The Fundamental Role of Electrostatic Forces Within Pore Systems and Their Effects on Resource Evaluation and Reservoir Performance

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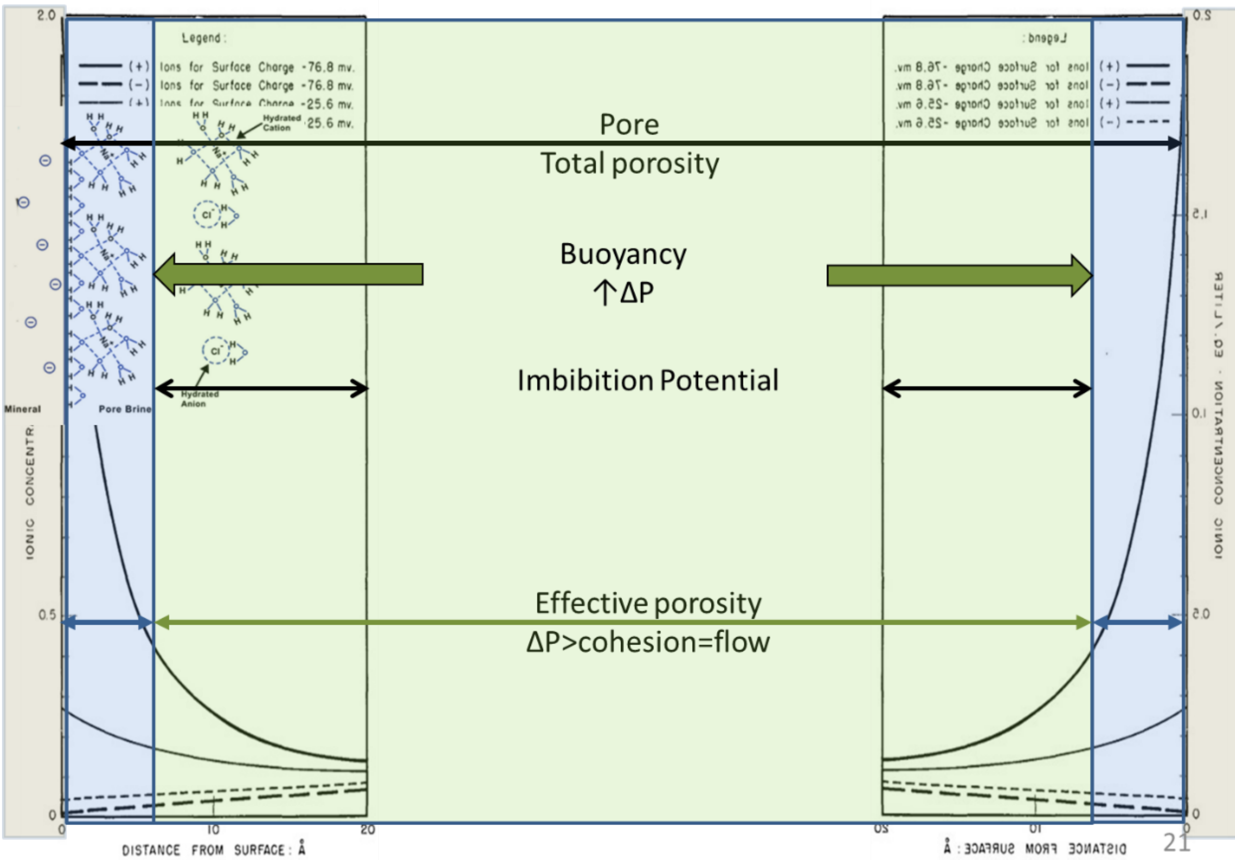
Part 2b: Capillary Forces Theory: a model for understanding the electrostatic forces and their effects within pore systems.

Emplacement

Buoyancy is the primary force that drives migration and emplacement outside the areas affected by the high-pressure expulsion of active hydrocarbon generation. It is the pressure difference between the extrapolated water hydrostatic pressure and hydrocarbon static pressure at any elevation above the free water line. It results from the density contrast between the hydrocarbons and pore waters [1–3]. It is not a strong force at the molecular scale but is additive and grows as a vertical column accumulates [2,4]. Buoyant displacement of pore waters is resisted by the capillary forces that tend to hold water within pores and pore throats. The balance between these determines fluid saturation distributions. The most common means for visualizing this balance is with capillary pressure drainage (saturation height) curves.

Fundamentally, capillary pressure drainage curves represent a measurement of the force required to break the interfacial tension holding water across a range of pore throat sizes. Gas is much lighter than liquid hydrocarbons so generates significantly higher buoyancy pressure at any height above the free water. Heavy oils do not have as much density contrast so cannot generate as much buoyancy force at any height. Low capillarity reservoirs produce very different saturation height curves than high capillarity reservoirs for a given fluid. Saturation height curves also differ depending on the density of the fluid in a given reservoir. The last two points are important factors for the exploration geologist. A natural gas column will generate a saturation profile with a lower S_{irr} than crude oils across the entire spectrum of reservoir qualities. The inherent variability of oil properties means a wide range of fluid saturation profiles, and related S_{irr}, can be generated by buoyant emplacement in a given reservoir. The result is that irreducible water saturation depends on the combination of reservoir and fluid properties. Using well log pay cutoffs based on a gas column results in most semi-conventional oil deposits being bypassed.

As an oil column grows, increasing buoyancy displaces water from progressively smaller pores, and capillary films within larger pores are compressed. This continues until, theoretically, only the water held by highly overlapping adsorption fields remains. Electrostatic and pressure forces are balanced at every elevation within the column by the strength of the interfacial tension. Interfacial tension is pervasive throughout the pore system and buoyant displacement of capillary film water creates an electrostatic imbalance in the pore system called the Primary Imbibition Potential (PIP). The PIP will tend to draw expelled water back in when there is natural or induced change in reservoir conditions.



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