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A Geological/Mechanical Basis for Creating Fracture Reservoirs in the Bakken

Application of the Secor Theory for tensional rock failure suggests that fracture-reservoir development in the Bakken Formation and adjacent rocks is controlled by three basic co-dependent parameters: (1) rock properties, such as strength, Poisson's ratio and thermal expansion coefficient; (2) a critical amount of pore-fluid overpressure and (3) a critical amount of differential rock matrix stress. The inter-relation of these factors may be determined by basic physical measurements and illustrated through graphical concepts common to the fields of materials science, civil engineering and structural geology. Stress fields of structural stability and fracture failure may be approximately predicted through the diagrammatic representation of effective stress circles and failure envelopes.

Critical amounts of fluid overpressure are created by processes of matrix collapse and volume change associated with high rates of hydrocarbon generation in kerogen-rich shales of the Bakken and basal Lodgepole Formations. The amount of overpressure generated is ideally related through Darcy's Law to the generation/expulsion rate fromm the shale matrix and to the available permeability through which generated hydrocarbon fluids must move. The fact that Bakken fluid pressure gradients have never been observed at values exceeding approximateLY 0.73 psi/ft., even though these should theoretically be much higher, suggests that the fracture gradient of confining rocks in the overlying Lodgepole or underlying Three Forks Formations has been exceeded.

Critical states of stress leading to fracture failure may be created by a number of independent additive mechanisms, including the arrangement and mechanical properties of kerogen and mineral grains, elastic/plastic discontinuities between mechanically-defined beds; bedding curvature stretch, and loading history. Ideally, the amount of strain distortion produced by any of these mechanisms when completely relieved by tensional fracturing should resolve into an equivalent amount of porosity. Fracture spacing may be controlled by a number of factors, including elastic plate (bedding) thickness and contrasts with adjacent plates, and plate matrix permeability. The width of each fracture, as controlled by fracture spacing and porosity, controls the permeability of an individual fracture.

Many of the basic factors producing effective fracture reservoirs may be measured, mapped or modeled in a quantitative or semi-quantitative manner. This should allow geological/mechanical concepts to be used in a predictive manner for both exploration and exploitation.