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A Case Study of Porosity Deficit in Digital Rock Measurements

Holly Vescogni[1], Jorge Sanchez-Ramirez[1], and Jon Capsan[1]

[1] BHP Billiton, Houston, TX, USA

ABSTRACT

Porosity measurements from a well in the Lower Eagle Ford (LEF) of south Texas using methods at several scales of investigation are compared, including petrophysical analysis and core measurements (GRI, NMR, and digital rock analysis). The data are analyzed with the intent to reconcile porosity discrepancies related to the different scales of investigation.

Porosity values from all the scales of investigation are in very good agreement with the exception of porosity from digital rock analysis. This porosity discrepancy is found only in the lower zone of LEF in the pilot well investigated for this study. In this lower zone of LEF, the digital rock porosity is significantly less than the porosity from the other core measurements and petrophysical analyses by approximately a factor of two or greater. Conversely, in the upper zone of LEF, digital rock porosities are in good agreement with the other measurements and analyses. In addition, the 2D SEM digital rock images show a difference in pore size between the upper and lower zones of LEF, with the upper zone having larger inter-particle and organic matter (OM) pores (pore diameters on the order of 1 liD) and the lower zone having smaller inter-particle and OM pores (pore diameters <<1 liD). Our hypothesis to explain the discrepancy in the digital rock porosity data compared to all of the other porosity data is that the smaller pores in the lower zone are at or below the resolution limit of the SEM digital rock analysis.

To investigate this hypothesis, we compared porosity and pore size distributions from the standard-10om/pixel resolution 2D SEM and from a higher resolution -2.5 nm/pixel2D SEM of the exact same field-of-view. This was done on one sample each from the upper and lower zones of LEF. The sample in the upper zone showed a minimal difference in porosity (<10% difference) between the 2.5- and -10-nm/pixel resolution 2D SEM's, as expected. From this we conclude that the -10 om/pixel resolution is able to resolve the majority of the porosity for that sample. The sample in the lower zone showed a more significant difference in porosity (>30% difference) between the -2.5- and -10-nm/pixel resolution 2D SEM's. This uplift is not enough of an increase in porosity to match the other porosity data, but we suggest that at higher resolutions, it theoretically would be possible to resolve all of the porosity such that the digital rock porosity would converge with the porosity from the other methods.

Pore size distributions from both of the two 2D SEM resolution scales first of all confirm the visual observation that the dominant pore size of the lower zone is significantly less than that of the upper zone. Secondly, the distribution curves were fit to a series of regressions to estimate the amount of porosity that is below the resolution detection limit. The regressions indicate that there is more porosity that could be imaged at some theoretical higher resolution. It is important to note that the regression solution is non-unique; thus, it is not possible to determine the actual porosity of the sample using this method. However, it does support our hypothesis to explain the porosity discrepancy at the different scales of investigation.

In conclusion, we propose that the digital rock data underestimate porosity in the lower zone of LEF where pore sizes are close to or less than the resolution limit of the digital imaging technology and that the differences in pore sizes from the upper and lower zones are in fact real and

potentially significant. This porosity difference may have implications for production from the two different zones of the LEF. If so, being able to predict this dichotomy in pore size would be an important consideration for development planning. Given observed mineral associations and depositional fabrics, a possible explanation may be that differing mechanical properties of the framework grains relating to depositional changes throughout the LEF time could produce the different pore sizes observed in this study.