GM06

Rock Mechanical Knowledge Building in Complex Carbonate and Diagenetic Environments

C.O.H. Hindriks* (PDO - Petroleum Development Oman) & U. Prasad (Baker Hughes)

SUMMARY

Introduction

In many operational applications, an upfront expectation of the mechanical behaviour of the rocks we will drill in is of importance. This is especially valid in an unconventional setting. In many clastic environments correlations with depth, porosity and shale content, mainly based on compaction models, work reasonably well. In mixed carbonate and clastic environments, like found within Oman's concession area, such correlations are quite often not applicable, due to the varying structural nature of carbonate rocks, mixed compositional nature, early diagenesis, etc. Appropriate QA / QC review of rock property values will then be an essential step in building a representative description of the rock and decomposing the elements that determine the behaviour as observed. This paper presents a process for Q'cing Strength and hardness values measured from lab combined with a practical approach to infer these values from log data, opening a possibility for seismic characterization of rock mechanical parameters in a quantitative manner. Such knowledge will be invaluable for any operational design related to rock mechanical behavior

Pairs of property values are cross-plotted and compared with correlations from the literature or previously established with qualified data from related formations. Conformance with those correlations gives confidence in the data, whereas outliers are flagged as questionable. Data in question is investigated to locate the source of the inconsistency, which can be a result of both quality of the sample and measurement or specific behaviour of the rock at hand. The former being a reason to reject the result, the latter being a reason for determining additional characteristics to hopefully establish a more dependable value.

Abundance of log data enabled us to establish average rock behaviour of typical Oman lithology. Any wellbore and log quality effects, compositional and structural effects measured on log scale which are almost impossible to capture on plug scale are averaged out. Effective pore characterization of averaged log data allows a direct correlation with the quality assessed lab measurements. In well analysis of deviations from the established trends allows us then to gain additional structural and compositional information, allowing for instance for sweetspotting and defining leading indicators for hydraulic fracturing jobs.

Method and Theory

Level I QA/QC starts from identifying cores for its Lithology (segregating rock types of sandstone, limestone, shale or coal etc.) and assigning proper depth shift, if any. The measured rock properties are compared with digital logs which are obtained separately. The current QA/QC work demonstrates how the measured or interpreted UCS can be verified for sandstones only; a similar concept could be used for other rock types, say limestone, coal or shale. Segregating rock types under few well known rock types (say, sandstone, limestone or shale or coal) are for simplicity; in reality due to typical mineralogy, grain cementation, and grain texture, there could be 100s of rock types. This causes high scatter in UCS (Prasad, 2009) when interpreting under 3-4 rock types only. Also the other reasons for scatter are how anisotropic the core was, what were the core orientation, was the core tested in dry or saturated condition, was the confinement same etc. Level II QA/QC starts by comparing measured rock properties with most suitable analogue or well researched reference rock types.

Averaged Vp & Vs and density logs are created on a single lithology base and visualized on a differential effective medium based template as function of pore aspect ratio, similar to Xu and White. The template plots log density versus log velocity as function of pore aspect ratio, with on the one end, 100% highly compliant pore systems and on the other end close to spherical stiff pore systems. A set of average properties for a single lithology as measured in 30 wells spread over a significant spatial area, show a remarkable consistency with a clear indicator of the average pore aspect ratio, as can be seen in the right hand figure, enabling the construction of trends of elastic properties against porosity and determining calibration parameters for multi aspect pore systems, giving high confidence in estimating structural parameters, crack density and matrix damage on a single log scale. Moreover, they can carry a significant signature on the seismic scale. These derived parameters can be proven crucial to assessing leading performance indicators for for instance hydraulic fracturing jobs.

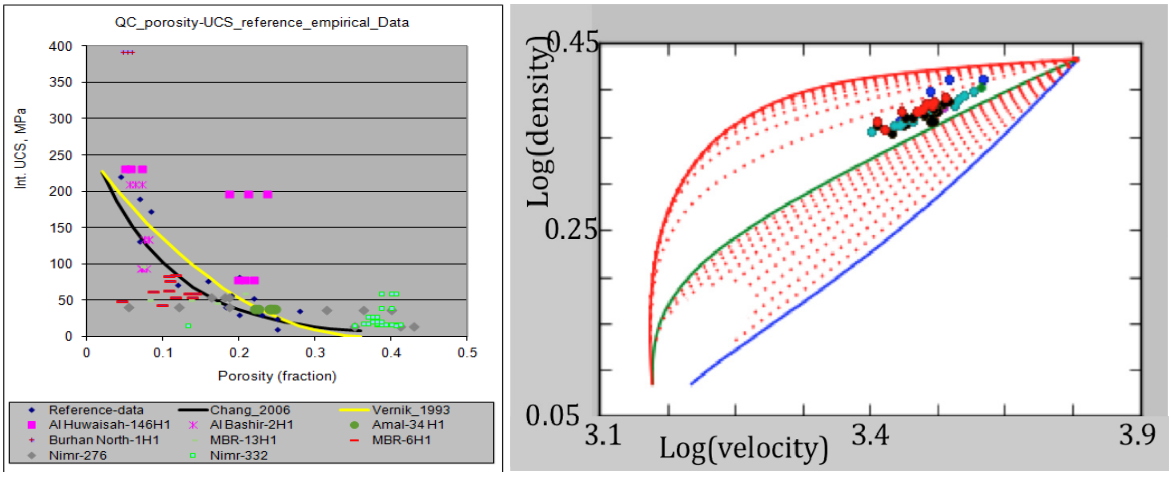

Figure 1 *a) An example of QA/QC rock property using cross-plot of porosity and strength and b) superimposing averaged log data on a specific carbonate template related to compliant and stiff rock characteristics.*

Conclusions

We have presented a comprehensive workflow to characterize a broad range of rock mechanical behaviours in a mixed carbonate and clastic environment, comprising rigorous analysis of both laboratory data as well as log data. The workflow allows the dissimination of micro and macro scale parameters on the expected rock mechanical behaviour. Such rigorous assessment allows for a determination of geomechanical parameters allowing for confident operational decisions.

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