Whether we Push or Pull our Logs, What Should We Worry About ?
A Quick Review of Some Issues Concerning Log Quality Assurance and Quality Control.

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Introduction

This article will take a brief look at some of the issues and uncertainties surrounding the acquisition and use of open-hole electric log data, whether the well is logged by wireline, LWD or any other conveyancing method. It will review some of the reasons why logs are run and some of assumptions made about logs. It will try to show why the calibration and quality control of logging tools and log curves is so important. Logs are frequently the only safe and cost effective way of collecting accurate borehole data that can be used to meet well objectives and so they add considerable value to our business.

Electric logs can be acquired by a variety of conveyancing methods; wireline, wireline on drill-pipe, Logging While Drilling subs in the drill string (LWD), pumped down through drill-pipe on slick line or in memory mode, on the end of coiled tubing, or wired drill-pipe. But whether logs are acquired by pushing or pulling, they all have a number of common quality control and quality assurance (QC/QA) issues with which petrophysicists and other users of log data should concern themselves.

Why Do We Run Logs?

Electric logs are run in the vast majority of wells drilled by the oil and gas industry, but why are they run? For many, or most wells, the real objectives can be summed as;

- Is there any oil or gas down there?
- Where is it (depth/location)?
- How much is there?
- Can we get it out safely?
- Can we make any money?

for some wells we could add;

- can we inject water/gas/waste?
- can we use it to monitor fluid levels?

Logs should therefore be run to meet specific objectives defined during the well planning process. Logs then help us meet our well objectives by answering specific questions and needs;

- Identify lithology including reservoirs

- Identify fluid types and fluid contacts
- Quantify reservoir thickness
- Quantify fluid volume (porosity and saturation)
- Estimate productivity (permeability or ease of flow)
- Establish formation pressures and take fluid samples
- Understand structure and sedimentology
- Estimate changes in fluid volume and type
- Correlation with other wells
- Calibration to surface seismic data
- Predict rock strength
- ....etc…etc……

Of course logs are not exclusive in achieving these objectives, and it should be remembered that other borehole data such as formation pressures, core, cuttings, gas-logs and well-tests play an important role when used in an integrate formation evaluation programme.

What Do Logs Measure?

Now that we have established the importance of logs in meeting well objectives, we need to turn our attention to the QC/QA issues. What do the logging tools measure? The log headers say that we get data such as;

- Depth
- Borehole diameter
- Density
- Porosity
- Resistivity
- Gamma Ray
- Interval Transit times

But these aren't actually what the tools measure, in fact what they really measure are parameters such as;

- Lengths of cable or drill-pipe
- Time
- Voltages
- Count rates

The Density tool doesn't really measure bulk density, the Neutron Porosity tool doesn't really measure porosity, the Gamma-ray sonde doesn't really measure Shale volume. We use calibrations, inferences and interpretations to derive the parameters we want, and we must remember that there is always error and uncertainty getting from log measurements to the curves we require to meet our well objectives.

Calibrations and Verifications

The logging companies use calibration procedures to derive parameters that will turn the measured volts and count-rates into the meaningful curves that we can use.

The SPWLA describes Calibration as "the process wherein the zero and sensitivity of the measuring circuit is adjusted to meaningful units so that the recorded measurements will be accurate with respect to an industry standard, where sensitivity is the magnitude of the deflection of a curve in response to a standard signal".

The Wikipedia explanation is a little clearer, "wherein Calibration is the process of establishing the relationship between a measuring device and the units of measurement. This is done by comparing a device or the output of an instrument to a standard having known measurement characteristics".

The calibration and verification process in electric logs generally works in three steps. Initially there is a Primary Calibration of each tool, then a regular series of Master Calibrations made in the logging companies' bases, and finally verification checks are made before and after each logging job.

Primary Calibration is made by mathematical modelling of the tool responses and through physical measurements in test pits with well known physical properties. For example the API Neutron test pit using Carthage Limestone, Indiana Limestone and Austin Chalk, all with well characterised properties.

Primary Calibration is the process where the tool is exposed to a Calibrator standard, such as a test-pit. Coefficients, typically a gain and an offset, are derived and input so that the tool reads correctly in the test-pit. These coefficients are then applied to each tool in subsequent logging jobs.

The term 'Master Calibration' is used for the regular calibration of a logging tool in the workshop, usually monthly or quarterly. These are run to ensure that tool is operating within the tolerances of the calibration coefficients from the Primary Calibration. Tools are checked with a well characterised standard. For example, Bulk Density tools may use test blocks made of Aluminium and/or Magnesium. Neutron Porosity tools may use a water tank. Induction tools are hung in the air in a non-conductive frame and checked with a metallic loop of known resistivity. Some tools have internal devices built-in for calibration, for example Laterologs and Spectral Density tools.

The Wellsite Verifications are those checks performed at the wellsite to establish whether a logging tool is functioning properly. Verification is also known as an operational check. These verifications are generally done before and after each logging run. Verification is distinct from calibration and is often preformed with internal tool standards such as a weak permanent source on some Density tools.

Given that calibration and verification is fundamental to getting accurate logging measurements, it is beholden on all users of these data to ensure that the proper procedures have been successfully carried out. Fortunately, this is easy to do, because all these data should appear on the log field print.

The log header should always include information about each tool that was run as well as information about logging depths, depths of Total Depth (TD) and casing points, information about the drilling fluid, borehole temperature and any remarks concerning issues encountered during logging.

At the foot of the log field print, the 'calibration tail' should contain all the relevant information about the Primary and Master Calibrations and the verifications. These data can also be included in the final digital dataset. It is the job of a wellsite witness to make sure that all of these are performed correctly and that the information is captured and displayed.

Log Quality Control and Quality Assurance

Even with correct calibrations and verifications, there are further quality control checks that need to be applied to ensure good logs. During the logging process, a critical QC operation is to run a repeat pass of the logging tools, preferably over some interesting Geology within the logged section. Repeat runs should be made on every logging job, even on LWD jobs, unless there are valid safety reasons not to do so. Repeats are used to make sure that the logs are working properly and give a chance to collect data to correct logs if it is required. A wireline repeat should be at least 200ft or 60m. With LWD or drill-pipe conveyed logs, the repeat should be at least one stand of 90ft or 27m. The repeat can be run before the main run. It doesn't have to be run at TD, it can be over a zone of interest. It is important to compare main pass with repeat as soon as possible to give an opportunity for re-logging if a tool problem exists, before the tool string is out of the hole.

Further QC checks include monitoring the log responses in known formations and/or in casing to confirm that the tools responses are as expected and thus working properly. It is also good practice to record wireline logs whilst running into the hole, with pad tools closed, as a set of 'insurance' logs in case of any tool failures on the run out of hole.

Measurement Uncertainty

Even if the calibrations and the QC checks are all okay, just how accurate are the measurements? Each logging tool has a specific range of measurement uncertainty which will result in a definable range of accuracy. Nuclear processes are essentially random, but can be described with Poisson statistics. All tools use man-made instruments to measure the logging responses and are thus subject to accuracy limits. These are the published by the logging companies in their various tool catalogues and QC guides The ranges of accuracy of logging tools should be the concern of all users of logs, especially if you are running probabilistic type evaluations.

Some general observations on tool accuracy include; the Neutron Porosity is much more accurate at low porosity than at high porosity, and the opposite is true of Density logs. Induction resistivity is not very accurate above 200 Ohmms, for example the uncertainty for one published tool at 200 Ohmms is +/- 30 Ohmms and at 1000 Ohmms it is +/- 750 Ohmms.

What can go wrong?

Even with all the calibrations, verifications and initial quality assurance checks complete, there are still many things that lead to poor quality or even unusable logs. These are some of the things can effects logs;

- Hole size and shape
- Hole inclination
- Mud type, mud weight and mud salinity
- Mud cake and filtrate invasion
- Temperature, borehole and formation
- Logging speed
- Drilling rate of penetration
- Tool vibration
- Shoulder beds
- Bed thickness
- Bedding inclination.

'Environmental' (Borehole) Corrections are used to try to account for some of these borehole effects. However they are based on simplifications and assumptions such as the beds being perpendicular to the hole axis and a stepped mud filtrate invasion profile. There are different charts for each service company and they are not always available in computer applications. They can be used for single well and multiwell studies, to normalise logs so that evaluations can use field parameters. It should be remembered that they can't fix bad logs.

One of the main causes of poor logs is rugose or enlarged borehole, this affects most logs to a greater or lesser extent, for example;

- GR can read low
- Density reads low
- Neutron reads high
- Sonic reads slow and/or cycle skipping
- Resistivity maybe affected
- Micro-resistivity is affected

Always display a calliper log, if available, to show where these problems may occur. Rugose hole can effect LWD logs as well as wireline logs. Frequently these problems can't be corrected.

With wireline logs, bad-hole can also cause the tool string to stick. With tool sticking, the Tension log shows a saw-tooth effect, when the tool sticks the cable stretches, when tool works free, it jumps up and the result is that there are problems with the depths and the quality of all the logs in the tool string. The pad contact tools generally stick more often than slick tools. So, with wireline logs, as well as always displaying a calliper, we should always display a tension curve on wireline logs to properly QC your logs.

There are some QC issues with using logs in high-angle and horizontal wells, such as depth offsets crossing dipping beds, different depths of investigation between logging tools and the direction in which those tools are reading the formation.

LWD logs have a set problems unique to themselves. These include depth control as these logs are recorded in time and converted to depth based on Rate of Penetration (ROP) and accurate clocks, and it requires constant monitoring by the LWD engineers. Poor sampling can occur when ROP is too fast. Data gaps can occur with real-time data when there is interference with mud pulse telemetry, often due to other drilling parameters. Tool memory has been known to fail, or as have tool batteries.

With LWD resistivity logs in deviated boreholes, Polarization horns can be an issue. According the SPWLA Glossary, Polarization horns are the effect on a propagation resistivity of charge build-up at the boundary between two formation layers with different dielectric properties. In a vertical well with horizontal layers, the current loops generated by the tool in the formation are parallel to the layers and do not cross bed boundaries. However, with an apparent dip between borehole and formation, the loops cross the bed boundaries and generate a charge build-up at the boundaries. The charge build-up acts like a secondary transmitter that increases the measured resistivity. The result is a spike to high resistivity as the tool crosses the bed boundary. In deviated wells, polarization horns can be used to detect a bed boundary. But it makes for more difficult formation evaluation at the bed boundaries.

The spike increases with apparent dip and resistivity contrast between beds. The magnitude of polarization spikes varies with tool type and spacing, being larger for the propagation tools.

Depth is a fundamental measurement with logs, but it can be subject to error. Depth matching then becomes an issue when comparing different logging runs or wireline with LWD and using log data with core.

Conclusions

Logs are frequently the only safe and cost effective way of acquiring essential information from boreholes, so they add considerable value to our business, but we have to be aware of the issues and uncertainties involved in using log data. All users of log data should concern themselves with these issues, which include calibration and quality control, error and uncertainty, causes and manifestations of bad logs, and environmental (borehole) corrections.

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