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Petrophysical & Geological Evaluation Of The Heterogeeous Carbonate Reservoirs Reveals Need To Redesign The Historical Standard Laboratory Core Analysis (Rca & Scal) Equipment And Technology

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ABSTRACT

Multi-scale geological and petrophysical evaluation of carbonate reservoirs from different countries and basins (Chitale et al, 2010 AAPG Memoir 92; Chitale et al, 2015 SPWLA Petrophysics Journal) reveal that these carbonates exhibit significant spatial heterogeneity in terms of lithology, textures and pore geometry. Multiple episodes of digenesis generate the following typical heterogeneities (a) variations in texture and composition of the carbonate rocks within 1 mm; (b) thin and random non-depositional layering (1-5 mm); and (c) profound changes in pore geometry and permeability within millimeter-to-centimeter distances.

Laboratory equipment and technology used today for petrophysical & geological evaluation of cores was historically designed for either the whole core samples (3”-4” diameter and up to 10” length) or the plugs cut from whole core / rotary sidewall cores (typically 1-1 1/2” in diameter and 1”-2” long. Whereas the routine core analyses (RCA: including litho-facies description, gamma, CT, porosity and permeability) can be obtained from plugs as well as whole cores, the critically important special core analyses (SCAL: capillary pressure and relative permeability) can only be performed on plugs. Meanwhile, over the last two decades the vertical resolution of e-log measurements (LWD/Wireline) has improved consistently from 2.5 m to <0.1 m. Radial depths of investigation of modern e-logs range between 5-30 cm. Laboratory core analyses provide "ground truth" for e-log interpretation, which is used to calibrate the seismic-data-based reservoir modeling. The latter is performed at 5-m or coarser resolution. The above reservoir description practice, although not perfect, has often been applied successfully in the evaluation of homogeneous subsurface reservoirs. However, its application becomes questionable in the case of heterogeneous carbonate reservoirs whose pore space characteristics often change within 1 mm distances! As observed often, the properties derived from RCA- and SCAL analyses of whole core and plugs cut from the same whole core do not match in the case of most such carbonates. Consequently, the accuracy of core-to-log integration for up-scaling purposes gets compromised leading to increased uncertainty for the static and dynamic modeling of such reservoirs.

This paper presents examples of description and evaluation of heterogeneous carbonates from US, India and other countries. It emphasize that the mitigation of the issues discussed in this paper could be achieved by designing new equipment and technology that offers full range of RCA and SCAL on same-size whole cores and plugs! A specific sample size of 30x15 cm is recommended for such analyses as it matches the spatial resolution of the current state of the art e-logs. The rock properties so obtained from the new RCA and SCAL techniques are bound to

ultimately enhance the accuracy- and reduce the errors and uncertainty in the estimation of reserves and produceability of heterogeneous carbonate reservoirs.