CANADIAN WELL LOGGING SOCIETY

CWLS NEWSLETTER

in site 2

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President's Remarks

Welcome to the Fall edition of InSite. To be perfectly blunt, I thought that I had to only write one message for the year, and I believe that my limited literary capabilities were exhausted last Spring. That being said, this past six months has certainly seen a welcome change in fortune for our business. Let's all hope this current pricing hangs in there for the winter and well into next year.

Our society, perhaps more than most of the other oilfield professional organizations, has a very even mix of representation from both the service and production sectors of the business. Like a lot of CWLS members, I have worked for many years on both sides of the fence. While we are all aware of the inter-dependence that exists between producers and suppliers, commodity price swings, typified by the last year's events, effect each sector in somewhat different ways.

While a lot of producers can weather short-lived price slumps, the service sector has trouble making ends meet when the rigs stop moving. So even though we all generally sink or swim together, certain portions of the industry, and indeed various companies within each group, differ in how long they can tread water.

As the industry begins to reap the benefits of the recent higher prices, and the re-investment of profits leads to a busy winter drilling season we should keep in mind the fact that there will likely be a lot of new folks entering the field. Unfortunately, as long as we are in an environment of wild price swings, we will be forced to deal with a fluctuating workforce. Let's work together to enjoy a safe and profitable winter.

One of the projects that the CWLS is currently undertaking is the creation of an electronic form of the Rw Catalogue. We currently have a group working to define the methodology for updating our database and designing a user-friendly interface. As this work progresses we will be calling on the membership (both individual and corporate) to provide sponsorship and assistance in preparing the data. The Rw catalogue is one of the key contributions of the CWLS to the Canadian oil patch and your support and assistance will be needed when a member of the Rw Committee comes calling in the near future.

Finally, for all the photographers in the society (and I know there are lots) don't forget to get your entries in to the Photo-Contest which winds up in November

Running a Bond Log in the Dukhan Field, Qatar

Resistivity Measurements Prior To Invasion In Deep Foothill's Reservoirs in Western Canada Using the ARC5 LWD Tool

◆ Glen Sine - Shell Canada Ltd. – Foothills Business Unit
Steve Peach – Schlumberger of Canada

Evaluation of Rt in deep foothill's wells has proven to be difficult using conventional wireline logging techniques. It is suspected that mud filtrate invades much deeper than the depth of investigation of wireline resistivity tools – beyond 90 inches. Under these conditions it is difficult if not impossible to assess if a particular reservoir interval is hydrocarbon bearing - or deeply invaded. A decision was made to attempt to evaluate the reservoir's resistivity prior to invasion and to monitor the invasion process using an LWD resistivity tool – the ARC5 – while the well was being drilled. Application of this technology has improved the level of confidence the petrophysicist has in determining a true resistivity.

Introduction

Historically, petrophysicists in Shell Canada have had difficulty in determining a true resistivity in the deep foothill's carbonate reservoirs. The numbers of examples of "resistivity anomalies" have been too high. Attempts to recognize these "resistivity anomalies" have been inconsistent resulting in an unsatisfactory number of production tests of wet zones, a lack of confidence in the determination of gas saturation in these reservoirs and poor quality input into the earth models for these reservoirs.

The reservoirs are found in thin-bedded carbonates, at measured depths of 3000 – 4000m. and have relatively low porosity and low permeability. Average porosity is 5-6 %, with a porosity range of 3-15%. Matrix permeability is very low with core measured permeability ranging from a low of micro-darcies to a high of 1 milli-darcy. The reservoir beds range from less than 1m up to 5m in thickness and are surrounded by very resistive carbonates.

The Petrophysical Challenge

Resistivity is still a key input into determining saturation, as there is not a direct measurement of hydrocarbon saturation yet. The resistivity environment we have in our deep foothill's wells is likely one of the toughest in the world. It is characterized by large contrasts between Rt and shoulder bed resistivities, large contrasts between connate water resistivity and invading fluids, thin beds and deep invasion, stretching the measurement capabilities of the conventional wireline resistivity services. Even use of the latest galvanic technology, Baker-Atlas's HDLL and Schlumberger's HRLA, has proven unsatisfactory. Typical ratios of Rs/Rt are in the range of 100-1000 and the ratios of Rmf/Rw are greater than 3. Depths of invasion have been estimated to be 90 inches or greater. Deep invasion of a relatively fresh mud filtrate has the effect of masking wet zones and creating "resistivity anomalies." Attempts to mitigate invasion, obtain resistivity data before invasion, recognize the invasion and/or correct for it with existing current induction and galvanic or laterolog technology technology has not been satisfactory.

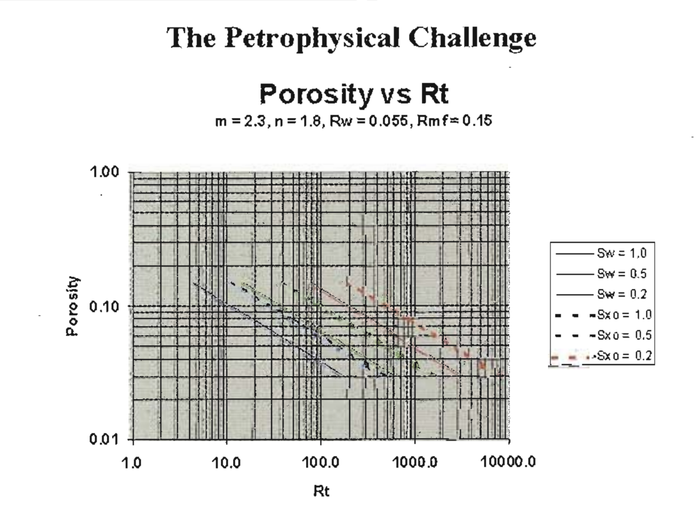

Figure 1.

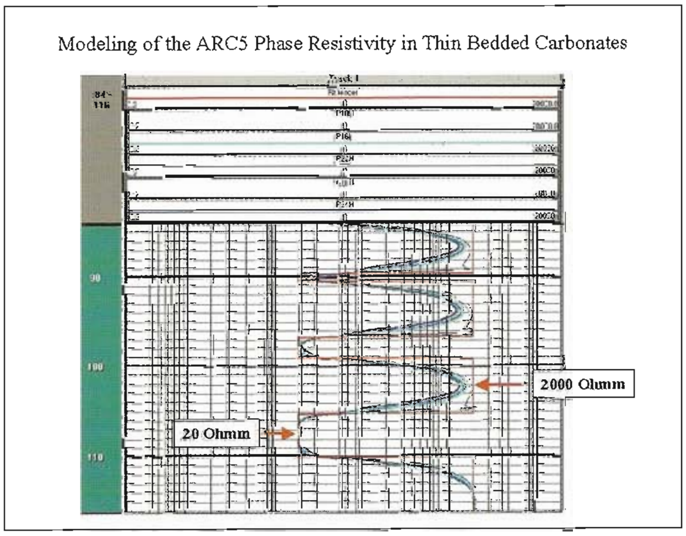

Figure 2.

To illustrate the problem of deep invasion on the resistivity response an Archie resistivity model has been used to generate lines of equal water saturation on a Pickett plot, a plot of porosity vs. resistivity in figure 1. The solid lines were generated using an Archie model and a Rw = 0.055 ohm-m. The dashed lines represent equal mud filtrate saturation assuming the connate water has been replaced with a mud filtrate of 0.15 ohm-m. Assume that the original water saturation was 0.50 (solid green line) and that during the drilling process the connate water is replaced by the invading mud filtrate resulting in Sxo = 0.50 (green dashed line). The result is that this Sxo = 0.50 line plots in the region of Sw = 0.10 (solid red line). If the interpretation of saturation were based on the invaded resistivity measurement the zone would be interpreted to be gas bearing. However, if the zone was tested it is unlikely we would produce any water free gas and we would have a "resistivity anomaly." Resistivity measured after invasion creates the potential masking of a wet or transitional zone.

The large uncertainties in resistivity have lead to testing "resistivity anomalies," because, without better knowledge, these "anomalies" have to be assumed to be hydrocarbon bearing. This has resulted in an unacceptable level of costly production tests ($500,000 to $1,000,000 Cdn.) of zones that prove to be wet.

Application of Anadrill's ARC5 Logging While Drilling Tool

One solution to the problem of deep invasion is to acquire the resistivity data prior to invasion taking place. Attempts at acquiring resistivity data prior to invasion with wireline tools have not been satisfactory. The idea of using LWD to obtain data prior to invasion is not a new idea. However, historically LWD has been considered too costly for these wells and there has been limited availability of the tools in Western Canada. Management needed convincing to invest extra money in acquiring the data with LWD.

To justify the extra investment, the value of Rt, prior to invasion was determined. In calculating the VOI (value of information) we assumed that the LWD resistivity would remove the uncertainty in Rt due to deep invasion. In the first well it was proposed to run the LWD resistivity tool, the VOI was determined to be in the order of $250,000 Cdn. Based on this VOI management approved running the tool.

Anadrill's ARC5 LWD tool was chosen because of the hole size (152.4mm) and availability. The ARC5 is housed in a 114.3mm collar for hole diameters from 146mm to 171.5mm. The choice of the ARC5 created a problem, a concern with the tool's capability to handle the relatively high resistivity environment. The tool is a high frequency array induction type tool with measurement limitations above 200 ohm-m. Keeping in mind that the objective of running the tool is to identify wet or transitional zones, which are generally less than 200 ohm-m; there was a desire to press on with the plan. In order to understand any potential problems, modeling of the tool's response in the expected resistivity environment was completed. The results of the tool modeling are shown in Figure 2. The modeling demonstrated the tool's capability of identifying thin conductive streaks in the middle of relatively thick resistive shoulder beds.

Example

The first well we ran the ARC5 in illustrates the effect of invasion on the resistivity measurement over time. The tool was logged while drilling and then logged while tripping at three different time intervals acquiring time lapse data. An AIT was run on wireline at total depth.

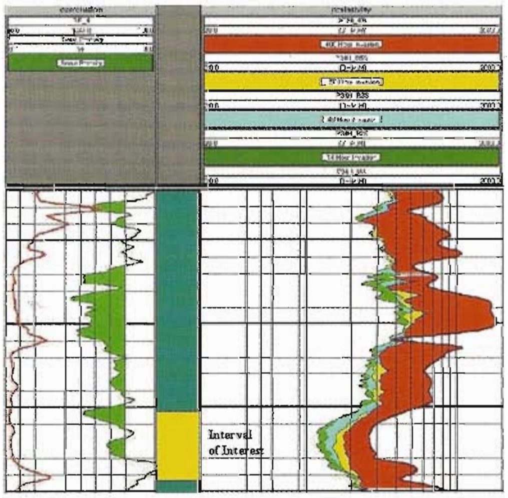

Figure 3.

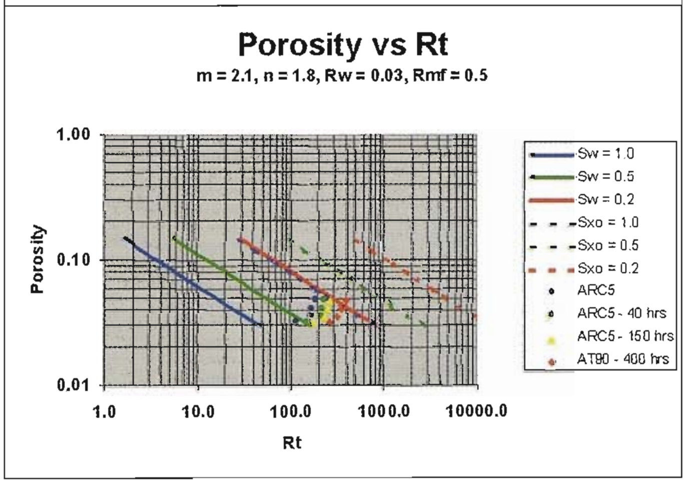

Figure 4.

In Figure 3 we have plotted the GR and interpreted porosity in track 1. In track 3 the deepest reading ARC5 phase resistivity curves are displayed along with the 90-inch curve from the AIT. The interval of interest is highlighted in yellow. The first ARC5 curve (black) was acquired within 1-2 hours of penetrating the reservoir and was acquired while drilling. The subsequent ARC5 resistivity curves were acquired while tripping at 14 hours (green), 40 hours (blue), and at 150 hours (yellow) after penetrating the reservoir. The AIT was acquired 400 hours (red) after penetrating the reservoir. The observed increased resistivity with time was attributed to invasion of the more resistive mud filtrate, replacing the less resistive connate water.

Figure 4 illustrates the consequence of deep invasion on the interpretation of the saturation profile. Figure 4 is a Pickett plot of the data from the interval of interest. Using the resistivity data acquired while drilling with the ARC5, the calculated water saturations were interpreted to be transitional and the interval would likely produce gas and water on test. Calculating the water saturation using the data acquired with the AIT, this same interval would have been interpreted as gas bearing. Based on the interpreted saturation profile from the ARC5 along with the post well geological model, the business unit decided the structure did not warrant any further investment of money and elected not to test. By not testing, the total planned investment in the well was reduced by approximately $900,000 Cdn.

ARC5 Repeatability in Impermeable Zones

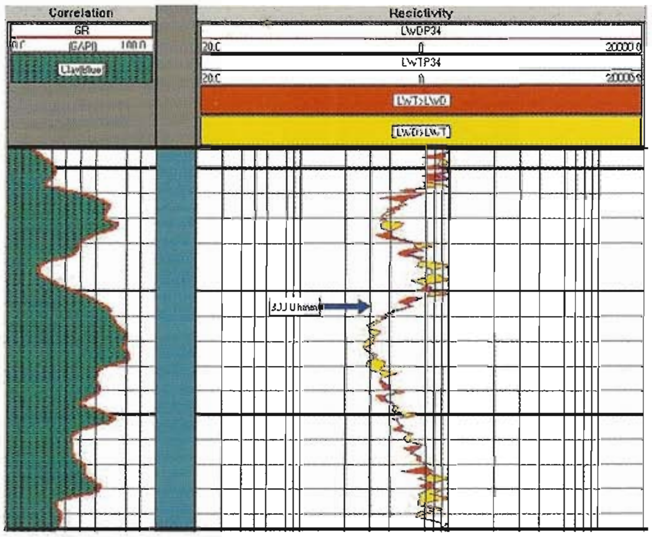

Figure 5.

Business Impact

The running of an LWD resistivity device has become a recommended strategy for the determination of an accurate Rt in our deep foothill's carbonate reservoirs. Generally, in a situation where uncertainty in the structure, spill points, or closure are part of the technical risk of the well, it can be shown that the value of the information from the LWD resistivity device will be in the order of $250,000 Cdn. If the tool is required to make a decision in a well at TD because the well did intersect a transition zone, that value of information will increase and be in the range of $500,000+ Cdn.

A LWD resistivity tool has been run in a total of 10 wells. The average cost for running LWD resistivity (ARC5 or CDR) is approximately $70,000 Cdn. per well. The cost per well has ranged from $32,000 - $133,000 Cdn. The total estimated tangible value of the acquired data is $1,450,000 Cdn.

Conclusions

• LWD Resistivity is not a panacea for all the resistivity problems in the deep foothill's wells of Western Canada but the uncertainty in Rt has been reduced and a significant saving in the cost of testing wells using the better data has been realized. The increased confidence in the saturation profile has increased the business teams' overall confidence in the earth models for these reservoirs leading to improved decision making about future investments.

• The ARC5 has proven to be capable of measuring resistivity effectively in this environment. Figure 5 is an example of the ARC5 run over shale and demonstrates the repeatability of the tool in a resistivity environment above 200 ohmm. The tool modeling and the repeatability of the tool in a relatively high resistivity environment has provided confidence that the tool is capable of measuring resistivities as high as 200 ohmm and resolving thin conductive beds in the middle of relatively thick resistive shoulder beds.

The Authors

Glen Sine received his Mining Engineering degree from Queen's University, Kingston in 1978. He joined Shell Canada in 1978 and has held various Petrophysical Engineering positions in Western Canada, Nova Scotia, and the Calgary Research Centre. He is currently Staff Petrophysical Engineer in the Foothill's Business Unit. He is a member of APEGGA. Email: glen.sine@shell.ca

Steve Peach received his Electrical Engineering degree from Royal Military College in 1976. He joined Schlumberger in 1981 and is currently an Alliance Development Engineer on assignment with Shell Canada in Calgary. He is a member of APEGGA, CWLS, and SPE. Email: peachs1@slb.com

Providing Solutions For the Shallow Gas Market

◆ Mark Rixon, Business Mngr., Wireline and testing

Schlumberger Oilfield Services' MAXPRO* initiative in Canada brings the latest technological solutions to production and completion services. New technologies recently developed by Schlumberger include: the PS Platform* new-generation production services platform; the Flo View* holdup measurement tool; Flagship; PatchFlex*, a through tubing casing patch using in-situ polymerization; the through tubing mechanical plug back took (MPBT); the cement mapping tool (CMT); the PowerJet* deep penetrating shaped charge; and the Pivot Gun, just to name a few.

With today's favourable gas prices, shallow gas is becoming a vibrant market, with more and more emphasis on cast-effective methods of identifying prospect zones and them bringing the wells into production with optimum results. This drive has initiated many cost-effective solutions within Schlumberger Oilfield Services in Canada such as the DSI* Dipole Shear Sonic Imager, CNL* Compensated Neutron Log Surveys and COILFRAC* Stimulation through coiled tubing, which complement each other in providing a total solution.

DSI Measurement

Sonic logs provide the same information in cased and uncased wells. Compressional transit times are converted to porosity and integrated for correlation with borehole seismic measurements. Combined with a neutron log run in casing, a through-casing sonic log can reveal lithology and identify gas. The DSI tool combines new dipole-based technology with the latest monopole developments, giving the best method available for obtaining borehole compressional, shear and Stonely slownesses in one system. (Slowness is the reciprocal of velocity and corresponds to the interval transit time measured by standard sonic tools.)

Dipole technology allows measurements of borehole shear in "soft" as well as "hard" rock formations. Limited by borehole physics, monopole tools detect only shear velocities that are faster than the borehole fluid velocity. Dipole tools overcome this fluid velocity barrier. The DSI tool has a linear array of eight receiver stations, a monopole transmitter and two dipole transmitters. The receiver array provides more spatial samples of the propagating wavefield for full waveform analysis. The arrangement of the transmitters and receivers allows measurement of wave components propagating deeper into the formation. Processing with the MAXIS* Multitask Acquisition and Imaging System displays a full wave and its component characteristics. The MAXIS high-speed array processor uses the slowness-time-coherence (STC) method to determine compressional, shear and Stonely slowness values. A choice of band-pass filters allows optimum use of the frequency range within a mode.

The process reliably provides unambiguous transit times, even in difficult borehole conditions. The resulting values are useful inputs for mechanical properties, formation evaluation and seismic applications.

In mechanical property analysis three important concepts exist: rock strength, earth stress and rock failure mechanisms. All three concepts contribute to explain or predict when where, why and how mechanical failure can occur in the formation. DSI waveform measurements are used to obtain quantitative information on dynamic elastic moduli. These moduli are critical in determining the strength of the rock and estimating the magnitude of the earth stresses within the formation. Several different rock failure models are considered when evaluation the mechanics of rock failure.

An accurate estimate of the height a hydraulic fracture is likely to achieve during a fracture treatment is critical in the fracture stimulation design. Besides hydraulic fracture height determination, the pump pressure and treatment fluid volumes needed to achieve the desired results can also be determined. The most important factor limiting vertical height growth of hydraulic fractures is in-situ stress differences. These differences can be estimated from dynamic elastic moduli computed from the DSI waveforms. Together with the petrophysical analysis, they yield a picture of the in-situ stress distribution in an around the hydrocarbon-bearing formations.

The example demonstrates a through-casing DSI and CNL gas-identification method and compares it to traditional open-hole neutron density or cased-hole neutron count rate techniques. DSI processing uses the significantly different effect of gas on compressional (P) and shear (S) waves. In gas, P-velocities decrease while S-velocities are relatively unaffected. This can be monitored on the log with the ration of P-velocity to S-velocity (VPVS). For typical Belly River porosites, VPVS values below 1.85 indicate gas-saturated sands. The combined cased-hole CNL and DSI data corroborate gas with its characteristic crossover in the gas zone from X09 to X17 m. If the zone were wet, there would be no crossover and VPVS would be higher.

The sonic compressional transit time (green curve, track 5) verified by openhole density, easily identified a low-porosity calcareous zone at X13.0 - X14.2 m. The CNL count rate gas detection technique (track4), used by itself, mistakenly identifies these low-porosity zones as gas. The combined DSI-CNL and VPVS techniques provide a powerful corroborative gas detection method to effectively discriminate true gas-bearing zones from tight or wet zones. After this zone was perforated from X09 to X15 and fractured, it produced 381,000 cubic feet of gas per day.

The combined DSI-CNL measurements play a large part in identifying the right zones for perforation and also contribute to a cost-effective, efficient hydraulic fracture stimulation design.

* Mark of Schlumberger

Schlumberger

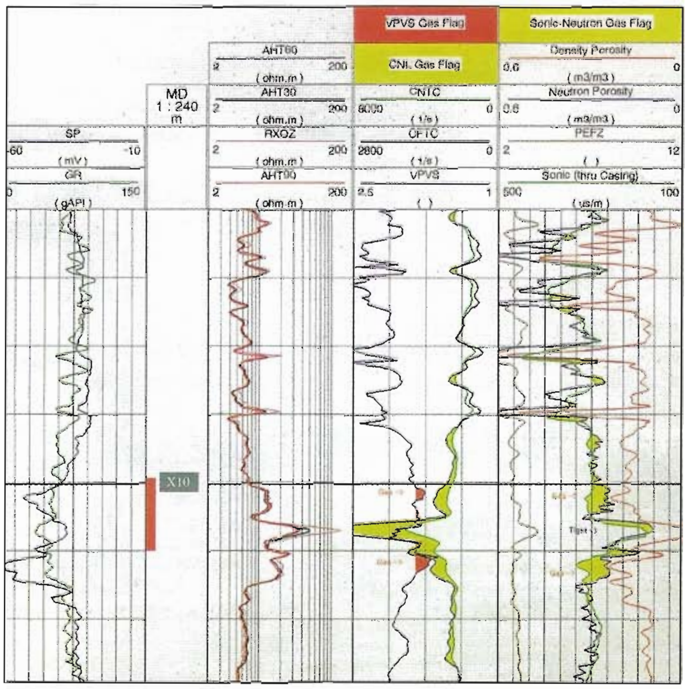

Figure 1.

PHOTO CONTEST: WIN A NEW DIGITAL CAMERA

A Picture is worth a thousand words... and a new Digital Camera!

The CWLS is excited to announce our first ever photo contest! We are looking for your photographs that tell the story of our exciting industry. Photos should be related the oil field and/or historically significant to the CWLS. The winner will receive a digital camera, courtesy of Schlumberger. Participants should send there entries to Pat Miller at the CWLS, along with a brief description about the photograph. Pictures can be color or black & white. All entries will become the property of the CWLS for use in it's publications. Deadline for entries is November 11th 1999. The winner will be announced at the December CWLS luncheon. Good luck! The CWLS is also looking for volunteers to assist in the judging of this exciting contest. If you are interested please contact Pat Miller.

Chairman's Remarks

It's fall again and a lot has changed in the past year. Last year at this time it was looking pretty dismal and I'm not talking about the weather! If all indications are correct, it looks like this winter is going to be a busy one. I hope that this renewed enthusiasm will translate into the contribution of articles for both the InSite Newsletter and 2000 Journal. Keep the CWLS publications in mind when you come across something interesting. Remember that the best articles are always based on real work situations! Thanks for your continued support of the CWLS and I hope everyone has a prosperous winter.

Pat Miller
Publication Co-Chairperson

Committee Members

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Committees Report

The CWLS committees have initiated a number of projects this year in order to meet the technical and service demands of our members for the coming millennium. These projects include:

1. Update of the CWLS Rw database by incorporating commercial available data of the Western Canadian Basin. This enormous task is spearheaded by Mr. Pat Miller of the Rw committee.
2. Setup of an editorial subcommittee to evaluate technical papers that are submitted to the InSite Newsletter and Technical Journal. The subcommittee will provide recommendations to the publication committee with regard to acceptance of papers which are of great interest and value to the petroleum industry. The subcommittee members are volunteers who are specialized in their areas of expertise.
3. New version of LAS 3.0. The LAS committee, chaired by Mr. Ken Heslop, will present the Beta version at the 1999 SPE annual symposium in Houston. The main feature of the new version is its ability to handle a wide variety of data type, ranging from array data such as FMI, NMR to core, geologic top, well test, directional survey, logging run information, etc.
4. Update CWLS website to incorporate the InSite Newsletters and Rw database.

The update of Rw database and CWLS website are evolving processes and will continue in the next millennium. To date, we are progressing with encouraging results. The editorial subcommittee will need additional volunteers, particularly in geophysics and core analysis, and I sincerely encourage you to join us and share your expertise with our CWLS readership.

Michael Cheng
Chairman of Committees

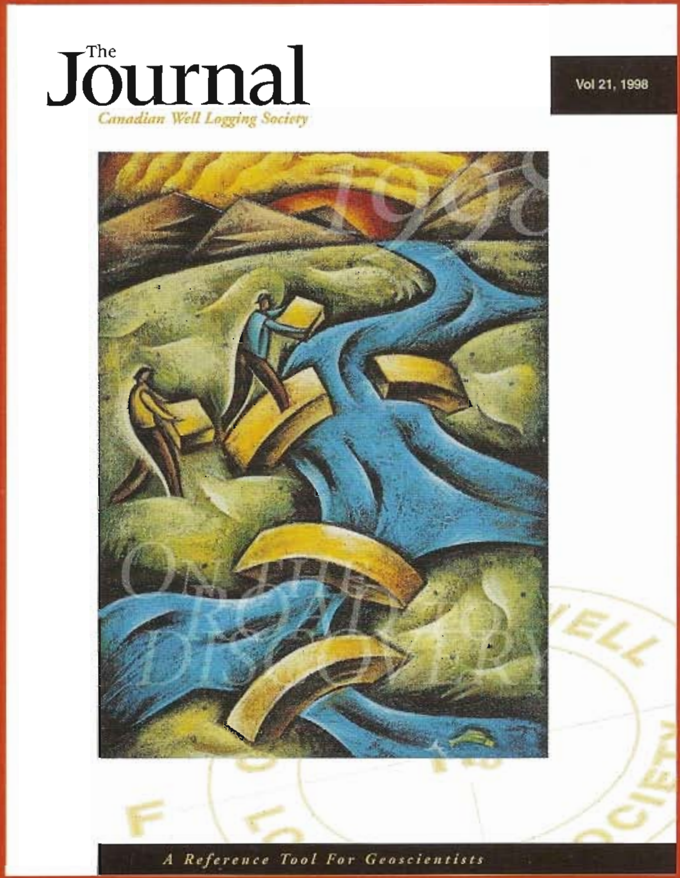
Rw Committee Report

Since joining the 1999 CWLS Executive I have had several calls asking when the Rw Catalogue will be updated. The Rw Catologue update has been initiated due to the interest expressed by the membership and a continued commitment of the CWLS society to supply a service to their membership.

The Rw Committee was formed with two objectives. The first is to convert the 1987 Rw Catalogue to computer media for either a CD ROM or website release. The second (more monumental task) is to update the Rw Catalogue with data from the past 12 to 15 years and release it using new millennium technology. In 1985, International Petrodata was kind enough to donate the required data for the Rw Catalogue. Once again they have stepped up to the plate to make the same generous offer. As you can imagine, this will be a very time consuming task. Therefore we would like to invite members to get involved with this very interesting and rewarding project. **Please contact me at landau@cadvision.com to sign up for the Rw Committee.**

Pat Miller
Rw Committee Chairperson

CALL FOR PAPERS



In Conjunction with GEO Canada 2000 we will be publishing the next issue of

The Journal
Canadian Well Logging Society