InSite

CWLS Newsletter

APRIL 2004

Table of Contents

Cover Photo: Ready to log in the Dawson Area. Photo Courtesy Robert Bercha.

If you have a photo that the CWLS can use on it's next InSite cover please send a high resolution jpeg format version to Robert_Bercha@anadarko.com or meddy@wellsitegas.com. Include a short description of the photo with your submission.

President's Message

The CWLS is not a commercial enterprise. We are a technical society.

This is my understanding of a well logging society:

> *People who work in formation evaluation, and who have in common various technical challenges, getting together to share knowledge so that they can collectively work through those challenges more effectively.*

I think we often act more like a business and less like a society. For this year my efforts will be aimed at moving us back towards making us more of a society. The following is a list of the things I will try to make happen during my term, along with some of the reasoning behind each of the initiatives.

Create a Logging Standards Committee: In the early days society members would gather at luncheons and discuss various technical issues. Most members were oil company people, some were logging company people. The discussion could be lively, unfettered and productive. Now the ratio of oil company to service company people is much different, and the number of logging companies has increased. It is considered bad manners to discuss "problems" in an open forum in front of competitors. Consequently, oil company society members are each wrestling with the same technical issues independently. This new committee would be comprised solely of oil company employees and independent consultants. They would discuss and resolve issues of common concern. Where appropriate, they would recommend standards of practice. Some topics they could address are:

- Depth control procedures (currently logs show tool calibrations but do not indicate anything about how depth was determined)
- Log headers on deviated wells (a measured depth log on a deviated well should be labeled "Measured Depth?" How about on a vertical well?)
- Log formats (do we always need a linear resistivity presentation?)

Create a Log Graphic Standard Committee: LAS has become the standard for the delivery of log digits. There is no standard for log graphics. This creates inconvenience for our members who wish to view and archive log graphics. It also discourages people from working in the digital world so there is lots of wasted time and wasted paper. Also, the AEUB plans on requesting digital graphic submissions of logs within a year. It would be better for our members if we could suggest a format instead of having them force one upon us.

Attract First Rate Luncheon Speakers: The President's Award for the best luncheon presentation of the year has been at $500 for a number of years. This year's committee has approved a motion to increase it to $1,000. Also, in the past we were frugal when it came to reimbursing speakers for expenses. I don't know why. A careful reading of the society by-laws shows that Corporate Membership funds are to be used specifically for this purpose. After gifts and awards, this year's Vice President must spend about $13,000 to get nine luncheon speakers.

Encourage More Non-Commercial Local Luncheon Speakers: In addition to the President's Award there will be an award of $500 for the best luncheon talk by a Canadian-based speaker who is from an oil company or from a university or college. Most speakers that are willing to present at our luncheons are not based in Canada and are not CWLS members. If they are local, they are from service companies. Instead of being a society where members share information, we are a business that brings in qualified buyers to which third-parties can make presentations.

Run Technical Events at a Loss: As a non-profit society the CWLS has usually tried to run the luncheons, workshops and other technical events at breakeven. The exception is when we have a symposium. Then we make money. We haven't been very good at finding ways to spend that money. Consequently we have an embarrassing amount of money in the bank. To keep this from happening we will price technical events so that members and students can participate at below cost.

Bring in More Students: The experience of sharing technical information is enhanced if we are always bringing in fresh blood. The Scholarship Committee will be reformed as a Student Liaison Committee. Already we have revamped our scholarship offerings and have made free luncheon tickets available to U of C and SAIT students. We will also try to have an introductory petrophysical day for summer students in July or August.

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President's Message

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Spend on a Legacy Item: We could easily spend $100,000 without any risk to the long term viability of the CWLS. We collected this money from members. We must spend it in a way that benefits the members while fulfilling the society's goals. It would be difficult to trickle away that much money. If anyone has suggestions for appropriate ways to serve our members with this money please let us know.

If anyone has any comments or ideas please contact me at (403) 232-1705 or at jlevack@tuckerenergy.com. Or you can heckle me at one of the luncheons. Either way is fine.

Jeff Levack, CWLS President

Membership Renewal Reminder

It is that time of year again; please submit your membership renewal forms as soon as possible. This will ensure that you do not miss any of the upcoming events and benefits of being a member of the CWLS. If you have not yet received your renewal forms please contact Dion Lobreau at 231-7673 or email dlobreau@mancal.com or contact the CWLS office at (403) 269-9366.

Editor's Note

The second quarter of 2004 is just beginning and it has been a busy winter for E&P and Service companies alike. With the rig count reaching 650 it seems as though the winter will never end. Break-up will give everyone a chance to reflect on the busy winter and look ahead to an exciting summer. As long as commodity prices remain at there current levels, the remainder of the year should be as hectic as the beginning.

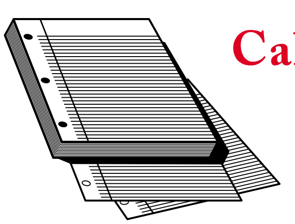
This beginning also brings Mike to the second half of his two-year term as Publications Co-Chair. Mike's predecessor Steve Burnie was a pleasure to work with and we would like to thank Steve for the work he did with the committee. Mike is pleased to introduce his new co-chair, Robert Bercha, whom he looks forward to working with this year.

We are looking for more papers for the Journal and for the InSite. This year we want to add more content to the InSite Newsletter with relevant papers to well logging and formation evaluation. Our goal for this year is to get more content from LWD/MWD and Core Analysis. The papers for the InSite do not need to be overly long or highly technical. So if you or someone you know would like to write a paper for the InSite please contact us. The InSite Newsletter will be published on a quarterly basis, so you can expect to see it every three months.

The CWLS web site continues to evolve and is updated on a regular basis. We hope this website provides a useful resource for the members. CWLS members can now advertise upcoming industry courses and employers can post jobs for recruitment. These services are free to the membership. For those who are interested, a copy of the AGM Report is now available to be downloaded from the website. If you have not checked out the website please take the time to have a look at it (www.cwls.org).

If you would like to submit a paper, advertise on the website or in the InSite Newsletter, you can contact either of us: Mike Eddy at (403) 230-0630 or Robert Bercha at (403) 231-0249.

Mike Eddy
Robert Bercha
CWLS Publications Co-Chairmen



Call for Papers

The CWLS is always seeking materials for publication. We are seeking both full papers for the Journal and short articles for the Newsletter. Please share your knowledge and observations with the rest of the geoscience community. Please contact publications co-chairs Mike Eddy (meddy@wellsitegas.com) at (403) 230-0630 or Robert Bercha (robert_bercha@anadarko.com) at (403) 231-0249.

CWLS 2004 to 2005 Executive

Front row from left to right:
Richard Bishop,
Khrista Kellet, Jeff Levack,
Dion Lobreau

Back row from left to right:
Mike Eddy, Dave Shorey,
John Nieto, Darren Aldridge,
Robert Bercha

As the Winch Turns

Become a wireline engineer and travel the world. That is what the recruiters tell you in the job interview. They neglect to tell you that the world they speak of is in Northwest Alberta or Northeast B.C. Nor do they mention it is usually at night when you are seeing it or that it is -40 C with a 50kph wind blowing. To top it off you probably have not slept in two days.

That is beside the point though as you often get to see some truly beautiful country that other people do not have an opportunity to visit.

I was in Northeast Alberta, Newby to be exact, on a fine winters night heading to a rig 50 kilometers down an ice road. Driving over muskeg where our top speed was 20 kph, a typical drive in the winter months. It was a rather nice night with clear skies and a temperature of about -20 C when I saw them.

There in the middle of the road was a family of lynx playing as only felines can. They are beautiful animals and when you see them in their natural habitat, it makes you realize what an amazing country we live in. These cats were running and jumping through the trees and deep snow with out a care in the world as we sat and watched for about 20 minutes and then they just disappeared. The next three nights we traveled down this stretch of road we saw the lynx family playing in the same area at about the same time of the night. It is nice to know that some parts of our world are still pristine and nature moves at its own pace without a care to what is happening in the rest of the world.

Vern Mathison
Precision Wireline

If you have story you would like to share with the membership please contact Mike Eddy at (403) 230-0630 or email meddy@wellsitegas.com or contact Robert Bercha at (403) 231-0249 or email Robert_Bercha@anadarko.com.

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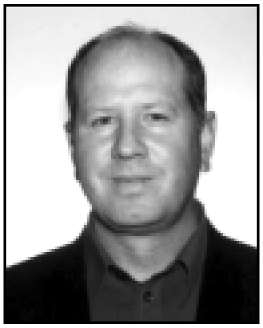


Treasurer's Message

Ever wonder what's going on with the CWLS's finances?

Financially, the society is in very good shape. For details please see the recent 2003 annual report. The CWLS currently has over $200,000 in equity. The majority of this amount is secured in low risk investments such as GIC's. Even so, it still generates around $3200 a year in interest. As a non-profit organization it is important that we do not generate a significant amount of returns. To this end the executive is currently looking for ideas on ways to spend this money which will benefit the society's members. If you have an idea please contact me.

One of the ways that the society reduces the amount of equity it has is through the Fall Social. All of the proceeds from this event are given to charity. It costs the society $2900 to put on the event (for room rental and catering), which for the most part uses up the interest we are generating. Last year the proceeds from ticket sales were $1240. This was donated directly to the Children's Cottage.

For those of you who are unaware of what this charity does, I'll explain. The Children's Cottage is an organization that takes care of children under 9 years of age that do not have parents to look after them for one reason or another. Last year in Calgary alone, there were 1500 children that needed such care. The CWLS's donation was used for supplies such as diapers and food.

In addition to supporting a great charity, the Fall Social is a great way to see our colleagues as well as enjoy a drink with some of the CWLS's senior members. I look forward to seeing everyone at this year's Fall Social in November.

Darren Aldridge
Treasurer

CWLS Speaker Evaluation Committee

Each year at the CWLS Annual General Meeting an award is given for the best Technical Luncheon presentation of the past year. The award is made by the CWLS Executive Committee based on a recommendation from the CWLS Speaker Evaluation Committee.

The award is for the best presentation made since the last AGM. Since there are no presentations in February, July and August, nine papers are usually in the running.

The Evaluation Committee weighs a number of criteria when evaluating the presentations. These are:

Material Type	Originality of the material and the degree to which it meets the CWLS mandate to present case studies at the technical luncheons.
Material Content	Quality of the technical content.
Slides or Illustrations	Clarity, relevance.
Speaker's Presentation	Organization, style, clarity.
Overview	Overall impression.
Audience Reaction	Attendance, questions, comments.

It has not been the role of the committee to give any feedback to the presenters. From now on though, part of the award presentation will include a listing of the winning qualities of the best presentation.

The current Evaluation Committee members are:

Robert Bercha, Mark Ducheck, Jim Earley,
John Gilroy, Randy Hughes, Jeff Levack, Carlos Rosita,
Larry Song and Mirek Zaoral.

The committee is currently looking for new members. The commitment of time and effort are minimal. There is only one meeting per year and lunch is served. If you can help out, and you attend at least four CWLS Luncheons per year, please call Robert Bercha at 231-0249 or email robert_bercha@anadarko.com.

Canadian Well Logging Society

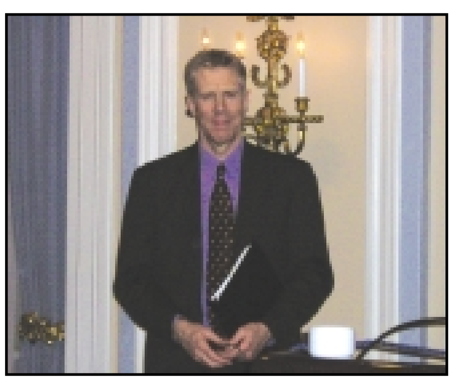
2003 Annual General Meeting

This year's AGM was a huge success with over 200 members and guests in attendance. The honorary guest speaker, Stuart McLean of the CBC radio show "The Vinyl Café" kept our undivided attention while entertaining us throughout the evening. Again this year the food was that of a five star restaurant. Dave Shorey handed the President's position over to Jeff Levack and Ted Jennings was inducted as an honorary member. For those of you who missed the meeting you can download a copy of the annual report from the website. The AGM is a social event and is not business the entire time. The formal meeting only takes up part of the evening. The rest of the night is a great opportunity to network, meet people, and spend time with colleagues and friends. If you have never attended it is well worth bringing your spouse or a friend to. A few of the highlights from the evening are shown.

Dave Shorey, 2003 President, handing the reigns over to Jeff Levack 2004 President.

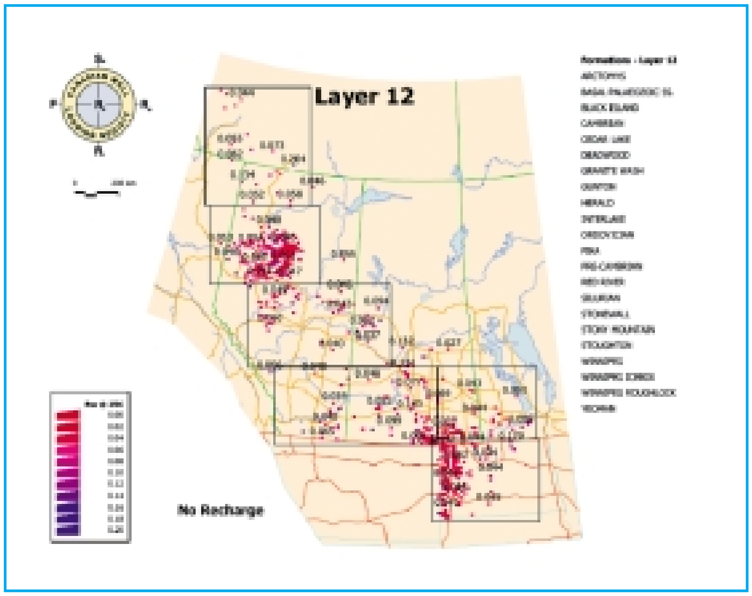
Dave Shorey presenting an award to Patrick Lasswell of Omni Laboratories Inc. for his talk on Laboratory Analysis of Electrical Rock Properties and Capillary Pressure.

Dave Shorey inducting Ted Jennings as an honorary member for his longtime contributions to the CWLS.



Stuart McLean, honorary guest speaker at the AGM

2002 CWLS Rw Catalog



Information included on CD:

- 2002 Rw Catalog
  (Over 50,000 Data Points)
  – PDF Format
  – Spreadsheet (XLS) Format

- 1987 Rw Catalog
  (5,600 Data Points)
  – PDF format
  – Original "Data on Disk" Digital Format

- LAS 2.0 and 3.0

Prices (Shipping Not Included):

Members:	$25.00 CDN (limit one per member, two per corporate member)
Non-members:	$65.00 CDN

Network License (corporate members):	$500 CDN
Network License (non-members):	$1000 CDN

To order contact the CWLS office at (403) 269-9366.

A high resolution copy of the latest newsletter is posted on the CWLS web site at www.cwls.org. For this and other information about the CWLS visit the web site on a regular basis.

Please forward this newsletter to any potentially interested co-workers. We would appreciate any feed back on anything you've read in the InSite and any suggestions on how this newsletter can better serve the interests of the formation evaluation community. Feel free to contact anyone on the CWLS executive with your comments.

How Many Acoustic Waves Can Dance On The Head Of A Sonic Log?

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Introduction

The discussion of acoustic wave theory and practice in the literature is exceedingly complex and confusing. This is partly because it is a complex subject and the sound waves are moving in a complex environment (the borehole, borehole wall, and rock with porosity filled with an unknown fluid mixture). It is also confusing because authors have used different terminology for the same acoustic waves. In some cases, there are at least six names for the same acoustic wave. In addition, there is a confusing mix of terminology taken from the "plane wave" environment at the Earth's surface (earthquake and seismic environments) and the very different cylindrical geometry of the borehole.

Many authors have not clarified the conditions of their experiments (eg. borehole size, tool size and construction material, energy source type and frequency range, velocity detection and calculation method, fluid-rock-borehole velocity contrasts). These factors affect which acoustic modes are transmitted. Conclusions drawn from one experiment will not necessarily apply to another with different assumptions.

The following material is my simplified version. It is intended as a tutorial only - not as a detailed theoretical treatise. The emphasis is on wireline logging, although LWD is mentioned briefly.

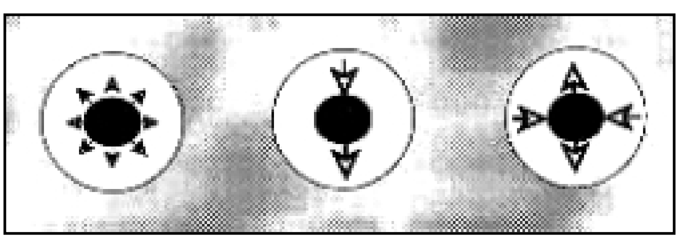

Figure 1: Direction of pressure waves from (left to right) monopole, dipole, and quadrupole sources (from Zemanek et al, 1991)

Energy Sources for Acoustic Logs

Acoustic log source types fall into three categories: monopole, dipole, or quadrupole, illustrated in Figure 1.

1. **Monopole sources** emit sound energy in all directions radially from the tool axis. They are sometimes called axisymmetric or radially symmetric sources. Commercial wireline sonic logging tools, from the earliest tool to the present-day, carry a monopole source along with two or more monopole receivers. This tool arrangement creates the conventional compressional sonic log that we are all familiar with.

   Sound energy from the source that reaches the rock at the critical angle is refracted (bent) so that it travels parallel to the borehole inside the rock. This energy is refracted back into the borehole, and strikes the receivers. The difference in time between arrivals at the receivers is used to estimate the travel time, or slowness, of sound in rock. Sound velocity is the inverse of slowness.

   In fast formations, this tool design can also receive shear waves generated in the formation, where some of the compressional energy is converted to shear energy. A fast formation is a rock in which the shear velocity is faster than the compressional velocity of the fluid in the borehole. A slow formation is a rock in which the shear velocity is equal to or slower than the fluid velocity.

   The monopole source also generates a shear wave on the borehole surface in fast formations, called a pseudo-Rayleigh wave. The converted shear and the pseudo-Rayleigh arrive at the monopole detector with nearly the same velocity and cannot usually be separated. Monopole sources also generate the Stoneley wave in both fast and slow formations. The low frequency component of the Stoneley is called the tube wave. More detailed descriptions of all wave modes are given later in this article.

2. **Dipole sources** and receivers are a newer invention. They emit energy along a single direction instead of radially. These have been called asymmetric or non-axisymmetric sources. They can generate a compressional wave in the formation, not usually detected except in large boreholes or very slow formations. They generate a strong shear wave in both slow and fast formations. This wave is called a flexural or bender wave and travels on the borehole wall (Figure 2).

   Unlike the pseudo-Rayleigh from a monopole source, which also travels on the borehole wall at near shear velocity, the flexural wave field is asymmetric.

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Acoustic Waves

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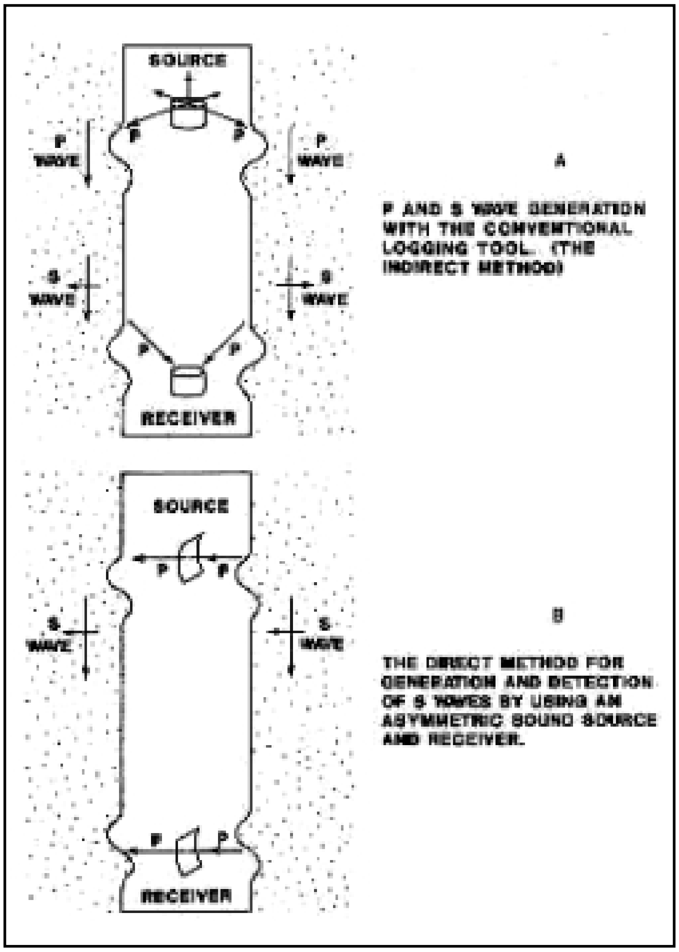

Figure 2: Shear wave propagation from monopole source (upper) and dipole source (lower) (from Zemanek et al, 1991)

Modern open-hole sonic logging tools carry both monopole and dipole sources and receivers so that compressional and shear arrivals can be recorded in slow and fast formations. The sources are fired alternately; the sound from one source will not interfere with the other.

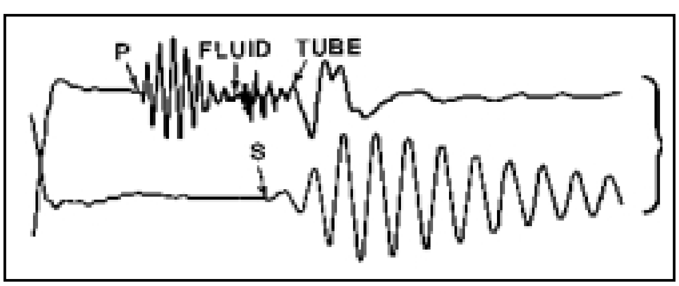

Figure 3: Monopole (upper) and dipole (lower) waveforms in a slow formation (from Zemanek et al, 1991)

Some modern sonic logging tools have two sets of dipole sources set orthogonally, with corresponding dipole receivers. Shear data can be recorded in two directions in the formation. These are called crossed-dipole tools. After suitable processing, the two acoustic velocity measurements are translated into a minimum and maximum velocity.

The ratio of these velocities is a measure of acoustic anisotropy in the formation. This is an important property in formation stress analysis, hydraulic fracture design, fractured reservoir description, and tectonic studies.

Figure 3 (upper) shows a waveform from a monopole source in a slow formation. There is a compressional wave (P) but no shear arrival. The dipole waveform (lower) at the same depth shows no compressional but good shear (S) arrivals. Notice that the shear wave arrives after the fluid wave (the definition of a slow formation).

In a fast formation, the shear arrival will be seen on the monopole waveform (Figure 5) as well as on the dipole waveform.

3. **Quadrupole sources** generate asymmetric pressure waves, called screw waves, which behave similarly to those of dipole sources. They can be used on open-hole tools, although no such tool is commercially available. They are more suited to the logging-while-drilling environment where recent developments have shown some success in measuring shear velocity. The quadrupole source generates quadrupole waves, which travel in the collar and the formation, the two being coupled through the annulus. At low frequencies the formation quadrupole travels at the formation shear speed. The quadrupole LWD tool collar is designed to be thick enough that the collar quadrupole mode is "cut off" (very highly attenuated) below some frequency chosen to be well above the frequency used for quadrupole logging, thus minimizing the interference with the formation quadrupole.

   While there are strong collar arrivals on monopole LWD tools, there have been monopole LWD sonic logs operating successfully for many years, using various mechanical and processing techniques to attenuate the collar arrival. For LWD dipole tools, the collar mode interferes with the formation dipole, forming coupled modes where the formation shear speed is difficult to extract.

Dispersion

The velocity of sound varies with the frequency of the sound wave. This effect is called dispersion. Most waves travel faster

Continued on page 12…

Acoustic Waves

continued…

at low frequency (normal dispersion) but tube waves are slightly reverse dispersive in fast formations and normally dispersive in slow formations.

Compressional waves have very little dispersion. The various wave modes used to measure shear velocity are very dispersive, which may account for errors in shear velocity on older logging tools, when high frequency sources were the norm. Today, tools are designed to work below 5 KHz for shear measurements, instead of 20 to 30 KHz on older tools. Typical theoretical dispersion curves for a particular velocity assumption are shown in Figure 4 to illustrate the problem. For larger boreholes and/or slower formations, the dispersion curves shift to lower frequencies.

Real Logging Tools

Modern sonic logs, often called dipole shear sonic logs, usually carry monopole and dipole sources, and generate the measured values for compressional, shear, and Stoneley slowness in different ways depending on the formation characteristics. Such a tool can give us all three measurements in both slow and fast formations.

Earlier tools, commonly called full-wave, array, or long spaced sonic logs, could give us all three measurements in fast formations but shear was not possible in slow formations. Shear could be estimated by a transform of compressional or Stoneley slowness, and this is still done today in many real situations where the dipole log is unavailable. Waveforms were recorded in digital form but were seldom preserved, so reprocessing is not usually possible.

Earlier still, conventional and borehole compensated sonic logs could provide compressional slowness values directly. Shear slowness in fast formations was derived by digitizing an interpretation of the waveform traces or a VDL display of the traces. Most of these tools were short spaced, so it was difficult to pick the shear as the tail of the compressional wave stretched into the shear region. Waveform traces or VDL displays were on film and difficult to process accurately.

Acoustic Transmission Modes

The monopole source generates several wave modes, some of which have been used more or less successfully, to estimate shear velocity. Other wave modes are mentioned in the literature and described here to help clarify terminology. The following comments deal primarily with the monopole wireline tool, but dipole and LWD are mentioned briefly to contrast important differences.

Monopole sources can develop both body and surface waves; dipole and quadrupole sources create only surface waves. Body waves travel in the body of the rock. Surface waves travel on the borehole wall or bounce from the wall to the tool and back to the wall. The surface waves are also called guided waves or boundary waves.

1. **Fast compressional waves,** also called dilational, longitudinal, pressure, primary, or P-waves, are recorded by all monopole sonic logs, beginning in the mid to late 1950's. They are the fastest acoustic waves and arrive first on the sonic wave-

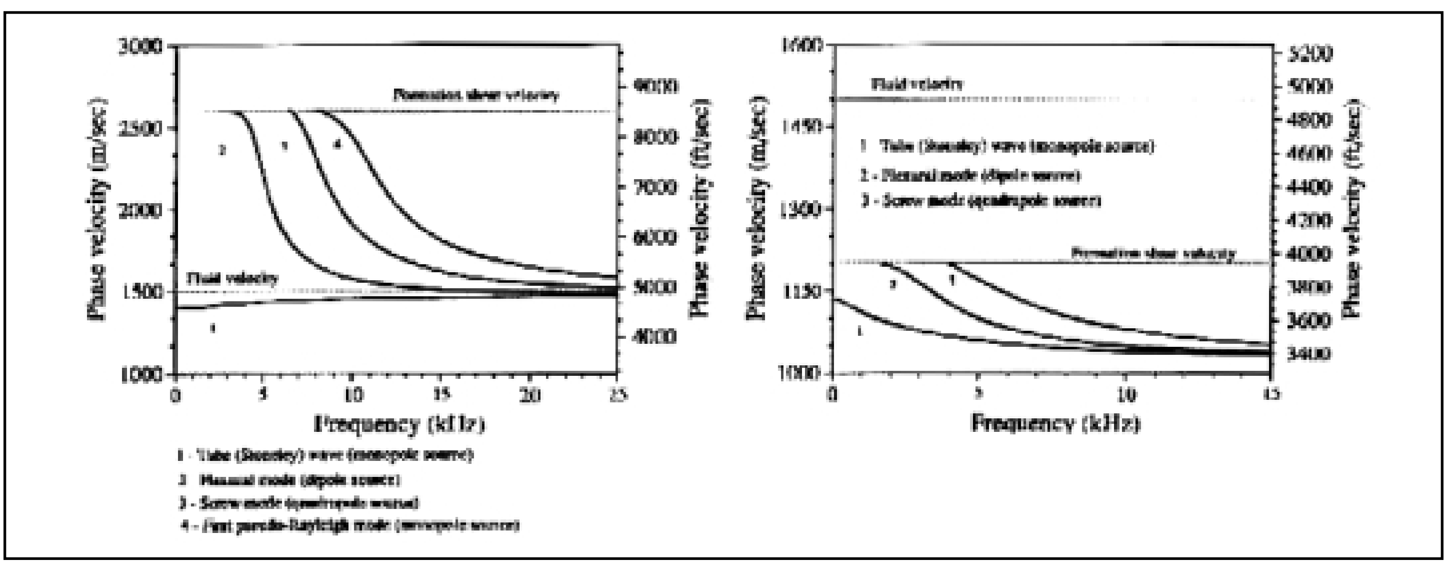

Figure 4: Shear velocity dispersion curves for fast (left) and slow (right) formations (from Zemanek et al, 1991)

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Acoustic Waves

continued…

train. Biot called these dilational waves of the first kind and are body wave. The velocity of this wave is related to the elastic properties of the formation rock and fluid in the pores. It has been used successfully for years as a porosity indicator.

The compressional wave is initiated by a monopole energy source and is transmitted through the drilling mud in all directions. Sound traveling at the critical angle will be refracted into the formation, which in turn radiates sound energy back into the mud, again by refraction. The sound waves refracted back into the borehole are called head waves. The compressional head wave is detected by acoustic receivers on the logging tool.

A dipole source generates a noticeable compressional wave in slow formations and in large boreholes, especially on tools running at higher frequencies. The wave is probably present in faster formations and smaller boreholes, but is below the detection level of most processing techniques (see Figure 3).

The velocity of the compressional wave does not vary much with the frequency of the wave. The frequency spectrum of the wave depends on the source frequency spectrum and is usually in the 10 to 30 KHz range.

An acoustic ray path is a line that traces the path that the sound takes to get from the source to the receiver. Compressional waves vibrate parallel to their ray path.

2. **Slow compressional waves** are transmitted, as well as the fast waves described above. It is called a dilational wave of the second kind by Biot. It is also a body wave and travels in the fluid in the pores at a velocity less than that of the fast compressional wave in the formation fluid. Its amplitude decays rapidly with distance, turning into heat before it can be detected by a typical sonic log. No pores, no fluid, no slow compressional wave. Although predicted by Biot in 1952, it was not detected in the lab until 1982 by Johnson and Plona. I am not aware of any practical use for this velocity in the petroleum industry.

   The slow and fast compressional waves as described above should not be confused with the slow and fast velocities found by crossed-dipole sonic logs in anisotropically stressed formations.

3. **Surface compressional waves,** also called leaky compressional, compressional "normal mode", or PL waves, follow the fast compressional wave. This is a surface wave from a monopole source and travels on the borehole wall. Amplitude varies with Poisson's Ratio of the rock/fluid mixture. It is present in both fast and slow formations.

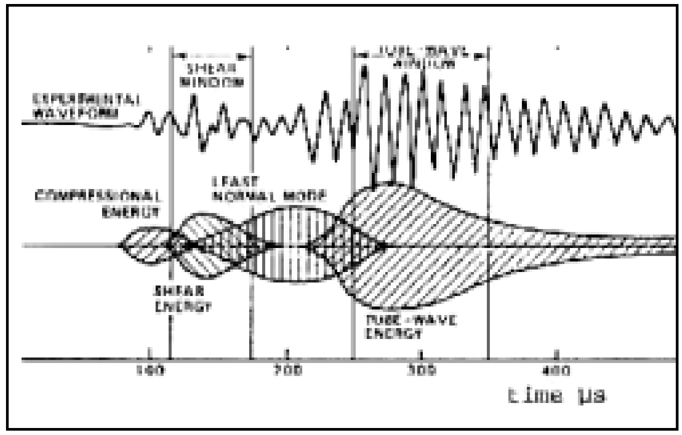

Figure 5: Waveform from a monopole source in a fast formation, showing some of the definitions used in the literature (FROM Paillet, 1991)

   The wave is dispersive, that is, low frequencies travel faster than high frequencies. It has velocities that range between the fast compressional wave through the formation (Vp) and the fluid wave in the borehole (Vf). The first arrival coincides with Vp and the balance of the wave shows up as a "ringing" tail on the compressional segment of the wavetrain. It usually decays to near zero amplitude before the shear body wave arrives. This monopole leaky compressional wave is strongest in very slow formations, large boreholes, and boreholes with significant near-borehole mechanical damage.

   The number of normal modes depends on source frequency; if frequency is too low, there will be no surface compressional wave. The first normal mode is sometimes called the least normal mode.

4. **Shear body waves,** also called transverse, rotational, distortional, secondary, or S-waves, are generated by conversion of the compressional fluid wave when it refracts into the rock from the wellbore. It converts back to a P wave when it refracts through the borehole to reach the sonic log detector. This wave is also a body wave. The refracted wave returning to the logging tool is called the shear head wave. Shear waves vibrate at right angles to the ray path.

   Monopole sonic logs cannot detect a body shear wave in a slow formation (Vs < Vf) because refraction cannot occur. The modern dipole sonic log can generate a shear wave in all formations, but the shear wave is actually a surface wave

Continued on page 14…

Acoustic Waves

continued…

called a flexural wave. A quadrupole source generates what is known as a screw wave with the same result.

When shear is missing on a conventional monopole log (and there is no dipole shear data), it can be estimated by a transform of the Stoneley wave velocity. However, the empirical formula ignores many of the minor variables, so the method is not very accurate.

Shear waves travel at a slower rate than compressional waves. Compressional velocity is approximately 1.6 to 1.9 times higher than shear velocity in consolidated rocks but the ratio can rise to 4 or 5 in unconsolidated sediments.

Shear velocity at sonic log frequencies is not very dispersive but the wave modes used to measure shear velocity are highly dispersive. Low frequency components are faster than high frequency components (see Figure 4). Because even low frequency logging tool sources have a moderate frequency spectrum, the shear body wave will show the "ringing tail" effect on the shear arrival.

Dispersion is important to us for another reason. Lab measured sonic velocities are made at high frequency, usually 1 MHz, and logs make their measurements at low frequency, 3 to 30 KHz, so comparisons of the results from lab and log measurements is difficult.

The shear wave velocity from a sonic log can be used to predict porosity just like the compressional wave. This is not true for 1 MHz lab measurements because the wavelength is too small to treat the rock/porosity mixture as a single coupled material.

Shear velocity is relatively independent of fluid type, so there is no appreciable gas effect on the measurement, unlike the compressional wave, which has a large gas effect. Combined with compressional wave velocity and density data, all the elastic properties of the rock can be computed. Similarly, at seismic frequencies, the shear wave is not significantly affected by the fluid type in a rock so, like the shear sonic log, there is no gas effect on the shear seismic section. Thus, a gas related bright spot (direct hydrocarbon indicator or DHI) on a compressional wave seismic section will have no comparable shear wave anomaly. In contrast, a lithology related anomaly will have a corresponding shear wave anomaly. Thus, it is possible to use shear wave seismic data to evaluate the validity of direct hydrocarbon indicators.

5. **Shear surface waves,** also called pseudo-Rayleigh, multiple-reflected conical, reflected conical, or shear "normal mode" waves, follow the shear body wave. They are a surface wave generated by a monopole source. They are also classified as a guided-wave. Monopole sonic logs cannot generate a surface shear wave in slow formations for the same reason that they cannot generate a body shear wave. Dipole sonic logs can generate a different form of shear surface wave, the flexural wave, but cannot create the shear body wave.

   These waves have also been called slow shear waves and shear waves of the second kind in a few papers. This usage should not be confused with the slow and fast shear velocity found by crossed-dipole sonic logs in anisotropically stressed formations.

   These are called pseudo-Rayleigh waves because the particle motion is similar to a Rayleigh wave on the Earth's surface, but it is confined to the borehole surface. It may also be called a tube wave as it travels on the tubular surface formed by the borehole wall. This latter terminology can be confusing because Stoneley and Lamb waves are also called tube waves.

   Surface waves on the Earth include Rayleigh and Love waves. Particles in Rayleigh waves vibrate vertically in elliptical retrograde motion and cause severe damage during earthquakes. They are also the principal component of ground roll in seismic exploration. Love waves vibrate horizontally, similar to a shear wave, and can be considered as a surface shear wave when found on the Earth's surface.

   The number of normal modes depends on source frequency; if frequency is too low, there will be no pseudo-Rayleigh wave. The first normal mode is sometimes called the least normal (shear) mode.

   This wave is dispersive, that is, low frequencies travel faster than high frequencies. The lowest frequency component arrives at shear velocity (Vs) and reinforces the shear head wave arrival, if one exists. The balance of the energy is dispersed over the interval between shear wave velocity (Vs) and fluid velocity (Vf).

   The Airy phase of the shear normal mode (pseudo-Rayleigh) occurs just after the fluid wave. It can distort the surface shear wave and make it difficult to determine shear velocity. It can also distort the fluid wave and the Stoneley wave arrivals. I am not aware of any practical use for this part of the waveform in the petroleum industry, but it is mentioned often enough in the literature to warrant this brief description.

Continued on page 15…

Acoustic Waves

continued…

In the absence of a shear head wave, which may occur due to attenuation, the onset of the pseudo-Rayleigh wave is used to estimate shear velocity (Vs). If the onset of the pseudo-Rayleigh is low amplitude, Vs may be chosen a little further along the waveform, resulting in a slower value than the correct Vs. When both surface and body shear waves are transmitted, the surface wave may overwhelm the body wave, resulting again in a slow Vs determination. This problem was common in the early days of hand digitized full wave sonic logs, before the advent of computerized shear picking.

If the source does not transmit low enough frequencies, the fastest surface shear wave will be slower than the corresponding body shear wave. If the log processing system picks the surface wave instead of the body wave, it will give a slow Vs. Service companies make an empirical correction for this on flexural dipole logs, but not on monopole shear logs, before presenting the log to a customer.

The Slowness-Time Coherence or STC velocity analysis method, a form of cross-correlation for picking velocity or travel time from sonic waveforms, minimizes this problem. The newest sonic logs use a dispersion corrected STC process. On older logs without the low frequency source, Vs is probably too slow even when STC is used.

If the rock is altered near the borehole wall due to drilling or chemically induced damage, the surface shear wave will be slower than the body shear, which travels in the undamaged formation. A recent paper shows clearly that two shear arrivals can be seen on waveforms from a dipole sonic in young unconsolidated sediment - one through the altered zone, one through the undisturbed formation.

There are lots of reasons why a log might give too slow a Vs. This problem has been the bane of fracture design and mechanical properties calculations for years. As the shear velocity technology gets better each year, we may be able to generate more reliable results.

6. **Stoneley waves** are guided waves generated by a monopole source that arrive just after the shear wave or the fluid compressional wave, whichever is slower. The wave guide is the annulus between the logging tool and the borehole wall. They are also called tube waves or Stoneley tube waves, in some of the literature.

   Various authors have shown the Stoneley wave in slow formations to be slightly dispersive (low frequency arrive faster than the high frequencies); in fast formations it is slightly reverse dispersive (high frequency arrives first).

   Amplitude of the Stoneley wave depends on the permeability of the rock, among many other things. The wave motion acts as a pump forcing fluid into pores and fractures. Higher permeability absorbs more energy, thus reducing amplitude. There is no simple equation for calculating permeability from Stoneley amplitude.

7. **Tube waves,** also called Lamb waves or "water hammer", are the low frequency component of the Stoneley wave (in theory, the zero frequency component).

8. **Fluid compressional wave** or mud wave is the compressional body wave from a monopole source that travels through the mud in the borehole directly to the sonic log receivers. It travels at a constant velocity with relatively high energy. When it occurs after the shear arrival (Vs > Vf), shear detection is relatively easy with modern digital sonic logs.

9. **Direct tool arrival** is sound that travels along the logging tool body. The wireline tool housing is slotted to make the travel path, and hence the arrival time, too long to interfere with other arrivals.

   In the LWD environment, the tool body cannot be slotted like an open hole tool. However, internal and external grooves, or holes filled with acoustically absorbent materials, are used to attenuate the tool body signal. This mechanical filter is designed specifically for the frequency content of the source. Separating the tool direct arrival is still difficult with monopole and dipole LWD sources. The LWD tool direct arrival is negligible at low frequencies for the quadrupole source when the collar wall is thick enough.

Conclusions

If you weren't confused before, you should be by now! Which modes are detected by the sonic log on your desk? Which source was used to generate them? Will the real shear travel time please stand up!

Calculating porosity from shear or compressional data, deriving mechanical properties for fracture design, calibrating shear and compressional seismic data to ground truth, and modeling AVO require a log that measures the real shear travel time. We

Continued on page 16…

Acoustic Waves

continued…

only get approximations in slow formations and maybe not much better in fast formations. Comparison of lab results to log data is meaningless due to frequency effects. Empirical corrections allow us to get by, but is this as good as the world can be?

References and Bibliography

1. Shear Wave Logging Using Multipole Sources, J. Zemanek et al, The Log Analyst, May 1991.
2. Qualitative and Quantitative Interpretation of Permeability Using Acoustic Full-Waveform Logs, F. L. Paillet, The Log Analyst, May 1991.
3. Acoustic Waveform Logging - Advances in Theory and Applications, F. L. Paillet et al, The Log Analyst, May 1992.
4. Shear Velocity Measurement in the Logging While Drilling Environment, X. M. Tang et al, The Log Analyst. Mar 2003.

These papers have long lists of further reading.

Ross is a Professional Engineer and member of the CWLS, with over 35 years of experience in reservoir description, petrophysical analysis, and management. Many thanks to Ross for allowing us to publish this article.

The Canadian Well Logging Society announces yearly awards for undergraduate and graduate students in engineering and earth sciences. The purpose of these awards is to raise interest and awareness of careers in Petrophysics and Formation Evaluation. Formation evaluation and Petrophysics are the studies of rocks and their fluids as they pertain to the oil and gas industry.

Three $2000 awards will go to students who submit thesis proposals that critically examine some aspects of well logging, formation evaluation or petrophysics. Award winners will be selected in April of each year.

An additional $5000 will be awarded yearly for the best thesis related to Formation Evaluation and submitted to CWLS upon graduation. The winner of this award will be invited at the expense of the CWLS to make a presentation at a lunch meeting of CWLS in Calgary. The final thesis can be submitted at any time in the year of graduation. The award winner will be selected in January of next year.

For more information on how to apply please visit www.cwls.org.

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Tuesday, June 1, 2004: 7:30 am to 4:00 pm
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Payments may be made online with credit cards only (*VISA, MC or AMEX*). To pay by check or money order, please make payable to **2004 CSPG/CHOA/CWLS Conference**. Send payment with registration form(s) to:

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CWLS/CSPG 2004 CONVENTION

Short Courses - CWLS

Resistivity and Water Saturation

Instructor: **David Herrick (Baker Atlas)**
Date: **25th May 2004**
Venue: **Baker Atlas Office, Calgary**
Participant limit: 40
Fee: $500

Course Content and Objectives: This course provides a new insight into the meaning and interpretation of resistivity data from both logs and cores. Using the concepts developed in the course, participants will improve the quality of log and core data interpretation, saturation evaluation and net pay determination. This course is designed for petrophysicists, geologists and engineers who desire to improve their interpretation skills with a better understanding of resistivity and saturation data.

Key Issues in Coring, Core Analysis and Rock Mechanics

Instructor: **Bob Skopec (Petrophysical Applications International)**
Date: **26th May 2004**
Venue: **Schlumberger Leduc Room, Calgary**
Participant limit: 40
Fee: $500

Course Content and Objectives: This course provides an understanding of how accurate reservoir rock attributes can lead to enormous economic benefits in all phases of petroleum reservoir development. Core analysis is the most tangible and direct means of determining critical reservoir parameters; however, it is one of the least understood reservoir evaluation methods. In this one day seminar, pitfalls in the evaluation of core data and comparison of various methods of data collection are reviewed. The vast difference between soft and hard rock core acquisition and laboratory pro-

Continued on page 18…

Short Courses - CWLS

continued…

tocol will be discussed. Integration and use of core data in reservoir engineering, geoscience evaluations, drilling and completion engineering, and petrophysical calibration is emphasized.

Acoustic Logging

Instructors: Denis Schmitt (Halliburton),
Doug Patterson (Baker Atlas),
John Walsh (Schlumberger)
Date: 27th May 2004
Venue: Schlumberger Leduc Room, Calgary
Participant limit: 40
Fee: $500

Course Content and Objectives: The objective of this short course is to provide both an overview and understanding of the theory, physics, and measurements of borehole acoustic devices. The course will discuss the basic system configurations of the older generation monopole devices, still being utilized, as well as the new generation mulitpole and cross-dipole systems more commonly used. The critical issues of log quality control and the borehole environmental effects will also be covered. The course focus will be the application and limitations of the measurements from these devices in petrophysical, geophysical, and reservoir engineering disciplines using real-world examples.

Log-Core Integration

Instructors: David James, John Nieto, Ross McLean
(Anadarko Canada Corp)
Date: 28th May 2004
Venue: AEUB (CRC)
Participant limit: 25
Fee: $400

Course Content and Objectives: This course provides an in-depth look at the integration of wireline log response and rock lithofacies as seen in core. The course instructors will take several carbonate and clastic formations at the Core Research Centre and demonstrate that these can be subdivided based upon log response. This classification leads to a reservoir 'facies' curve which can be used directly in shared Earth Modelling, petrophysical evaluation and reservoir engineering. Course attendees may be Geoscientists, Petrophysicists or Reservoir engineers. A basic knowledge of core lithofacies description and wireline log response would be an advantage, but is not essential. By the end of the day, attendees will have a better appreciation of techniques of integrating core description and wireline logs into their daily workflow.

The Integrated Solution in Coal Bed Methane Reservoirs

Instructors: Barry Ryan (BC Ministry),
Satyaki Ray, Joseph Frantz, Charles Boyer,
Salman Khalid (Schlumberger)
Date: 28th May 2004
Venue: Schlumberger Leduc Room, Calgary
Participant limit: 40
Fee: $500

Course Content and Objectives: The objective of this short course is to provide a brief overview of Coal Geology, Formation evaluation and Coal bed Methane (CBM) reservoir engineering basics with special reference to Canadian coals (BC and Alberta). This will include discussions on coal, coal permeability and stress relationships, CBM exploration methodologies, prospect evaluation and pilot design considerations. Topics of interest will be advanced formation evaluation in coals using borehole image logs, dipole sonics, array induction resistivity, geochemical logs and wireline testing for effective CBM stimulation , engineering and well planning practices . CBM resource assessment techniques for in-place gas content estimates will be discussed. Some Canadian and US coal bed methane case studies will be presented."

Principles of Formation Testing

Instructors: Steve Burnie, Andy Chen (Consultant)
Date: June 3rd 2004
Venue: Schlumberger Leduc Room , Calgary
Participant limit: 40
Fee: $400

Course Content and Objectives: This one-day course focuses on the application and interpretation of pressure gradients, from analyzing a single pretest, to making sense of a group of pressures for gradient analysis, to interpreting multi-gradient slopes for fluid contacts in single and multiwells. The importance of pressure data quality control and gradient/slope error analysis will be emphasized.

The course will also discuss: current WFT tool types in the market; gauge specifications; drawdown mobility; WFT programs; and procedures for the QA/QC of data, before, during, and after testing. Factors that might re-shape the gradient slopes, including wettability/capillary pressure effects and supercharging will be discussed as well.

This course is designed for Geoscientists, Petrophysicists or Engineers who want to gain a better understanding of the integration of pressure data into their daily workflow.

Volunteers Needed

2004 CSPG / CWLS / CHOA Convention Volunteers:

The Canadian Well Logging Society is currently recruiting volunteers to evaluate technical sessions for the joint CSPG / CWLS / CHOA Convention in June 2004.

For information regarding volunteer opportunities with the Canadian Well Logging Society, please contact:

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Richard Bishop
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Cell: 403-818-9437
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Publications are also looking for people to review papers for the InSite and for the Journal.
Please contact Mike Eddy at (403) 230-0630 or email meddy@wellsitegas.com or contact Robert Bercha at (403) 231-0249 or email Robert_Bercha@anadarko.com if you are interested.

CWLS Cartoonist

Do you have a creative side? Do your friends think you are funny and you know how to draw? If you fit this profile this might be your big break. We are looking for an artistic, humorous individual to create a comic strip for each InSite with an oil patch twist. Please contact Mike Eddy at (403) 230-0630 or email meddy@wellsitegas.com or contact Robert Bercha at (403) 231-0249 or email Robert_Bercha@anadarko.com for the offical position as the CWLS Cartoonist.

CWLS Archivist

Rosalie McDonnell of Talisman Energy has volunteered to act as the archivist for the CWLS. The society is renting space at the Glenbow Museum to house and protect artifacts of interest to the CWLS. If anyone has anything they would like to donate please contact Rosalie at (403) 231-2973 or email her at rmcdonell@talisman-energy.com.

Announcement - Talk is No Longer Cheap

Local talent has been underrepresented at our monthly technical luncheons. So, in addition to the usual President's Award for the year's best technical luncheon presentation there will be a new Vice-President's Award. This award, in the amount of $500, will be for the best luncheon talk by a Canadian-based speaker who is from an oil company or from a university or college.

Anyone who is considering presenting at a luncheon or who has a suggestion for an interesting topic should contact John Nieto at (403)231-0276 or john_nieto@anadarko.com.

Error Analysis of the Archie Equation Part II: Uncertainty in the Exponents M and N

Steve Burnie
Skeele Petroleum Resources Inc.
steve@rpcl.com

The Archie equation relates the water saturation in a reservoir to the measured variables: Rw (formation water resistivity), ϕ (porosity) and R_t (formation resistivity) through three constants: a, m, and n as follows:

$S_w = (aR_wR_t^{-1}\phi^{-m})^{1/n}$ 1

This equation can be expanded to give:

$S_w = a^{1/n}R_w^{1/n}R_t^{-1/n}\phi^{-m/n}$ 2

Since R_w, R_t and ϕ are measured from logs, there is inherent error or uncertainty in these values. This was discussed in my article in the last InSite. "a" is generally considered to have a constant value of 1.0, which allows R_t to equal R_w at 100% water saturation. On the other hand, the two variables m and n are dependant on reservoir properties (texture and wetability) and should be determined from core. When core is not available, it is common practice in the logging industry to assume that m = 2 and n = 2. This introduces uncertainty, as the actual value of these exponents could be quite different particularly if the reservoir is a vuggy carbonate.

In my previous article I discussed the effect of the uncertainty in the measured values (R_w, R_t and ϕ) on the value of S_w. In this article I will add to this the effect of the uncertainty in m and n. I will also include the term for the uncertainty in "a" for those who feel it necessary to vary this parameter (see the Humble equation for formation factor).

Error Due to n

Using equation 1:

Let $aR_wR_t^{-1}\phi^{-m} = C$

$\therefore S_w = C^{1/n}$

$\partial S_w/\partial n = dC^{1/n}/dn$

Let $u = 1/n$

$$
\begin{aligned}
\therefore \partial S_w/\partial n &= dC^u/du \bullet du/dn \\
&= C^u \ln C du/du \bullet du/dn \\
&= C^{1/n}\ln C \bullet d1/n/dn \\
&= -n^{-2}C^{1/n}\ln C \\
&= -n^{-2}(aR_wR_t^{-1}\phi^{-m})^{1/n}\ln(aR_wR_t^{-1}\phi^{-m})
\end{aligned}
$$

Expressing the differentials as finite differences, the error in S_w due to the uncertainty in n is:

$\delta S_w = -n^{-2}(aR_wR_t^{-1}\phi^{-m})^{1/n}\ln(aR_wR_t^{-1}\phi^{-m})\delta n$

Error Due to m

Using equation 1 again:

Let $aR_wR_t^{-1} = C$

$$
\begin{aligned}
\therefore S_w &= (C\phi^{-m})^{1/n} \\
&= C^{1/n}\,\phi^{-m/n}
\end{aligned}
$$

Taking the natural logarithm of each side gives:

$\mathrm{Ln}S_w = n^{-1}\ln C + -mn^{-1}\ln\phi$

Taking the partial derivative and using the chain rule and implicit differentiation gives:

$\delta \ln S_w/\delta S_w \bullet \delta S_w/\delta m = dn^{-1}\ln C/dm - n^{-1}\ln\phi dm/dm$

$\therefore 1/S_w \bullet \delta S_w/\delta m = 0 - n^{-1}\ln\phi$

$\therefore \delta S_w/\delta m = -S_w n^{-1}\ln\phi$

Expressing the differentials as finite differences, the error in S_w due to the uncertainty in m is:

$\delta S_w = -S_w n^{-1}\ln\phi\delta m$

Error Due to a

Also From Equation 1:

Let $C = R_wR_t^{-1}\phi^{-m}$

$\therefore S_w = (aC)^{1/n}$

$\therefore S_w = a^{1/n}C^{1/n}$

$$
\begin{aligned}
\delta S_w/\delta a &= C^{1/n}da^{1/n}/da \\
&\quad C^{1/n}n^{-1}a^{(1/n - 1)} \\
&\quad (R_wR_t^{-1}\phi^{-m})^{1/n}n^{-1}a^{(1/n - 1)}
\end{aligned}
$$

$\therefore \delta S_w = (R_wR_t^{-1}\phi^{-m})^{1/n}n^{-1}a^{(1/n - 1)}\delta a$

Expressing the differentials as finite differences, the error in S_w due to the uncertainty in a is:

$\delta S_w = (R_wR_t^{-1}\phi^{-m})^{1/n}n^{-1}a^{(1/n - 1)}\delta a$

Continued on page 21…

Archie Equation Part II

continued…

Whereas is the previous InSite, specified values for R_t, R_w and ϕ were used, it is now necessary to rederive the contributions to the error in S_w from the uncertainties in these variables using the general form of the Archie equation (equation 1 or equation 2).

Error Due to R_t

From equation 2:

$$\delta S_w/\delta R_t = a^{1/n}R_w^{1/n}\phi^{-m/n}dR_t^{-1/n}/dR_t$$
$$= a^{1/n}R_w^{1/n}\phi^{-m/n}\ n^{-1}R_t^{-(1/n+1)}$$

$$\therefore \delta S_w = -a^{1/n}R_w^{1/n}\phi^{-m/n}n^{-1}R_t^{-(1/n+1)}\delta R_t$$

Expressing the differentials as finite differences, the error in S_w due to the uncertainty in R_t is:

$$\delta S_w = -a^{1/n}R_w^{1/n}\phi^{-m/n}n^{-1}R_t^{-(1/n+1)}\delta R_t$$

Error Due to R_w

From equation 2:

$$\delta S_w/\delta R_w = a^{1/n}R_t^{-1/n}\phi^{-m/n}dR_w^{1/n}/dR_w$$
$$= a^{1/n}R_t^{-1/n}\phi^{-m/n}n^{-1}R_w^{(1/n-1)}$$

$$\therefore \delta S_w = a^{1/n}R_t^{-1/n}\phi^{-m/n}n^{-1}R_w^{(1/n-1)}\delta R_w$$

Expressing the differentials as finite differences, the error in S_w due to the uncertainty in R_w is:

$$\delta S_w = a^{1/n}R_t^{-1/n}\phi^{-m/n}n^{-1}R_w^{(1/n-1)}\delta R_w$$

Error Due to ϕ

Using equation 2:

$$\delta S_w/\delta\phi = a^{1/n}R_t^{-1/n}R_w^{1/n}d\phi^{-m/n}/d\phi$$
$$= -a^{1/n}R_t^{-1/n}R_w^{1/n}mn^{-1}\phi^{-(m/n+1)}$$

$$\therefore \delta S_w = -a^{1/n}R_t^{-1/n}R_w^{1/n}mn^{-1}\phi^{-(m/n+1)}\delta\phi$$

Expressing the differentials as finite differences, the error in S_w due to the uncertainty in R_w is:

$$\delta S_w = -a^{1/n}R_t^{-1/n}R_w^{1/n}mn^{-1}\phi^{-(m/n+1)}\delta\phi$$

In summary, the error in the water saturation is calculated as the following sum:

δS_w Total $= -n^{-2}(aR_wR_t^{-1}\phi^{-m})^{1/n}\ln(aR_wR_t^{-1}\phi^{-m})\delta n$ .... due to error in n

\+ $-S_wn^{-1}\ln\phi\delta m$ .... due to error in m

\+ $(R_wR_t^{-1}\phi^{-m})^{1/n}n^{-1}a^{(1/n-1)}\delta a$ .... due to error in a

\+ $-a^{1/n}R_w^{1/n}\phi^{-m/n}n^{-1}R_t^{-(1/n+1)}\delta R_t$ .... due to error in R_t

\+ $a^{1/n}R_t^{-1/n}\phi^{-m/n}n^{-1}R_w^{(1/n-1)}\delta R_w$ .... due to error in R_w

\+ $-a^{1/n}R_t^{-1/n}R_w^{1/n}mn^{-1}\phi^{-(m/n+1)}$ .... due to error in ϕ

Each error term is considered to be positive in accordance with standard procedures for calculating error (Baird, 1964).

In the last InSite two examples of S_w calculations were given for a clastic reservoir and the errors determined for uncertainties in R_t, R_w and ϕ. I will now add to these examples the uncertainty in m and n. "a" was considered to be a constant, with a value of 1, and therefore have no uncertainty. Runs were made with both m and n assigned an error of ± 0.1 and ± 0.2. The results are shown in Table 1 and Table 2. Table 1 lists the param-

Table 1: Values and Associated Errors for Archie Equation Examples

Case #	n	m	a	R_t	R_w	f	S_w	dn	dm	da	dR_t	dR_w	df
1a	2.0	2.0	1.0	200	0.026	0.18	0.06	0.1	0.1	0	10	0.002	0.01
2a	2.0	2.0	1.0	1000	1.8	0.12	0.35	0.1	0.1	0	100	1	0.01
1b	2.0	2.0	1.0	200	0.026	0.18	0.06	0.2	0.2	0	10	0.002	0.01
2b	2.0	2.0	1.0	1000	1.8	0.12	0.35	0.2	0.2	0	100	1	0.01

Continued on page 22…

Archie Equation Part II

continued…

Table 2: Calculated Errors in Water Saturation for the Examples in Table 1

	dS_w	dS_w	dS_w	dS_w	Rel Err	dS_w	dS_w	dS_w	dS_w	Rel Err
Case #	(dR_t)	(dR_w)	(df)	(Total)	S_w (%)	(dn)	(dm)	(da)	(Total)	S_w (%)
1a	0.002	0.002	0.004	0.008	11.9	0.009	0.005	0	0.022	34.3
2a	0.018	0.098	0.029	0.145	41.1	0.018	0.037	0	0.201	56.9
1b	0.002	0.002	0.004	0.008	11.9	0.017	0.011	0	0.036	56.6
2b	0.018	0.098	0.029	0.145	41.1	0.037	0.075	0	0.257	72.7

eters for the Archie equation and the associated errors. Table 2 lists the calculated errors in S_w.

Columns 5 and 6, in Table 2, show the error and relative error in the water saturation only due to the uncertainty in R_t, R_w and ϕ for the low S_w (1a) and high S_w (2a) cases. These values are slightly different from the values quoted in the last InSite due to an error found in one of the previous calculations. When the errors due to the uncertainty in m and n are added (Table 2, columns 11 and 12) the uncertainty in the water saturation for the two cases becomes unacceptable whether an error in m and n of 0.1 (1a, 2a) or 0.2 (1b, 2b) is used.

In the above example, you may consider the errors in the parameters of the Archie equation, shown in Table 1, to be unreasonable. For example, the error in R_w of ± 1.0 seems unreasonably high. R_w would then vary from 0.8 to 2.8, which corresponds to a salinity that varies from about 2000 ppm to 90000 ppm. Variations this great can occur in recharge areas such as west of the Sierra Gas Pool in British Columbia and in Saskatchewan where recharge from low salinity Cretaceous clastics mixes with high salinity formation water from Mississippian carbonates. Perhaps you may feel that an error for m of ± 0.2 is unreasonable. However, whatever the error, I maintain that you should understand the impact that it has on your results. For example, in the low water saturation case (1b), S_w has a value of 0.06 ± 0.04. S_w can therefore vary from 0.02 to 0.10, which means that the gas saturation can vary from 0.98 to 0.90 (98% to 90%). This is only a variation of 8%. However, at values of high water saturation (2b), S_w can vary from 0.61 (0.35+0.26) to 0.09 (0.35-0.26). Therefore, the gas saturation can vary from 0.39 to 0.91 (39% to 91%). This is a considerable uncertainty.

Narrowing the uncertainty in the parameters of the Archie equation equates to spending money. When the error is unacceptable, it is worthwhile to make the extra expense and cut core and take water samples. When the error has little effect on your results, then there is little to be gained from narrowing the uncertainty. However, my point is, do make the effort to assess the error.

References and Bibliography

Baird, D.C. (1962) An Introduction to Measurement Theory and Experiment Design; Prentice Hall, Englewood Cliffs, New Jersey, 198 pp.

Steve Burnie is an Independent consultant who has his own company, Skeele Petroleum Resources Inc.

Editor's Note

For further reading on this topic see the following paper:

Hook, J.R. (1983) the Precision of Core Analysis Data and Some Implications for Reservoir Evaluation, SPWLA, Twenty-Fourth Annual Logging Symposium, June 27-30, 1983

Special Core Database

Members have free access to the Special Core Database. To gain access, visit the society's website at www.cwls.org and visit the Core Database page. From there members can request access. You will then be supplied a user name and password information necessary to access the special core site. To learn more about this database please contact the CWLS office at (403) 269-9366.

Canadian Well Logging Society

Wednesday, May 19th, 2004

CWLS Technical Luncheon Presentation
Fairmont Palliser Hotel 133 – 9th Avenue S.W., Calgary

Time: **12:00 pm (Cocktails at 11:30 am)**

Reservations By: **Friday, May 14th, (noon) - Call 269-9366 to Confirm a Seat**

Cost: **Members reserved meal (with confirmed seat): $25.00; Members at the door: $30.00**
Non-Members reserved meal: $30.00; Non-Members at the door: $30.00
(Special needs meals available with advanced booking only)

Topic: **A Triple Porosity Model for Petrophysical Analysis of Naturally Fractured Reservoirs**

Speaker: **Roberto Aguilera, Servipetrol Ltd.**

Abstract:

The analysis of vuggy and fractured reservoirs has been an area of significant interest in the past few years. Several researchers have studied the characterization of these reservoirs using dual porosity models (matrix and fractures, or matrix and vugs) and have looked for means of estimating values of the dual porosity exponent *m* for use in calculations of water saturation.

There are instances where the reservoir is composed mainly of matrix, fractures and non-connected vugs. In these cases a triple porosity model appears more suitable for petrophysical evaluation of the reservoir. A new technique is presented for these types of reservoirs that is shown to hold for all combinations of matrix, fracture, and non-connected vug porosities. At low porosities, the fractures dominate and the *m* values of the composite system tend to be smaller than the porosity exponent of the matrix (m_b). As the total porosity increases, however, the effect of the non-connected vugs becomes more important and *m* of the triple porosity system can become larger than m_b. This research is inspired by the availability of modern magnetic resonance, micro-resistivity and sonic image tools that permit reasonable characterization of some complex reservoirs. The use of the triple porosity model is illustrated with an example.

*This presentation is based on the paper "A triple porosity model for petrophysical analysis of naturally fractured reservoirs" by Roberto F. Aguilera and Roberto Aguilera, Petrophysics, (March-April, 2004), p. 157-166.

Biography:

Roberto Aguilera is president of Servipetrol Ltd. in Calgary, Canada and an Adjunct Professor in the Chemical and Petroleum Engineering Department at the University of Calgary, where he concentrates in teaching about the theoretical and practical aspects of naturally fractured reservoirs. He is a petroleum engineering graduate from the Universidad de America at Bogota, Colombia and holds Masters and Ph.D. degrees in Petroleum Engineering from the Colorado School of Mines. He was an AAPG instructor on the subject of naturally fractured reservoirs from 1984 through 1996. He has presented his course on Naturally Fractured Reservoirs and has rendered consulting services throughout the world. He is a Distinguished Author of the Journal of Canadian Petroleum Technology (1993 and 1999), a recipient of the Outstanding Service award from the Petroleum Society CIM (1994) and a Society of Petroleum Engineers (SPE) Distinguished Lecturer on the subject of Naturally Fractured Reservoirs (2001-2002).

Notes: Please forward this notice to any potentially interested co-workers. Thank you.

Please see the CWLS Website at www.cwls.org for information regarding a Corporate Network License for the recently published CWLS Formation Water (RW) Catalog CD.

Canadian Well Logging Society

Wednesday, June 9th, 2004

CWLS Technical Luncheon Presentation
Fairmont Palliser Hotel 133 – 9th Avenue S.W., Calgary

Time:	**12:00 pm (Cocktails at 11:30 am)**
Reservations By:	**Friday, June 4th, (noon) - Call 269-9366 to Confirm a Seat**
Cost:	**Members reserved meal (with confirmed seat): $25.00; Members at the door: $30.00** **Non-Members reserved meal: $30.00; Non-Members at the door: $30.00** **(Special needs meals available with advanced booking only)**
Topic:	**Formation Damage Issues Impacting The Productivity Of Tight Gas Producing Formations**
Speaker:	**Brant Bennion, Hycal Energy Research Laboratories**

Abstract:

Very low in-situ permeability gas reservoirs (Kgas <0.1 mD) are very common and represent a major portion of the current exploitation market for unconventional gas production. Many of these reservoirs exist regionally in Canada and the United States and also on a worldwide basis. These reservoirs have many unique challenges associated with the drilling and completion practices required in order to obtain economic production rates. Formation damage mechanisms affecting these very low permeability gas reservoirs, with a particular emphasis on relative permeability and capillary pressure effects (phase trapping) will be discussed in this presentation. Examples of reservoirs prone to these types of problems will be reviewed, and techniques that can be used to minimize the impact of formation damage on the productivity of tight gas reservoirs will be presented.

Biography:

Brant Bennion received B.Sc. and Ph.D. degrees in Chemical Engineering from the University of Calgary and has been involved in researching formation damage mechanisms in oil and gas reservoirs for over 25 years. Brant has authored over 200 technical papers on the subject and has lectured extensively in over 40 countries. Brant has served as a distinguished lecturer for both the SPE and the Petroluem Society and is the receipient of numerous industry awards for technical services to the oil and gas sector. Brant is a registered professional engineer with APEGGA, and has been employed at Hycal Energy Research Laboratories for over 25 years. He currently serves as Hycal's president, a position he has held since 1991.

Notes: Please forward this notice to any potentially interested co-workers. Thank you.

Please see the CWLS Website at www.cwls.org for information regarding a Corporate Network License for the recently published CWLS Formation Water (RW) Catalog CD.

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 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.

NAME:...

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FEES

Please enclose initiation fees (Cheque, money order or Visa) with the application of membership and mail to:

Membership Chairman
The Canadian Well Logging Society
2200, 700 – 2nd Street S.W.
Calgary, Alberta T2P 2W1
Canada

UPCOMING EVENTS

May 19, 2004

CWLS TECHNICAL LUNCHEON PRESENTATION

Fairmont Palliser Hotel, Calgary, AB

Roberto Aguilera

A triple porosity model for petrophysical analysis of naturally fractured reservoirs

May 31 - June 4, 2004

ICE 2004 - CSPG - CHOA - CWLS Annual Convention

Round-up Center, Calgary, AB

www.cspgconvention.org

June 6 - 9, 2004

SPWLA 45th Annual Logging Symposium

Noordwijk, The Netherlands

www.spwla.org

June 9, 2004

CWLS TECHNICAL LUNCHEON PRESENTATION

Fairmont Palliser Hotel, Calgary, AB

Brant Bennion, Hycal Energy Research Laboratories

Formation Damage Issues Impacting the Productivity of Tight Gas Producing Formations

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For information on advertisement in the In Site and the Journal, please contact either of the publications co-chairs:

Mike Eddy (meddy@wellsitegas.com) at (403) 230-0630.

Robert Bercha (robert_bercha@anadarko.com) at (403) 231-0249

Discounts on business card advertisement for members.

Chilly winter morning over the mud tanks.

Photo Courtesy of Robert Bercha.

Making hole in the Hoadley Area, AB.

Photo Courtesy Robert Bercha.

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