Deciphering the Effect of Saturating Fluid Salinity and Compaction on the Electrical Conductivity of Inorganic Shale

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Abstract

About 70% of the sedimentary section encountered while drilling for hydrocarbons is shale. The term “shale” used here is meant as a general classification of predominately fine-grained sedimentary rocks, without regards to laminations, fissility, or anisotropy. Insights into shale properties and compaction increases the operational shale knowledge base as it relates to basin modeling, pore pressure interpretation, and increasing drilling safety and efficiency. A better understanding of shale will help us map and predict their properties. A petrophysical reinterpretation of a soil/brine study infers that inorganic shale does not respond electrically like shaly sand. Electrical conductivity was measured for sand/clay mixtures saturated with various brine and water contents, i.e., saturated porosity. The anticipated typical shaly sand electrical response would predict the bulk electrical conductivity (Co) increasing with values of increasing saturating fluid salinity (Cw), at constant porosity. In stark contrast to the common shaly sand electrical response, the lower porosity data in this study illustrates no change in bulk rock conductivity (Co) when the saturating brine conductivity (Cw) is varied from 0 to 8,000 ppm NaCl. The lower porosity samples are comparable to the linear compaction stage of shale encountered below about 1500 ft (450 m). Additionally, this range of saturating brine salinity is expected for insitu natural shale. Inherent due to the isomorphic substitution in clay minerals are counterions, namely Na+ for shale. The bulk cation exchange capacity (CEC) of the shale are a measure of these exchangeable cations which insures electrical neutrality of the clay mineral. This constant Co with varying Cw is attributed to the electrical

buffering effect of the exchangeable cations in the shale. As the saturating brine salinity increases, the electrical mobility of the clay's hydrated exchangeable cations decreases. The net effect is a constant Co. Applying this concept to a compaction model shows that this constant Co with variable Cw is expected for shale commonly encountered while drilling for hydrocarbons. The commonly used shaly sand terms of clay-bound water and bulk water do not properly describe the inorganic shale pore water. Interlayer anion exclusion, effective anion exclusion, and anion dominant are more descriptive of the pores and associated water in shale. The CEC as well as effective stress and temperature are important parameters for putting these concepts into a compaction perspective. This increase understanding of shale properties can help reduce technical risk in seismic and pore pressure interpretation as well as improve drilling safety and efficiency for hydrocarbons.