A Predictive Shale Porosity Model which Includes the Effects of Mechanical Compaction, Temperature, Mineralogy, Chemical Diagenesis, and Overpressure

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ABSTRACT

Geologists have borrowed the model of exponential loss of water from shale due to increasing net overburden pressure from soil scientists and civil engineers. This method does not extrapolate well to the pressures, temperatures, and diagenesis encountered while exploring for hydrocarbons. Study of sorption isotherms of clays illustrates the defining variables that control the water content in mudrocks. These variables are: CEC (cation exchange capacity), the specific exchangeable cation, effective stress (mechanical compaction), and temperature. Sorption isotherms are simply a measure of the mass of water per gram of dry clay, as relative humidity (p/po) is varied between 0 and 100%. This water includes inter-lamellar, intra-aggregate, surface adsorbed, and inter-aggregate. Published desorption isotherms of Na-exchanged clays, the most abundant species in the subsurface, show that the amount of water per gram of dry clay increases with increasing CEC values for a given p/po. A plot of p/po vs. mass of water per meq (a unit of CEC measurement) for selected clays and clay mixtures results in a detailed compaction curve for the depths encountered in exploration. Thermodynamic equations enable the conversion of p/po to effective overburden stress, as well as quantify the temperature effects of thermal compaction. The effects of chemical diagenesis (*e.g.* smectite to illite) and variable mineralogy are incorporated in the compaction model via the bulk CEC parameter, calculated from well logs using a published algorithm. Density log derived porosity, and porosity from the model, show excellent agreement. Application of this model results in better understanding and quantification of pore pressure prediction, drilling fluid/wellbore interaction, and seismic modeling.