BENEFITS OF HIGH-RESOLUTION CORE LOGS INTEGRATION IN CHARACTERIZING GAS SHALES CORES

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ABSTRACT

Gas shales cores characterization needs to be addressed and consolidated from the following perspectives: geology, petrophysics, geochemistry, and rock mechanics. This means specialties integration, where quick answers are needed, particularly for unconventional resources such as gas shales where lab measurements must be conducted on fresh-state, not dehydrated samples. Planning a quick and educated sampling campaign of fresh-state samples is therefore essential. A pre-requisite is to rank the core sections from the least to the most prolific ones so as to target representative fresh-state samples and avoid at-random sampling. This can be achieved in the laboratory by running high resolution logs on cores, with the advantage that such acquisitions are quick, thus preserving the core in its hydrated condition. Running high resolution logs on cores is a common practice in laboratories, but core logging rigs are mainly available for applications in geology, petrophysics, and rock mechanic. For geochemistry, a proprietary logging device has been developed, the LIPS, which allows acquisition of core total organic content at a centimetric sampling rate. In the present case study, the following suite of core logs has been run: Spectral GR, CT-Scan, LIPS, and rock-mechanic Scratch Test. We present how they can be used in characterizing parameters such as porosity, bulk and grain density, clays and organic content, and how good correlations are with the corresponding lab measurements performed on spots samples.

INTRODUCTION

One constraint on gas shales cores is that petrophysical measurements must be conducted on fresh-state samples. Running a preliminary set of high resolution logs on cores may be useful to precisely target representative sections since such acquisitions are quick (at least several 10's of meter logged per day) thus preserving the core in its hydrated condition (cores can be processed by metric section and sealed back immediately). Some core logs, e.g. the Computed Tomography (CT) scanning, even have the ability to visualize directly inside the inner core barrel sleeve, thus making it possible to characterize the core sections without risk of dehydration. We present a case study where the following suite of high resolution logs has been run: Spectral GR, CT-Scan, scratch-test for rock-mechanic, and proprietary "LIPS" (Laser Induced Pyrolysis System) device for geochemistry. The dominant lithology over the 100 m thick studied cored section is quartz and clay with average concentrations of 45 and 35 wt%, respectively, plus minor concentrations of calcite and organic content of 10 and 3 wt%, respectively and the remaining minerals are plagioclase, apatite and pyrite.

BENEFIT OF CORE CT-SCAN LOGGING

A 3D X-Ray CT-scan imaging device (Figure 1) allows the acquisition of high resolution serial tomographic images and from these one can reconstruct grey-shaded 3D images (a GE LightSpeed RT 16 device, capable of acquiring 1,500 tomographies / m, has been used in our case). For petrophysical applications a 1D log of "grey-shades" can then be derived by stacking pixels along the radial slices. This log basically reflects both the mineralogy and the bulk density (RHOb). The 1D CT-scan log, for this gas shale, correlates very well with the RHOb measured on core samples (Figure 2) making this log a very efficient way to quickly identify the most prolific sections, those with high RHOb, for example where there is high porosity (PHI) and high organic matter content / low grain density (RHOgr). If PHI and RHOgr are correlated it is even possible to use the 1D CT-scan log as a reasonable indicator for both RHOgr (Figure 3) and PHI (Figure 4). The PHI – RHOgr correlation for this gas shale case results from PHI being mainly associated with the low RHOgr component, kerogen, (Figure 5). In this case study both PHI and RHOgr have been derived from low-pressure pycnometer measurements on crushed samples (including organic matter) dried at 150°C. Due to the correlation between RHOgr and TOC (total organic content) (Figure 6), the 1D CT-scan log can roughly characterize the TOC content (Figure 7).

BENEFIT OF LIPS PYROLYSIS LOGGING

The TOC contents is better characterized with the LIPS (Laser Induced Pyrolysis System), a proprietary high resolution logging device developed to evaluate the remaining hydrocarbon potential at a centimetric sampling rate [1 & 2]. The device uses a PID detector which record the pyrolyzable hydrocarbons content, thus reflecting the remaining hydrocarbon potential (similar to the S2 peak from Rock-Eval analyses). If dealing with similar original kerogen type and maturity over the cored section, the remaining organic matter content (locally calibrated with a few conventional TOC measurements, e.g., by Rock-Eval, Leco) appears correlated to the remaining petroleum potential (Figure 8). The dispersion seen in Figure 8 may result from the fact that the

LIPS log is a very high resolution log and pyrolysis is taking place on a pinhead-size fraction of the surface. The LIPS device is now automated as far as core loading, analysing and stocking are concerned (Figure 9), with a capacity of 30 x 1 m core sections programmable in a row (analysis duration for 30 m ~ half a day).

BENEFIT OF SCRATCH-TEST AND SPECTRAL GR LOGGING

Another core log that has been run is the Scratch-Test (Figure 10). This log is run for rock-mechanics purposes on conventional rocks, as it proves to be a good indicator of the Unconfined Compressive Strength UCS (magnitude of the axial stress at which the rock fails, [3]). The high resolution log of "EPS Specific Energy" reflects the variability of mechanical properties at millimeter scale, correlating here with variability of dry clay content (Figure 11), and is expected to be a good potential indicator of Brittleness Index and rock hardness. A Spectral GR log is systematically run on the cores as well. It allows deriving a shaliness index (Figure 12).

CONCLUSIONS

A wide range of high resolution core logs dealing with geology, petrophysics, rock mechanic and geochemistry, can be run in the lab. A rough but quick (several 10's of meter logged per day) characterization of the cored sections is then possible, thus allowing to plan a more efficient campaign of educated sampling. This is particularly a benefit on gas shales cores, since it is important to limit dehydration to a minimum and perform measurements on fresh-state samples. The other benefit of running such high resolution core logs is that upscaling of spot core measurements is made possible, using the core logs as external drift indicators.

ACKNOWLEDGEMENTS

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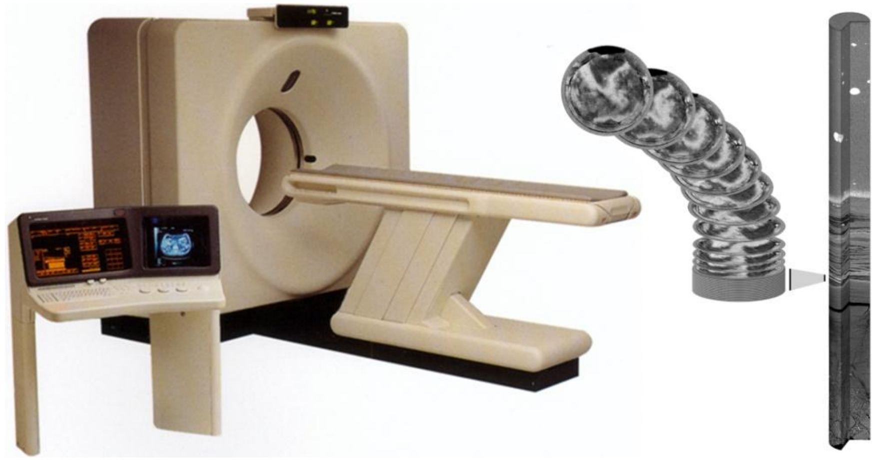


Figure 1: 3D X-Ray CT-scan imaging

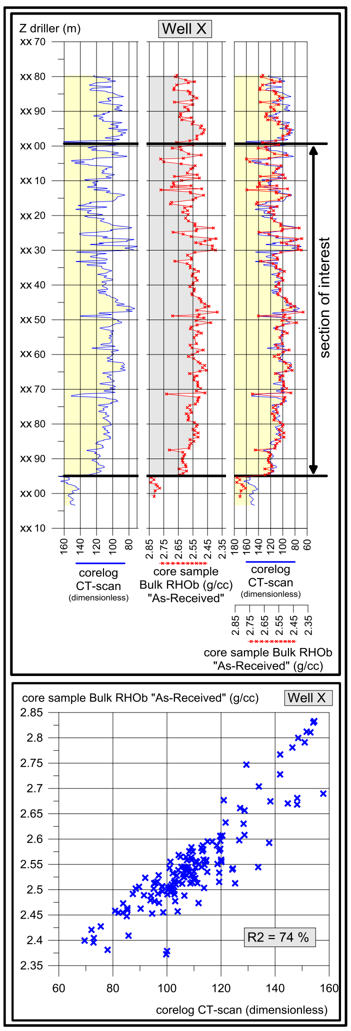


Figure 2:
Sample RHOb AR vs. CT-scan

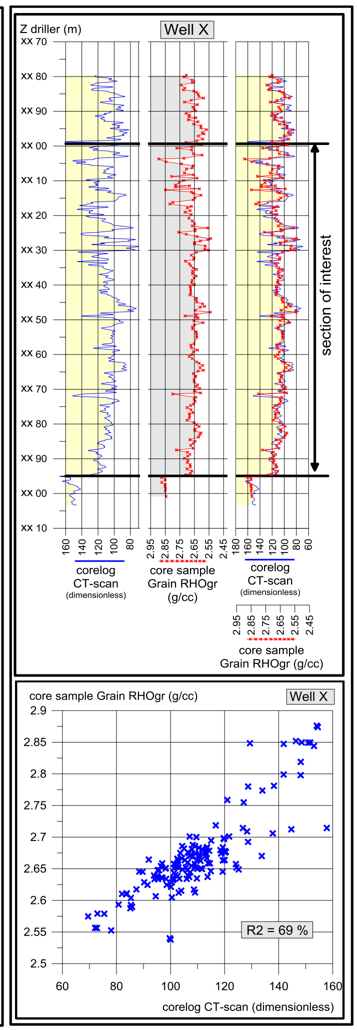


Figure 3:
Sample RHOgr vs. CT-scan

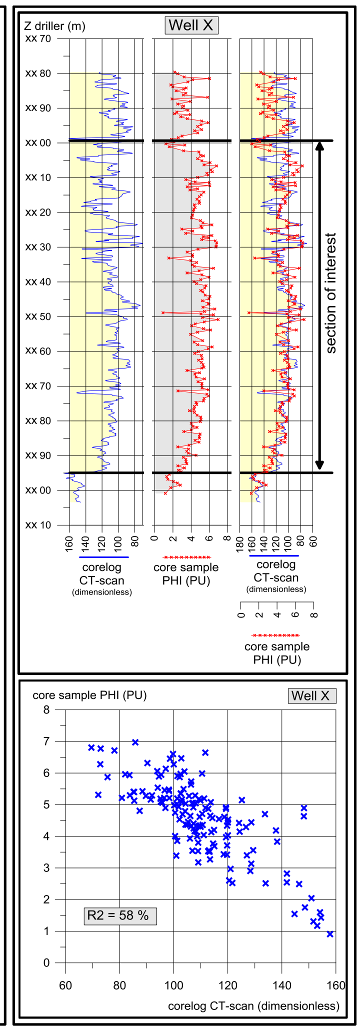


Figure 4:
Sample PHI vs. CT-scan

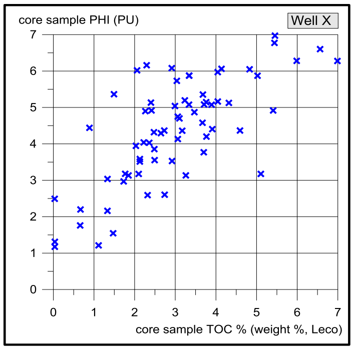
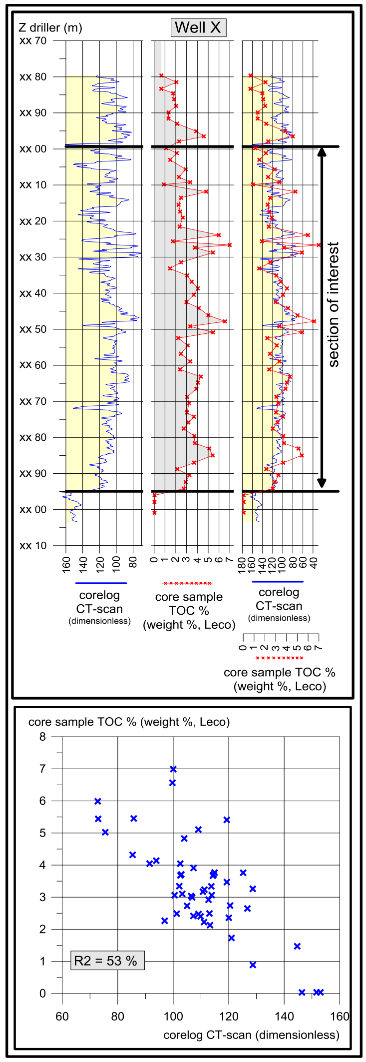
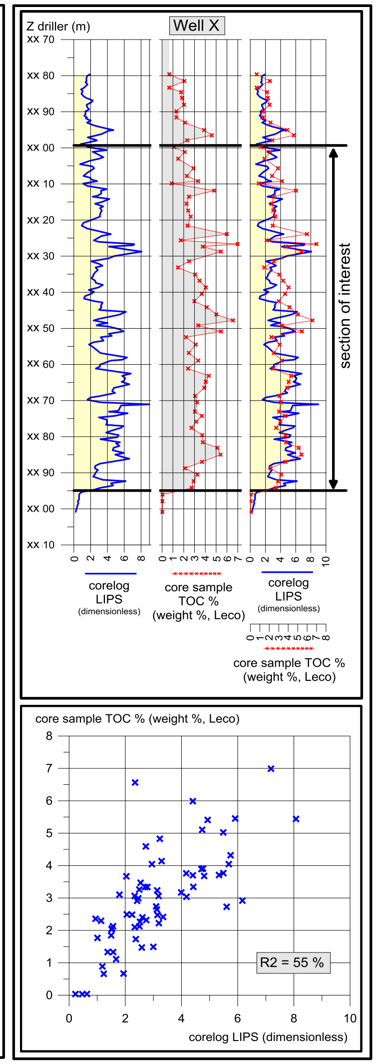


Figure5:
Sample PHI vs. TOC %





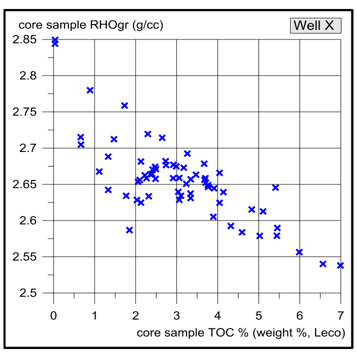


Figure 6:
Sample RHOgr vs. TOC %

Figure 7:
Sample TOC % vs. CT-scan

Figure 8:
Sample TOC % vs. LIPS

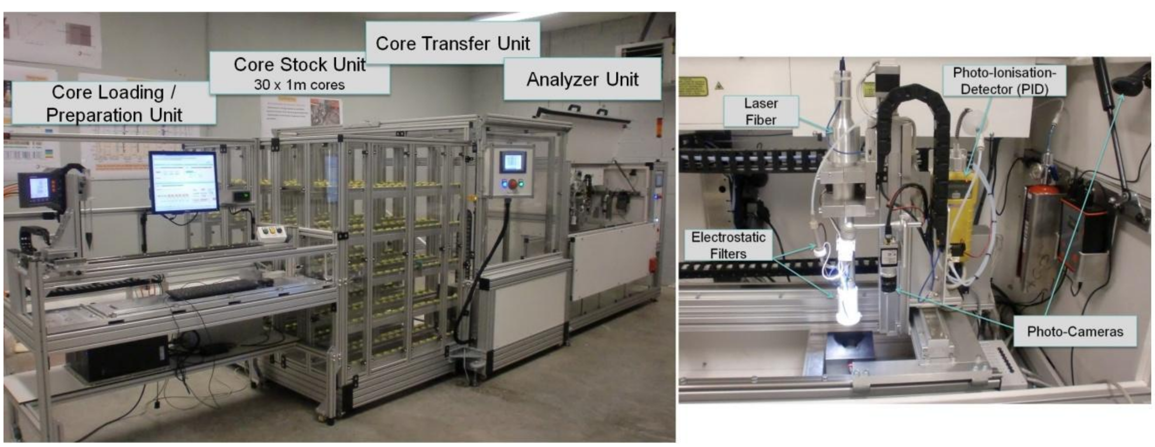


Figure 9: LIPS device and close-up

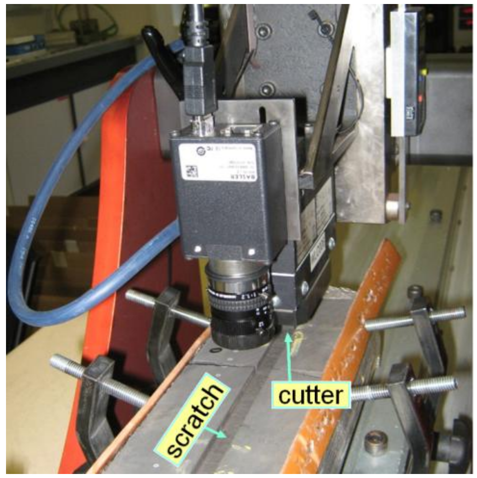
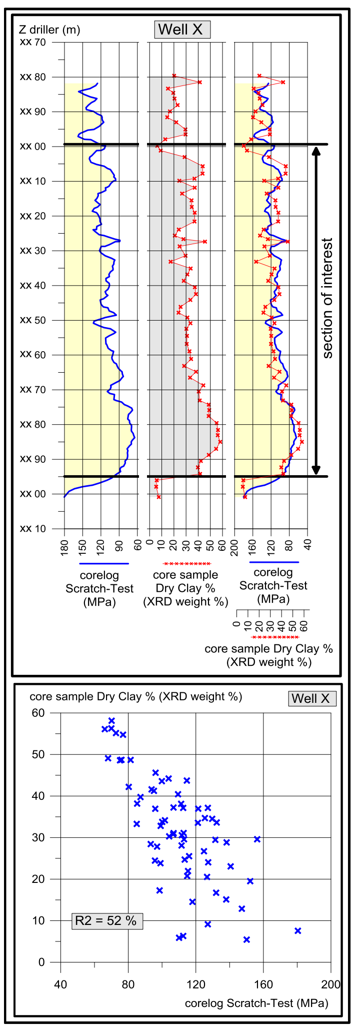


Figure 10: Scratch-Test device



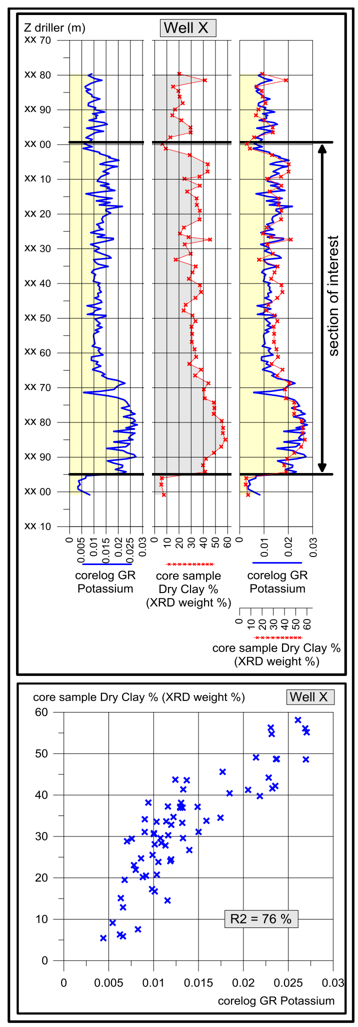


Figure 11:
Sample Dry Clay % vs. Scratch-Test

Figure 12:
Sample Dry Clay % vs. GR