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Cutting the line in wireline with an Autonomous Sonde

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SUMMARY

Rock core has long been one of the pillars of mineral exploration strategy. This strategy, however, is becoming less viable as the depth of exploration targets continue to increase. Exploration strategies based on physical and chemical attributes of the rock-mass measured in-situ have the best chances to deliver efficient exploration programs by providing new data channels that can be used to improve the models of the deposits. Unfortunately, the logistic costs of acquiring these data using conventional wire-line methods have precluded their widespread use in the mineral industry.

The autonomous sonde concept presented in this work drastically reduces the logistics costs of acquiring in-situ measurements. The autonomous sonde has been developed to integrate fully with the normal operations of current drill rigs. As such, it requires no specialised operator or equipment and no rig modifications.

In this work, we present the results of field trials of the autonomous sondes at two Australian field sites. In the first experiment, we show that a pressure transducer can be used to evaluate the position of the sonde and to depth register the natural gamma data. In the second experiment, we show data acquired when the autonomous sonde protrudes through the bottom of the drill string and is brought back to surface by pulling up the rods. The results show a good repeatability between logging runs and data quality compares favourably to traditional wireline data.

Key words: Auto Sonde, LWD, autonomous gamma logging.

INTRODUCTION

The increasing depth of potential mineral deposits is challenging traditional exploration strategies that have been core centric. Larger portions of exploration budgets are being spent drilling overburden or barren cover that has no economic value. This material, while often an integral part of the mineralisation system or its environment is often discarded because of insufficient resources to describe and characterise it during exploration drilling. As such, some of the contextual information about the deposit that could assist in refining exploration strategies is lost or poorly documented.

Wire-line logging was adopted by the petroleum industry because it provided an opportunity to modify drilling technologies to reach greater depths and enhance the information recovered from the reservoirs.

Logging while drilling (LWD) (e.g. Collett et al., 2012; Goldberg et al., 2003) emerged over time as a solution to the challenges imposed by ever deeper reservoirs and more complex settings. The real-time information generated by LWD systems reduce risk and improves the efficiency. Drillers are able to adapt to the conditions encountered downhole before they affect the safety of the personnel and the rig or jeopardise the well (McMonnies et al., 2007). In addition, the advent of LWD also significantly reduced the cost associated to rig standby that was required with wireline logging.

While the petroleum well represents a production asset, a borehole in the mineral industry represents an exploration cost. As such, the willingness to increase the investment per borehole has largely been responsible for the slow adoption. The autonomous sonde developed by the researchers of the Deep Exploration Technologies CRC has been designed to integrate seamlessly with normal drilling processes for conventional diamond drilling. While not as technologically advanced as most petroleum LWD tools, it is affordable to the mineral exploration industry and is expected to be widely adopted once refined.

The autonomous sonde is deployed inside the drill string once the borehole has reached its target depth. The sensor portion of the sonde engages passed the drill-bit and therefore has an un-obstructed view of the rock-mass. This method of deployment significantly simplifies the logistics of logging in unstable ground since the formation remains supported by the drill string. From this vantage point the autonomous sonde can log the entire borehole while the rods are pulled out of the borehole. To accomplish the same thing with traditional wire-line, the tool would have to make a return trip to the bottom of the borehole every time a rod is pulled. This is because the cable that is threaded through the drill rods makes it impossible to disassemble the string without damaging the cable. In practice this means that a large portion of the borehole may not be surveyed with traditional wire-line since the rig standby quickly becomes too onerous.

To speed up the research and development of the autonomous sonde concept the research team used the data acquisition system and surface data transfer system and protocols developed by Globaltech (a DET CRC affiliate and now part of the research team) for their core-orientation and borehole survey tools. This considerably shortened development time of the concept so that the research concentrated upon the sensors, depth registration and implementation issues without having to independently develop most of the electronic devices.

In the experiments presented here, we demonstrate that the natural gamma data can be depth registered by using the data from a pressure transducer. This depth registration is at the heart of the autonomous sonde concept. In this work we show that the repeatability of the depth encoding scheme is very good and that results obtained are on par with traditional wire-line data.

METHOD AND RESULTS

Before being lowered into the drill string, the autonomous sonde is initialised using a hand-held remote. This initialisation provides a system status and initialises the recording of data from the sensors. Once initialised, the autonomous sonde is lowered to the bottom of the drill string using a cable and winch system that is normally used for deployment of the core-barrel. Once at the bottom of the string, the autonomous sonde locks in place of the core barrel and the wire-line is pulled back to surface. The driller then proceeds with string recovery as per usual. The autonomous sonde is recovered from final rod once it reaches the surface and the data are downloaded via the same handheld that was used to initialise the sonde.

First validation of the depth encoding (sedimentary environment)

In order to test the possibility of using a pressure transducer for depth registration, our first experiment took place in a borehole drilled into a sedimentary environment. The well, WC05, was selected because it provided a good variation in lithological markers that could be identified from the natural gamma log. A traditional wire-line winch was used to deploy the autonomous sonde and to simulate the rod-pulls. The wire-line depth encoder provided reference data to compare our depth estimates and the gamma log provided a way to assess the repeatability of the measurements.

The increased pressure seen by the autonomous sonde as it was lowered in the well at a rate of 20m/minute is shown in Figure 1. The linearity of this curve shows that the response time of the pressure transducer and the acquisition system was able to keep up with the rapid descent. After the sonde touched bottom (1000 s) it was raised to 225 m (1150 s) and kept at that depth for 5 minutes. Again we can see that the transducer and the acquisition system behaved well as very little drift seem to be present on the flat portion of the record. After this extended pause at the bottom of the well, the autonomous sonde started its ascent at a rate of 4m/minute. We note that the natural gamma data acquired at 4 m/min data is of high quality and replicates that of a standard commercial Gamma log collected in this well.

In order to better determine the movements of the autonomous shuttle, we compute the time derivative of the pressure (dP/dt). When the sonde is stationary, the derivative is zero while it is positive when the sonde is descending and negative when it is ascending. This information is important because the drill string is stationary when the rods are added or removed and the rate of change allows us to evaluate the rate at which the rods are pulled.

The experiment that simulates rod pulling is shown in Figure 2. In this experiment for simplicity we simulated 10 m rods that were pulled at a rate of 10m/min. At every simulated rod a 10 seconds pause was simulated to correspond to the removal of the rod. The step wise nature of the pressure curve and dP/dt data clearly indicates the stop start points in the logging run. From this experiment we therefore concluded that the pressure transducer can be used to monitor the depth below the water table and that the time derivative provides information on the movement of the autonomous sonde.

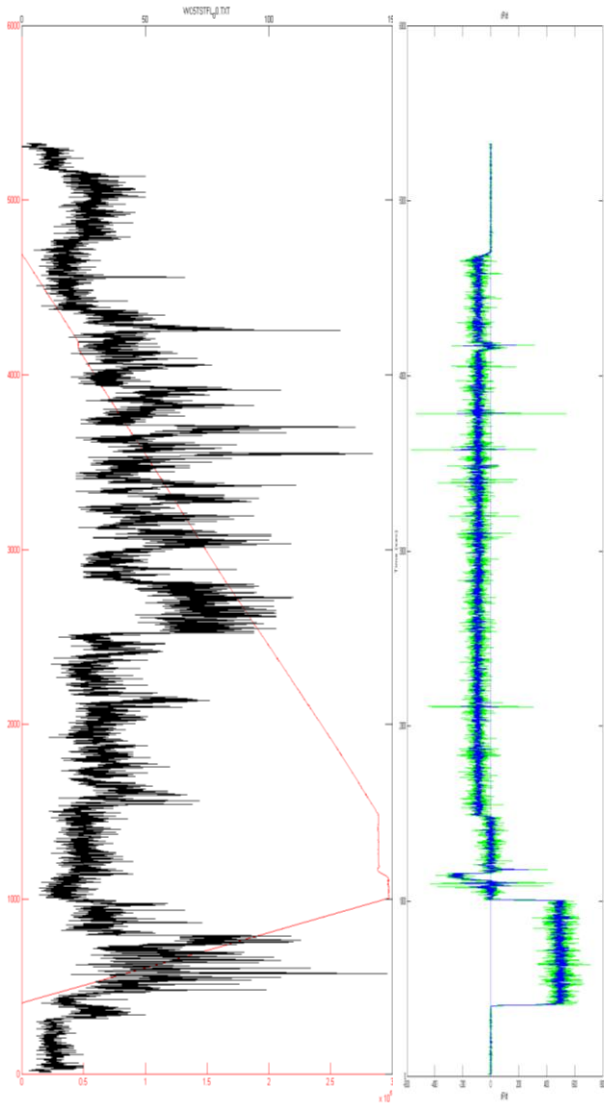

Figure 1. Sonde 01 test 25/02/2014 WC05, 20 m/min down 4 m/min up. TC Gamma black, Pressure (uncalibrated) red dP/dt Green and 3 sample average filter Blue. The vertical axis is in time (not depth) with start at the top and end of log at the bottom.

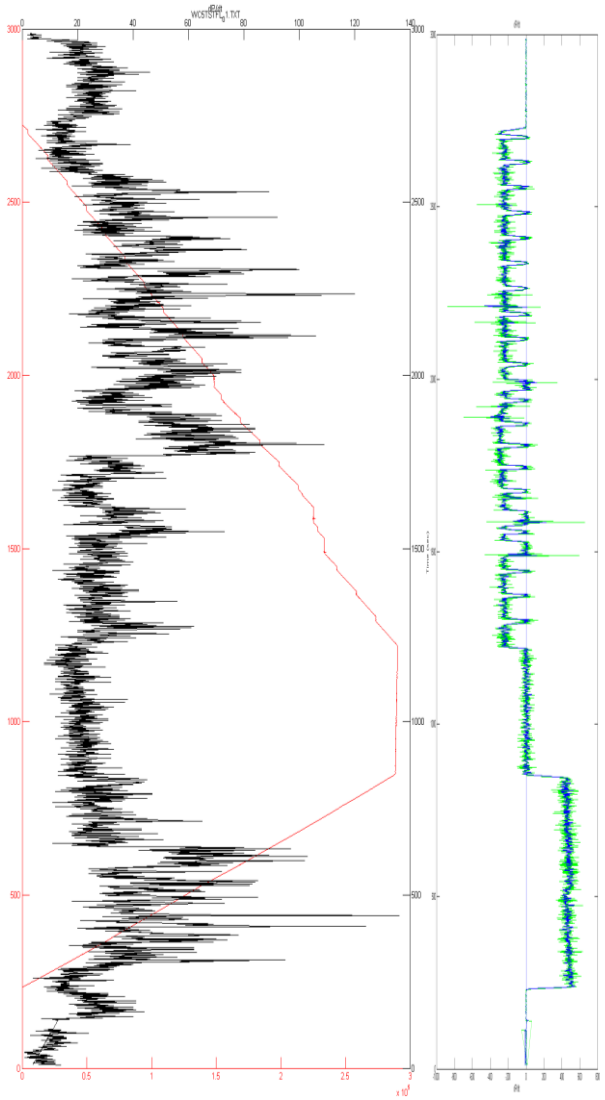

Figure 2. Sonde 01 test 25/02/2014, 20 m/min down 10 m/min up with 10 second stops every 10 m. TC Gamma black, Pressure (uncalibrated) red dP/dt Green and 3 sample average filter Blue.

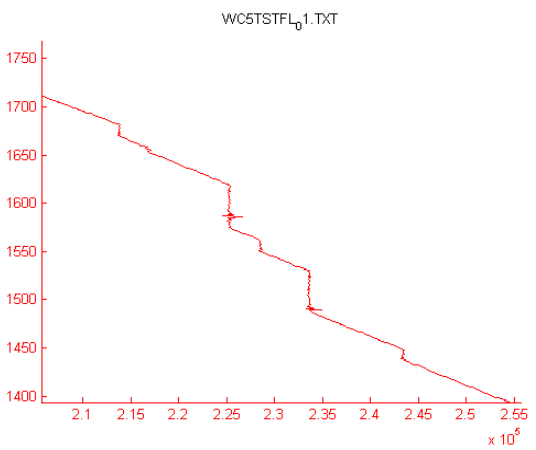

Figure 3. Magnification of a section of Pressure log during the 10 second at 10 m stops in Figure 2. Vertcal axis is time an dPressure on horizontal axis.

Field validation with a diamond rig

The second trial took place at the DET CRC research and training facility located in Brukunga, SA. This facility is located at a former pyrite mining operation (http://detcrc.com.au/programs/program-1/project-1-4/). For these trials, the autonomous sonde was lowered inside an HQ drill string and recovered by pulling up the rods. The natural gamma sensor protruded 0.9 m from the face of the bit.

During these trials, two different versions of the Autonomous sonde were trialled. While the mechanical assemblies were identical, the scintillator and electronics were two different versions. The results of the trials are illustrated in Figure 4.

In all, five different logging runs were completed during these trials. We see from the logs in Figure 4 that the scintillator in sonde 1 appears to be more sensitive than the one used in sonde 2. We can also see that the direction of logging seems to have little effect on the depth registration of the data. The gamma-logs show a good repeatability even if some of the curves appear to be under-sampled (eg. g_s1_2_down in Figure 4). This can probably be attributed to faster pull rates and is a characteristic that also appears on traditional wire-line logs when pull rates become too fast.

Table 1. **List of Sonde and Shuttle data sets**

File name / Run	Sonde	Direction	Depth (m)
g_s2_1_up	02	UP	60 to 33
g_s1_2_down g_s1_2_up	01	DOWN/UP	23 to 66.6; 66.6 to 23
g_s2_4_down g_s2_4_up	02	DOWN/UP	33 to 60; 60 to 33
g_s1_5_down	01	DOWN	23 to 66.6
g_s1_6_up	01	UP	66.6 to 23

CONCLUSIONS

In this work we have demonstrated that it is possible to use a pressure transducer for depth registration. The first experiment demonstrated that the pressure transducer and the associated acquisition system could cope with pull rates of up to 20m/min. It also showed that there was minimal drift when the sonde remains stationary. This controlled environment also allowed us to compare the natural gamma logs to traditional wire-line data and conclude that they are of equivalent quality. We also showed that the time derivative of the pressure data allows us to determine if the autonomous sonde is moving and the direction of this movement.

The second experiment allowed us to confirm that the mechanical assembly and the deployment mechanism works effectively for deployment with a diamond drill rig. We also showed that the logs acquired when the sonde is deployed at the bottom of the drill-string, as intended, are repeatable. Interestingly, logging direction has little effect on the logs. This is most likely due to the rigidity of the drill-string. In traditional wire-line logging the quality of the down-going log can sometime suffer when the tool's descent is slowed by the friction on the sidewalls. Future experiments should determine if the autonomous sonde can sustain this behaviour at greater drill-string lengths.

In conclusion, the autonomous sonde is an important innovation for the mineral exploration industry. By its integration with normal drilling operations, it removes the most important hurdle to the adoption of in-situ characterisation of the rock mass and paves the way for novel exploration strategies that will sustain the future of the mining industry.

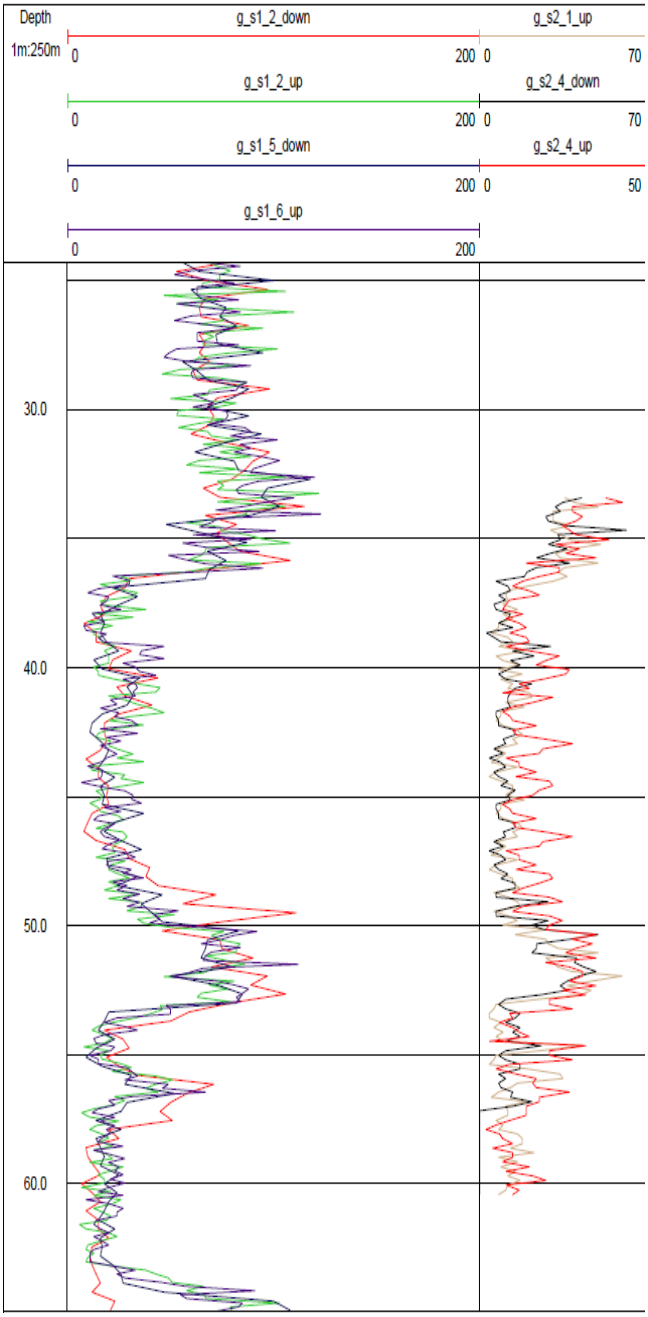

Figure 4. Gamma logs comparison between sonde 1 and sonde 2 for multiple deployments showing good repeatability.

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