Influence of Depositional Setting on Reservoir and Mechanical Properties of the Woodford Shale, Oklahoma

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Abstract

As a result of depositional setting, composition of the Woodford Shale changes across Oklahoma. The Woodford Shale in southern Oklahoma formed proximal to the axis of the Devonian Oklahoma Basin and is silica-rich due to radiolarian content provided by upwelling. Silica content ranges from around 70 percent bedded chert for the Arkansas Novaculite to 10 to 50 percent for cherty Woodford in the Arkoma Basin and outcropping on the Arbuckle and Criner uplifts. Bedded cherts have higher natural fracture density, with fractures terminating in adjacent clay-rich beds. In southern Oklahoma, fracture porosity and permeability are sufficiently high in some areas to allow economic oil and gas production from vertical Woodford Shale wells. In contrast, the Woodford Shale in northern Oklahoma lacks bedded chert, but contains silica-rich bands that appear to nucleate on detrital-silt-rich laminae. Thin section microscopy reveals that all detrital silt is not the same. Silt grains surrounded by clay result in relatively high silica content, but silica bands do not develop. Silica cement appears when silt grains are in contact and silica content is enhanced by radiolarian tests. Radiolarian-rich zones in now northern Oklahoma are distal to the basin axis and formed during shoreward encroachment of radiolarian-rich water in the stratified Woodford sea. Silica cement increases at the expense of clay content and alters wireline log response and mechanical properties. Intervals with lower-clay content are mappable because they exhibit higher resistivity and lower neutron porosity than clay-rich intervals. Silica cement, augmented by carbonate cement and sulfides, imparts competence and brittleness to the Woodford Shale. Competence is evident in the smooth outer core surface in cemented intervals that resisted erosion during coring. In contrast, clay-rich intervals are eroded, especially parallel to bedding, generating a rougher outer core surface. Cemented intervals may not store the bulk of the hydrocarbons, but are brittle and have a propensity to naturally fracture or propagate fractures during hydraulic stimulation. In northern Oklahoma, Woodford Shale wells located in areas within the oil window that contain Woodford Shale with the silica-rich interval have proven economic provided bounding strata have limited porosity and permeability.