatic head in an air drilled hole and therefore desorption begins immediately upon drilling the coal. Another factor which speeds up the desorption process is that air drilled cuttings are smaller than computed due to severe drill pipe abrasion of drill cuttings.

*Continued on page 29...*

## Determining Coal Gas Content … *continued from page 28*

### Measurement Errors

Two factors, which require accurate measurement, are drilling rate and gas volume. Both these factors can be measured accurately with the good mudlogging equipment, cooperative drilling crews and knowledgeable personnel.

Small drilling rigs typically do not have depth recording instrumentation or the depth recording instrumentation provided is not suitable for the fast drilling encountered in coals. Often drill rates of 0.2 min per foot, that is 5 feet per minute or 4 minutes per 20 foot kellys are encountered. Accurate determination of the penetration rate is important for good results. Best results are obtained by the uses of computerized depth counters that can resolve the subtle drilling rate changes.

Air drilling offers the most direct and accurate determination of gas volume. Even with this simple system it is apparent that both the air compressor flow rate and mudlogging gas detection system must be accurately measured. Air compressor flow rates can be accurately measured by using orifice meters, flow meter and pitot tubes. Alternatively the compressor flow rate can be estimated by knowing the compressor's RPMS, the atmospheric pressure, temperature and relative humidity. The degree of accuracy desired determines the methodology used.

The determination of a coal's gas volume in a mud drilled system is considerably more complex. The response of the gas trap and gas detection equipment to both methane and acetylene must be known. Gas Referencing© provides a continuous method of determining the acetylene response in the mud system. Carbide lagging uses a periodic method of determining trap response. A myriad of measurement errors can occur. Determining the volume of acetylene gas per amount of calcium carbide is a potential source of error. Determining the mudlogging response to both acetylene and methane must be undertaken with care. "Dropping carbide" regularly and carefully is imperative. Errors may be introduced into the computations if care is not taken during the calibration and measurement procedures. Competent mudlogging personnel perform most of these tasks routinely and should have no difficulty with this methodology.

Calibrated, well-maintained and functioning equipment is important part of this process. Typically one assumes that mudlogging equipment is functioning but it is important to discuss this as a potential source of error. Also much of the mudlogging commercially available today is over twenty years old and in disrepair. The famous adage often said about computers, "Garbage In, Garbage Out" applies equally as well to coals gas content mudlogging methods.

### Summary

The mudlogging technique used to determine a coal's gas content is solidly grounded in desorption theory. This is a cost-effective method to evaluate one coal or multiple coals. Some of the drawbacks of canister desorption such as missed core points, poor core recovery and measurement uncertainty are ameliorated. The technique is easy to implement with modern computerized mudlogging units, competent personnel and cooperative drilling contractors. The gas content determined by mudlogging agrees with canister desorption data. The procedure has been used by the author in the San Juan, Raton, San Wash and Powder River Basins with good results.

### Acknowledgements

The author wishes to thank the oil and gas operators who have used Automated Mudlogging Systems and allowed various "little experiments" to be conducted while drilling. Their patience,

*Continued on page 30…*

## Determining Coal Gas Content ... *continued from page 29*

help and insights are gratefully appreciated. Without ongoing employment and support, research such as this is not possible. It is the hope of the author that mudlogging information supplied will help develop their coal bed methane resources. Determining gas content of coal by mudlogging method is an on going effort and the author would appreciate comments on the technique proposed.

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### About the Author

**Bill Donovan** is a consulting Petroleum Engineer and the President of Automated Mudlogging Systems. He received a B. S. in Geology from the University of Wisconsin in 1970 and a M. S. in Petroleum Engineering from the Colorado School of Mines in 1979. Bill is a licensed Professional Engineer in Colorado and New Mexico. For the past ten years Bill has worked as a consultant specializing in formation evaluation, field studies, completion practices and reserve evaluation. Call (303) 704-7470 or send e-mail to donovan@petroleum-eng.com to contact Bill. This paper is also available on the Web at www.mudlogger.com.

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October 31, 2006

Dear Mr. Kubica,

On behalf of the 2007 Convention Organizing Committee, we would like to thank the Canadian Well Logging Society for contributing to the technical program. As such, and in recognition of the co-hosting relationship on past conventions by our three societies, the 2007 Committee would like to extend an invitation for CWLS members to register for Let it Flow, the 2007 CSPG CSEG Convention at the reduced member rate.

Beginning March 19, 2007 when Registration opens, your members would be able to register at the same discounted rate they enjoyed in 2006, as outlined below:

| | Early Bird Registration **Deadline: April 13, 2007** | Regular Registration **Deadline: April 27, 2007** | On-Site Registration **May 14 – 17, 2007** |
|---|---|---|---|
| Member | **$285** | **$385** | **$485** |
| Non-Member | **$385** | **$485** | **$585** |

Please do not hesitate to contact either of us to discuss this matter further.

Sincerely,

John Varsek
General Co-Chair, CSPG

John Townsley,
General Co-Chair, CSEG

John Varsek
General Co-Chair,
CSPG

cc. Ian McIlreath, CSPG Committee on Convention Chair
Oliver Kuhn, CSEG President
Jim Reimer, CSPG President

John Townsley
General Co-Chair,
CSEG

# Tech Corner – Why We Need Well Logging & LWD

*Bandar D Al-Anazi*

## Introduction

When early oil pioneers drilled their wells they knew little about the formations they were drilling and showed practically no interest in the stratigraphy their bits penetrated. Instead, their interest was focused on making holes and looking for the presence of oil. Later, realizing it was very helpful to know something about the formation, they examined and recorded the characteristics of cuttings brought to the surface by bailing operations. Eventually mineralogists applied a microscope to the cuttings and advanced formation-evaluation efforts further by measuring the density, hardness, and electrical properties of the rocks and by making chemical analyses of them.[1]

Core sampling and mud logging technology today is making everything easy but we must ask ourselves a few questions.

## Who needs well logging?

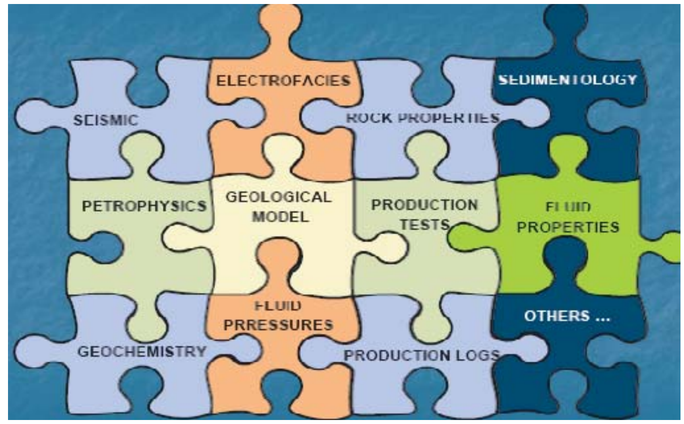
**Geophysics look to logs for:**
1. Are tops as predicted?
2. Does seismic interpretation agree with log data?
3. How is my synthetic doing with this new information?

**Geologists look to logs for:**
1. Where are my tops?
2. Do I have any reservoir?
3. Is there any Hydrocarbon in the well?
4. What type of Hydrocarbon(s) is there?
5. How good is my reservoir?
6. What kind of reserves do I have?

**Drilling Engineers are looking for:**
1. What is my hole volume (cement)?
2. What is my dog leg severity?
3. Where can I get a good packer seat for testing?
4. Where can I set up my whip stock?

**Production Engineers are looking for:**
1. Where should I complete this well?
2. What will be my expected production rates?
3. Will I have to deal with water?
4. How should I complete this well?
5. Do I need to stimulate this well?
6. How should I stimulate it?

## Reservoir Characterization




Fifty years after it was introduced, the Archie equation remains the keystone of log analysis for the solution of water saturation of potential oil and gas zones:

$$S_w = \left( \frac{a}{\Phi^m} * \frac{R_w}{R_t} \right)^{\frac{1}{n}}$$

The equation is actually made up of two separate equations. The first describes the relationship of the ratio of the resistivity of a water saturated rock, Ro, to its formation water resistivity, Rw, to the fractional porosity,

$$\frac{R_o}{R_w} = \frac{a}{\Phi^m}$$

This resistivity ratio is also known as the "formation factor", F. The second equation relates the ratio of the observed formation resistivity, Rt, to its expected resistivity, Ro, if it was completely saturated with water, to the fractional water saturation, Sw:

$$\frac{R_t}{R_o} = \frac{1}{S_w^n}$$

The equations are universally applied to reservoir fluid calculations from wireline logs in "clean" (shale-free) formations. Even when specialized equations are applied to clastic reservoirs that are markedly shaley, these same equations are adaptations of the Archie equation that accommodate shale effects.

The application of the Archie equations presuppose a knowledge of the parameters, or at least reasonable estimates of them, in order to calculate acceptable water saturations. Formation water resistivity can usually be established from field measurements and/or log analysis estimations. However, the quantities

*Continued on page 33…*

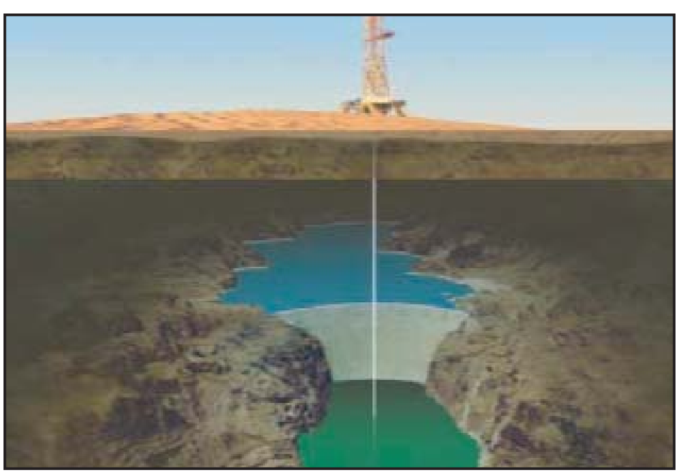
## Why We Need Well Logging & LWD *… continued from page 32*

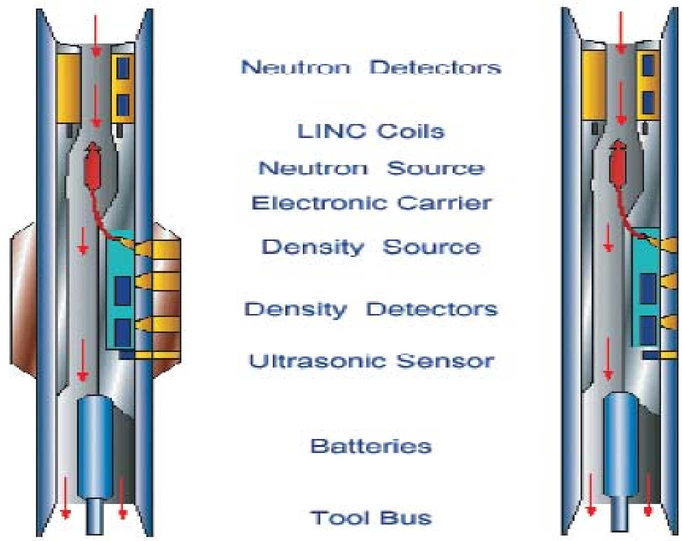
of a, m (the “cementation factor”), and n (the saturation exponent) are usually unknown and their values are given as a matter of experience. The range of values for m and their relationship with rock texture has been the subject of much measurement and discussion. By contrast, the variability of n is less well understood, but is generally taken to be the number 2 (at least, in water-wet zones). The problem is further compounded by the realization that these “constants” are only likely to remain so in relatively homogeneous reservoirs, where rock texture and pore geometry remain fairly uniform. Continuing advances in theory and measurement demonstrate that simple models may be poor (and puzzling) representations, or even downright misleading in heterogeneous and complex reservoirs that are the targets of many of today’s energy companies.

Petrophysics touches every aspect of the petroleum business. It provides universal, concise and comprehensive descriptive information on reservoirs. Petrophysics can be defined as “the study of formation rocks with their interaction with formation fluids”. It is about describing the oil and/or gas distribution and the production flow capacity of reservoirs, from interpretations of several types of logs and integration of these interpretations with other petrophysical data and analysis from other sources like cores and well tests. Petrophysics answers the most important questions associated with exploration, development and production. These questions are: Are there any hydrocarbons? If so, how much? If a reasonable amount, will they flow?

Today, oil companies produce an average of three barrels of water for each barrel of oil from their depleting reservoirs. Every year more than $40 billion is spent dealing with unwanted water. In many cases, innovative water-control technology can lead to significant cost reduction and improved oil production.

To answer these questions, porosity, permeability, fluids saturation, reservoir lithology, fractures, original fluid contacts and other reservoir parameters should be estimated under reservoir conditions. However, these parameters rarely can be measured directly. They can only be interpreted from a multitude of indirect measurements such as Resistivity, Density, Gamma ray and Neutron logs. Here comes the role of the well logging and the petrophysical interpretation to collect and analyze these indirect measurements in order to provide rock and fluid properties and find hydrocarbons zones.






### Neutron Tool

Logging tools have been developed to measure electrical, acoustic, radioactive, electromagnetic and other properties of rocks and their contained fluids.

Basically, there are two types of well logging: wireline logging and logging while drilling LWD. The wireline well logging consists of lowering a ‘logging tool’ on the end of a wireline into a well. This type of logging required removing the drill string. This is why Wireline logging is usually performed at various intervals during the drilling of a well and when total depth is reached. Data is recorded to a printed record called ‘Well Log’ and is transmitted digitally to office locations. Wireline logs have been and continue to be one of the most critical widely available tools for characterizing and managing reservoirs.

LWD is increasingly the primary logging method for petrophysical data acquisition. With rising rig rates pricing out wireline logging, and the advent of rotary steerable drilling systems allowing ever more complex well profiles that preclude any attempt at wireline logging, LWD data are often the only well data available.

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## Why We Need Well Logging & LWD … *continued from page 33*

The challenge is, therefore, to ensure that LWD tools deliver quantitative evaluation data in all conditions and environments. The nuclear measurements of density and neutron porosity are particularly challenging due to their low depth of investigation and the inadvisability of employing spring loaded pad type devices in the drilling environment (as per wireline) to ensure good formation contact. With the restriction of a fixed tool diameter, any hole enlargement while drilling will mean some degree of tool standoff, requiring the application of environmental corrections to yield true formation properties. Additionally, technology is constantly improving to drive faster drilling rates, which in turn require faster LWD logging speeds to maintain adequate data sampling.

The latest generation nuclear LWD technology addresses these issues to improve data quality, increase accuracy and acquisition speed to extend the operating limits of the tools, and ultimately ensure confidence in the data for petrophysical evaluation.

In the recent years, LWD has been introduced. The LWD tools are attached to the drill string and measurements are made while the well is being drilled. LWD real-time data are very helpful in terms of goesteering and horizontal or directional drilling considering the fact that LWD provides virgin and invaded formation evaluation. This data is transmitted to the surface via pressure pulses through the drilling mud. In addition, it can be retrieved from the memory of the tool when the drill string is removed from the hole.

Petrophyisicts utilize their skills and use advanced log processing software to analyze and interpret the data. They integrate this data with the goal of reducing risk and uncertainty in the in-place hydrocarbon calculation, maximizing recoveries and optimizing productions. Their interpretations are used for tracking reservoir depletions, planning workover operations and enhanced recovery strategies, and diagnosing production problems such as water influx and injection water breakthrough.

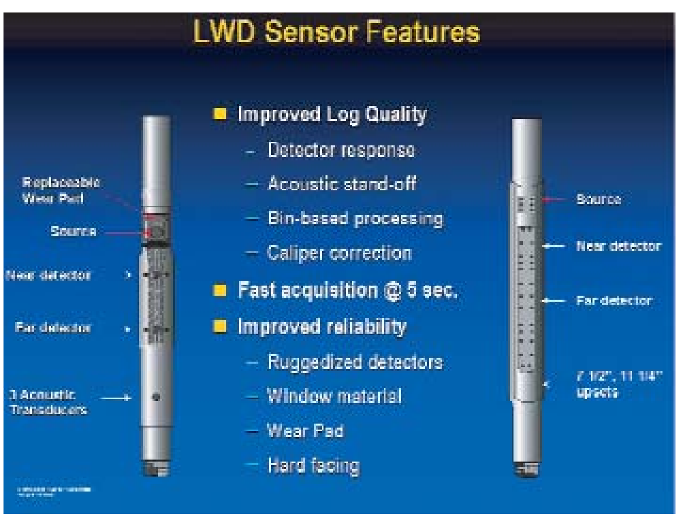


*Photo courtesy of Baker Hughes Inteq.*

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### About the Author

**Bandar D Al-Anazi** is a student in King Saud University in Petroleum and Natural Gas Dept. He joined KSU in 2003 and is a member of the Society of Petroleum Engineers (SPE), the American Association of Petroleum Geologists (AAPG), the Society of Exploration Geophysicists (SEG), the Dhahran Geosciences Society (DGS), the Candidate Fellowship the Geological Society of London, the Society of Petrophysicists and Well Log Analysts (SPWLA), the European Association of Geoscientists & Engineers (EAGE), the Canadian Society of Exploration Geophysicists (CSEG), the Edinburgh Geological Society (EGS), and the Geological Society of South Africa (GSSA). He was a secretary of SPE-KSU chapter from 2004-2006 and he is currently president for the chapter for 2006-2007

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## CWLS GENERAL INFORMATION

**INCORPORATED** – January 21, 1957

**Objective**

The objective of The Society (as stated in the Letter of Incorporation) is the furtherance of the science of well log interpretation, by:

(A) Providing regular meetings with discussion of subjects relating thereto; and

(B) Encouraging research and study with respect thereto.

### MEMBERSHIP

Active membership is open to those within the oil and gas industries whose work is primarily well log interpretation or those who have a genuine interest in formation evaluation and wish to increase their knowledge of logging methods.

### FEES

The CWLS fiscal year commences February 1, and all fees are due at this time.

Initiation Fee (including first year's membership fees) : $40.00
Annual Dues : $30.00
Student (no initiation fee) : $10.00

Memberships not renewed on or before June 30 of each year will be dropped from the roster and reinstatement of such a membership will only be made by re-application, which will require re-payment of the initiation fee plus the annual dues. All dues (Canadian Funds) should be submitted with the application or renewal of membership (Cheque, money order MasterCard, AMEX or Visa).

### ACTIVITIES

The Society also furthers its objectives by sponsoring symposiums and exhibits.

Research committees encourage and support research on relevant problems.

The Society is the spokesman to industry and government on topics pertaining to well logging and formation evaluation.

The Society holds a monthly luncheon meeting (except July / August) to hear an address on a relevant topic.

Each active member will automatically receive the CWLS Journal, 'InSite' newsletter and Annual Report.

### APPLICATION

Should our activities interest you we invite you to complete the attached application form and forward it to the CWLS membership Chair.

## CWLS MEMBERSHIP APPLICATION FORM

**To apply for membership to the CWLS, please complete this application form in detail.**

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## Wednesday, March 7th, 2007
## CWLS TECHNICAL LUNCHEON PRESENTATION
## FAIRMONT PALLISER HOTEL
## 133, 9TH AVE. S.W. CALGARY

**TIME: 12:00 PM (COCKTAILS AT 11:30 AM)**

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**COST**: MEMBERS RESERVED MEAL: $30.00; NON-MEMBERS RESERVED MEAL: $35.00
(SPECIAL NEEDS MEALS AVAILABLE WITH ADVANCED BOOKING ONLY)

**TOPIC:** **DIPMETER APPLICATION IN OILSANDS DEVELOPMENT**

**SPEAKER:** Milovan Fustic, P.Geol, Nexen Inc.

## ABSTRACT:

The Athabasca oil sands deposit contains more than a trillion barrels of oil within the Lower Cretaceous McMurray Formation of NE Alberta. The bitumen grade is largely controlled by the complex geometry and internal architecture of sedimentary bodies. In order to resolve, or at least to minimize, some of the subsurface interpretation challenges, dipmeter logs are commonly employed to provide key information about reservoir body distribution and character. Dipmeter logs may be applied in oil sands for predicting the presence of potential block slides in open pit mines, recognizing various channel fill types, estimating vertical continuity within individual channel fills and within multi-story sedimentary bodies, and estimating the lateral extent of point bar deposits.

Despite the noted applications, attempts to make geological correlations in subsurface data for use in 3D geological models have proved difficult. In order to solve this problem, the “Stratigraphic Dip Analysis” method was modified and tested. This method is applicable for recognition of paleochannel trends, delineation of major PB and AC deposits, and as a predictive tool for bitumen saturation between wells and in areas with little drilling. The results obtained provide new information applicable for mine planning, selecting zones for positioning well pairs in SAGD operations, and are the grounds for different numerical modeling and reservoir simulation approaches.

The intent of this presentation is to (1) show the evolution of dipmeter applications in oil sands development, (2) demonstrate the advantages and simplicity of using the tool, and (3) highlight that the dipmeter is an underutilized tool that can be more broadly applied in oil sands development projects.

## BIOGRAPHY:

Milovan Fustic, P.Geol., obtained his undergraduate degree (B.Sc. Hons. 1993) in Geology from the University of Belgrade. After graduating, Milovan worked in the petroleum and mining industry for 12 years. In 2000 he worked as a geologist with Albian Sands Energy Inc to develop Shell’s Oil Sands leases in the Athabasca region. Since 2004 he worked on Shell expansion projects in the Athabasca region and later on defining new heavy oil and oil sands prospects in the Peace River, Wabasca and Cold Lake regions. Recently Milovan accepted the position of geologist with Nexen where he works on oil sands In-Situ developments. He is also working part-time on a PhD research project entitled “Geological Controls on Reservoir and Bitumen Heterogeneity in Athabasca Oil Sands”. Milovan has published and/or co-authored several papers and conference proceedings related to McMurray’s sedimentology, reservoir characterization, petroleum geochemistry and applied petrophysics.



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## March 19 - 20, 2007
**1st India Regional Conference Formation Evaluation in Horizontal Wells**
Hotel Grand Hyatt, Mumbai

## March 20, 2007
**CSPG Technical Luncheon**
Intrusion, Deformation and Degassing at the Yellowstone Caldera, Jacob B. Lowenstern
Telus Convention Centre
Calgary, Alberta, Canada

## March 25 - 29, 2007
**Spring Tropical Conference**
SPWLA/SCA Core-Log Integration for Improved Petrophysical Analysis
Sunriver Resort, Bend Oregon

## April 1 - 4, 2007
**AAPG Annual Convention and Exhibition**
Long Beach, CA, USA

## April 15 - 19, 2007
**1st Annual SPWLA Middle East Regional Symposium**
Abu Dhabi, UAE

## May 14 - 17, 2007
**CSPG Annual 2007 Convention**
Round-Up Centre & AEUB Core Research Centre
Calgary, Alberta, Canada

## June 3 - 6, 2007
**2007 SPWLA Annual Symposium**
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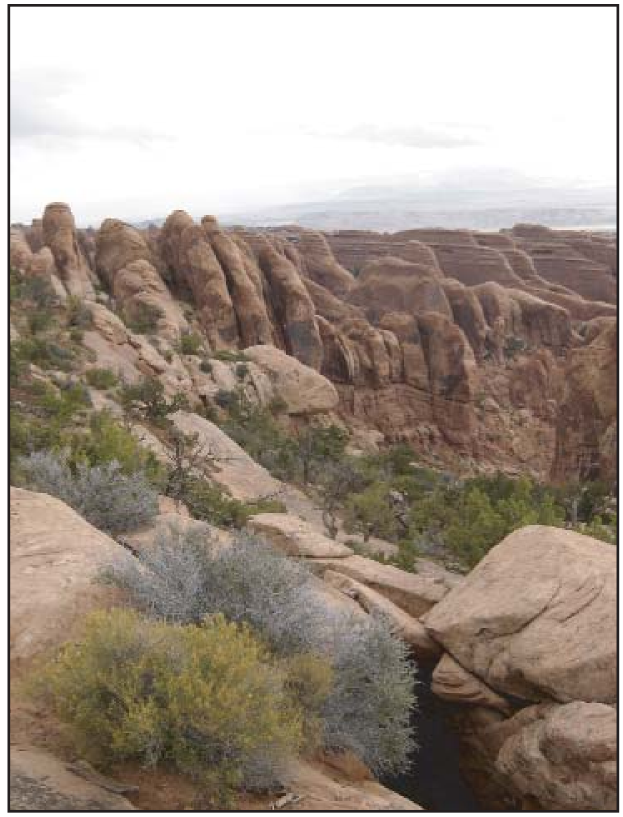

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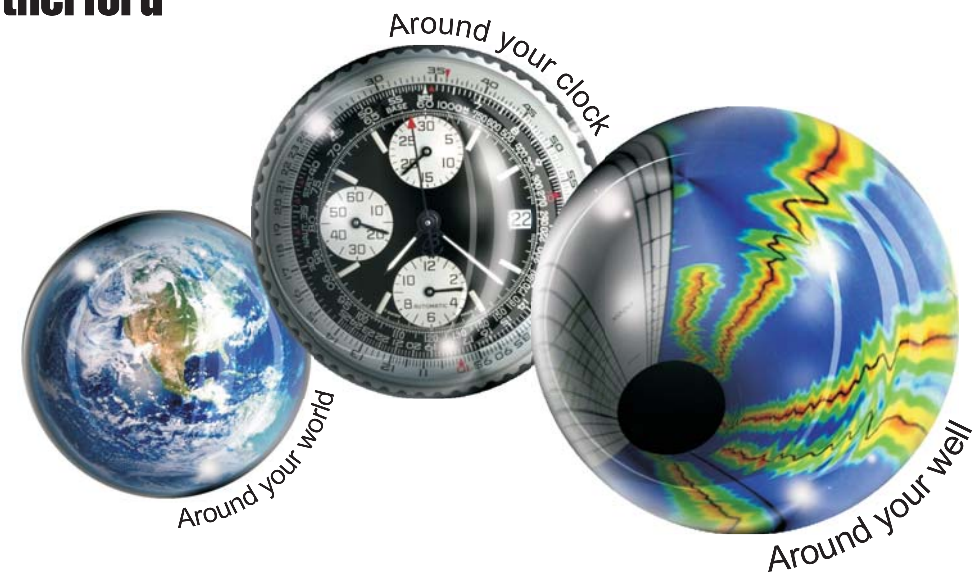


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