Petrophysical Interpretation of Electromagnetic Induction and Dielectric Dispersion Logs in Bakken Petroleum System

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ABSTRACT

Bakken Petroleum System (BPS) is composed of both conventional and unconventional units, which exhibits significant variations in lithology, rock texture, clay content, total organic carbon, accompanied by high connate water salinity, presence of disseminated pyrite grains, and low values of porosity. These petrophysical attributes of the BPS lead to inconsistency in the oil-in-place estimates for those obtained from electromagnetic (EM) induction log, NMR log, dielectric dispersion log, and Techlog Quanti-ELAN and Dean-Stark core measurements.

We perform an inversion-based interpretation of dispersive electrical conductivity and dielectric permittivity measurements at six EM-log-acquisition frequencies acquired across 1000-feet depth interval in one of the science wells intersecting the BPS. Three geoelectromagnetic mixing models, namely Lichtenecker–Rother model, Stroud-Milton-De model, and Waxman Smits model are coupled to jointly process the dispersive EM logs to simultaneously estimate oil-in-place, formation water salinity, cementation exponent and saturation exponent.

Oil-in-place estimates obtained using the proposed interpretation method were compared against those obtained from triaxial induction resistivity, NMR log, Quanti-ELAN solver, Dean-Stark core measurements and service company's dielectric inversion. Our estimates of water saturation and those obtained using the service company's dielectric inversion exhibit the best match with Dean-Stark's core water saturation in the Middle Bakken, Lower Bakken, and Three Forks formations. However, in the Lodgepole, Scallion, and Upper Bakken formations, our estimates of water saturation are closer to those obtained from NMR logs, which disagrees with the extremely high estimates obtained using the service company's dielectric inversion. The estimated values of water saturation and formation water salinity in Middle Bakken are in the ranges of 0.5 to 1 and 205 kppm to 250 kppm, respectively. The cementation index indicates enhanced tortuosity and cementation in the Scallion and Lower Bakken formations.