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Determination of Effective Water Saturation in Low Resistivity Low Contrast Fresh Water Shaly Sands Integrating SP Log with Resistivity and Other Conventional Logs and Core Data - A Case Study

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Abstract

The problem of low resistivity low contrast (LRLC) in fresh water shaly sands has always been a challenging task in formation evaluation across the globe. Tipam Formation of Miocene age in Upper Assam, India were deposited in fresh water fluvial environment and the problem of LRLC in TS-5A sand in Changmaigaon and Charali fields is so acute that the resistivity in oil zones is sometimes even lower than the water zones. Core studies revealed the presence of authigenic smectite clay coating sand grains with honeycomb morphology along with framboidal pyrite nodules, metamorphic rock fragments and altered mica. Fresh formation water forces the major part of the electric current through the clay-coated grain surfaces and only limited current passes through bulk pores rendering resistivity measurement practically insensitive to the presence of hydrocarbons in pore spaces. It has been observed that in wells drilled with high salinity KCl-PHPA muds, Oil Water Contact (OWC) is clearly demarcated by reduction in SP and slight increase in flushed zone resistivity (MSFL), whereas deep resistivity (LLD) fails miserably. The major or rather almost all contribution in SP amplitude recorded in high salinity KCl mud against fresh water formations is contributed by shale membrane potential as liquid junction potential is negligibly small due to almost equal mobility of K+ and Cl- ions and practically no streaming potential due to very low mud filtrate resistivity. Therefore, the SP log under such conditions can be treated as a membrane potential log, which has a strong correlation with cation exchange capacity (Qv) and hydrocarbon saturation in shaly sands. An innovative methodology has been developed for quantitative estimation of hydrocarbon saturation in LRLC reservoirs, integrating SP log with resistivity and other conventional logs. The technique is a judicious combination of Vshale and Electrical Double Layer (EDL) models for water saturation computation, coupled with multi-mineral log data processing and validation with capillary pressure measurements on cores. The methodology encompasses the effects of dispersed/laminated shale, fine-grained nature of sands, altered mica, metamorphic rock fragments and accessory conducting minerals on rock resistivity through in-situ calibration in water zones below OWC. The wells tested with the present technique produced clean oil @ 200-300 bbl/d, which were earlier thought to be water bearing.