Application of LithoScanner Logging Technology in CO2 Geological Storage Injection Well

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Abstract. The formation evaluation in a primary formation of a CO2 sequestration project in Western Australia has been very challenging due to the presence of glauconite and other iron rich minerals. The conventional method cannot handle the mineralogy effects, hence the accurate porosity, clay type and clay content cannot be calculated accurately. The latest generation in spectroscopy technology LithoScanner was brought to the project and run in well A for the first time in Australia. The tool has a high output pulse neutron generator and unique cerium-doped lanthanum bromide (LaBr3:Cr) gamma ray detector. This combination enables the tool to measure both inelastic and capture spectra for an expanded set of elements from that of previous-generation tools. We are measuring elements that make up more than 99% of the average abundance in the earth’s crust. Measuring the elements is the starting point to calculate minerals, matrix density and those are key to obtain accurate reserves estimates (porosity) and build an accurate petrophysical and reservoir model. For well A, the LithoScanner elements weight fractions are used in the Techlog QuantiElan module to solve mineralogy that includes quartz, K-feldspar, calcite, siderite, pyrite, illite, kaolinite, glauconite and chlorite. There is a very good agreement between the computed mineralogy and the mineralogy from core measurements. LithoScanner provides a continuous log of matrix density that is used as an input to porosity calculations. This formation evaluation based on Litho Scanner does not require the subjective inputs from the log analysis, but completely rely on the tool’s reading. It can be used for both simple and complex formation to obtain the good consistency and accurate answers.

Keywords: Log interpretation; LithoScanner technology; Mineralogy; CO2 Injection well; Matrix parameters.
1. Introduction
The study area is located in Gorgon field on Barrow Island (Figure 1). There are 9 CO2 injection wells at 3 drill centers, 4 pressure management wells, 2 initial and 2 future surveillance wells for monitoring CO2 movement. The perforation strategy is confirmed. Space on well pads for future wells if required, up to 18 CO2 injectors, up to 8 water producers. The injection target, distributary lobe system and weakly confined channel system is showing in figure 2. The evaluation objectives of project are including as 1) delivering required injectivity; 2) managing reservoir storage capacity 3) assuring CO2 reservoir containment; 4) mitigating risk to assets; 5) enabling monitoring and verification. While the goal of this paper only focuses on formation evaluation to confirm reservoir porosity, permeability and mineralogy from conventional logs and LithoScanner.

2. LithoScanner Logging Technology
The value of elemental spectroscopy logs is that they measure the rock matrix. Most sedimentary rocks are comprised of minerals like quartz, feldspar, micas, clays, and the carbonate minerals calcite and dolomite. The spectroscopy tools measure the elements that make up these minerals – these are the same elements that make up the earth’s crust. The first generation BGO detector spectroscopy tool ECS measured 80 weight percent of the crust, and that’s why they are so powerful in helping us unravel mineralogy. The next generation in spectroscopy technology LithoScanner fills in that 20% gap of elements ECS didn’t measure. Most notably, LithoScanner routinely measures Al (clay volume quantification) and Mg (calcite and dolomite distinction), in addition to the other elements. Now, LithoScanner measures elements that make up more than 99% of the average abundance in the earth’s crust. And, LithoScanner also measures carbon, which is a major element in carbon minerals and is obviously the major constituent of hydrocarbons and kerogen. LithoScanner Offers Elements from inelastic and capture spectroscopy (Al, C, Ca, Cu, Fe, Gd, K, Mg, Mn, Na, Ni, S, Si, Ti,…). It improves accuracy and precision. We can do that with really fast turnaround time (instead of waiting 4-8 weeks for core analysis). We can save operational time (logging 2x faster, avoiding extra rig up /rig down time related to chemical sources procedures and minimizing the number of runs thanks to the full combinability and the fact that we don’t need now 2 AmBe sources if we want to run it in the first run).
We are reducing risks because we don’t have a chemical source, we spend less time in the well and we are reducing the OD of the tool to 4.5” which can be key for small borehole sizes. Last, LithoScanner is suited for TLC and tractor, because we don’t have logging time limitations (the detector doesn’t require to be cooled down and the spectra doesn’t degrade with temperature).

The processing and interpretation workflow of LithoScanner logging data is shown in Figure 3. The first step is to collect capture and inelastic scattering gamma spectra in situ. The second step is spectrum stripping. The relative yield of elements is obtained by spectrum stripping. Stripping spectrum is realized by fitting the measured spectrum with the standard spectrum. The standard spectrum is derived from the laboratory. The third step is to convert the relative yield of elements to the absolute weight percentage of the element, which is achieved by oxygen closure technology. The oxygen closure technique is similar to the previous generation of element capture logging (ECS), but the difference is that LithoScanner requires oxygen closure of both captured and inelastic element yields. The last step is the interpretation process. Different minerals are selected according to the element content. The mineral composition, matrix properties and total organic carbon content of the formation are obtained by using the optimization processing technology.

![Figure 3. The processing and interpretation workflow of LithoScanner logging data](image)

3. Application of LithoScanner

3.1. Minerals

The mineral composition of the target layer includes calcite, chlorite, glauconite, illite, kaolinite, K-feldspar, pyrite, quartz, siderite. The minerals are complex. It is very difficult to identify lithology with conventional logging curves. Well A is the first well to measure LithoScanner logging data in this block. Coring and systematic analysis were carried out in the target formation. Figure 4 shows the comparison between the mineral composition obtained by LithoScanner and the results of X-ray diffraction (XRD) analysis in well A. From Figure 4, it can be seen that the main mineral components of quartz, k-feldspar, pyrite and clay content obtained by LithoScanner logging are in good consistency with the core analysis results. On the one hand, it can be seen that the formation lithology of this block is indeed very complex, and at the same time, it shows that the results of LithoScanner logging are highly reliable.
3.2. Porosity and permeability

One key parameter in the estimate of reserves is the continuous log of matrix density RHGE_INCP that is used as an input to porosity calculations (track 5 in figure 5).

\[ \Phi_T = \frac{\rho_m - \rho}{\rho_m - \rho_f} \]  
(1)

Where
- \( \rho_m \) - matrix density from LithoScanner (RHGE_INCP), g/cm\(^3\)
- \( \rho_f \) - formation water density, g/cm\(^3\)
- \( \rho \) - Bulk density, g/cm\(^3\)

The porosity result of formula 1 is in good agreement with that of TCMR (track 6 in figure 5).

Permeability is calculated by formula 2. Permeability is shown in track 7 of figure 5.

\[ K = 0.0474 \times e^{0.3451 \times \text{por}} \]  
(2)

Where:
- \( \text{por} \) - porosity, %

From figure 6, the range of porosity (2300-2528m) is 12%-30%, the median of porosity (2300-2528m) is 23.7%. The range of permeability (2300-2528m) is 10-1000mD, the median of permeability (2300-2528m) is 168.1mD. The last track is lithology of Well A derived using QuatiElan. Well A has good reservoir conditions.
4. Conclusion
LithoScanner logging combines the advantages of inelastic and capture gamma spectrum measurement. 99% of formation elements can be obtained by spectrum analysis. It provides an important means for detailed description of complex lithology reservoirs. Matrix density makes porosity calculation more accurate. The processing results of LithoScanner logging are supported by the core analysis data, showing a good consistency. LithoScanner provide more complete, more accurate and more precise result in first well (well A) of Gorgon field. Its performance has increased the oilfield's confidence in this technology.
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