Petrophysical Formation Evaluation of Carbonate Reservoirs by Integrating Borehole Images with Other Logs: Analyzing Facies to Define Flow Units

D. V. (Vivek) Chitale and John Quirein
Halliburton Energy Services, Houston, TX
Vivek.chitale@halliburton.com

Storage and flow of the oil and gas in the carbonate reservoirs is largely controlled by the fabric-heterogeneities induced by the digenesis of these rocks. Borehole images enable high-resolution visualization of the fabric of the carbonate reservoirs and permit core-like description of the all-too-frequent heterogeneities in the pore geometry of these rocks. On the other hand, the other open-hole log measurements, such as nuclear, acoustic, electrical and NMR, are commonly deployed to characterize the bulk petrophysical properties of the carbonates. Meaningful integration of the borehole images with the other petrophysical measurements is now possible thanks to recent advancements in image acquisition, image processing, and computational abilities to simultaneously process gigabytes of scalar and vector data. Such integrated formation evaluation helps enhance the accuracy of reserves estimation and fluid flow modeling.

This paper presents results of testing a modern method of integrated formation evaluation of carbonate reservoirs on two wells from the Permian Basin. Specially built software generates electro-facies based on the heterogeneities in carbonates as seen on the image logs, which are then integrated with electro-facies generated from all of the other open-hole logs. Since these carbonates are vugular and fractured, a newly developed software technique is used to quantify the pore space. The new technique is an interactive image sculpturing in which objects of interest (vugs and fractures with similar resistivity) are defined using simple thresholding. The objects of no interest are then removed using filtering and thresholding techniques, thereby producing a "sculpture image" containing only vugs and fractures. Semi-quantitative interpretation is presented as continuous depth plots of aperture, length, and density of fractures and secondary porosity due to vugs and fractures. The paper presents the sculptured images of fractured and vugular carbonates and also the estimates of the aperture, length, and density of fractures and total secondary porosity. Comparisons with the porosity estimates from other logs are also shown. Combining borehole images with the other logs also yields more accurate "sand count." The paper also includes high-resolution, sand-count images for the two wells from the Permian Basin.

Building a facies model for the carbonate reservoirs by combining borehole images with the other logs helps generate a meaningful flow unit model that is further refined by incorporating the results of secondary porosity and sandcount evaluation. It should follow that using image logs reduces uncertainties of the interpretation of fluid flow in the carbonate reservoirs. This method of formation evaluation can be very useful in effective and efficient field management, and it is being field tested in several wells in the Permian Basin and elsewhere in the world.