Compositional and Textural Variability of Shales as Hindrance to Understanding Shale Fracturing

Richard P. George, Jr.[1] and Marshall W. Deacon[2]
[1]Noble Energy Inc., 100 Glenborough Drive, Houston, TX 77067
[2]Noble Energy Inc., 1625 Broadway, Suite 2200, Denver, CO 80202

Deciding whether to invest in developing hydrocarbon-bearing reservoirs typically requires answers to the following:

1. How much oil or gas can we produce? ("What are the recoverable reserves?")
2. How fast can we produce the reserves? ("How quick is pay-out?)
3. How much will it cost us to produce the reserves?

Answering those questions is almost always far more difficult for shale reservoirs than for conventional reservoirs, because the permeability of the shale matrix by itself is too low to support flow of hydrocarbons to the wellbore at commercial rates. High-permeability artificial ("hydrofacs") and/or natural fractures can provide the enhanced permeability that is needed to justify development of the reservoir. Natural fractures also contribute to total storage capacity of reservoirs, albeit in only minor amounts (of the order of a tenth to a few tenths of a porosity unit) in most cases.

Among the many possible approaches to predicting the intensity, distribution, and orientation of fractures in the subsurface is analysis of the stress- and/or strain-history of the rocks involved, in conjunction with good understanding of their mechanical properties. Unfortunately, the mechanical properties of "shales" are poorly understood, largely because the term "shale" includes polymineralic rocks of vastly different compositions and textures and whose component minerals have different mechanical properties.

The major mineral components of "shale" include clays, quartz, carbonates, and feldspars. Even shales that are derived from a common provenance exhibit heterogeneity of composition (not just of texture) that depends on depositional environment. For example, in a classic study of the Mississippi River & Delta depositional system, Shaw and Weaver (1965) found that clay content increases (feldspar and quartz content decrease) with increasing distance of transport. Placing shales in a sequence stratigraphic framework (e.g., as in Sneider, 2003) offers hope for classifying shales in a way helpful for predicting their compositions and textures and, ultimately, their mechanical properties.

Depositional environment is also correlative with composition of connate waters, which also influences shale texture and hence mechanical properties   Increasing salinity causes kaolinite to flocculate more rapidly than smectite, thus giving a greater salinity-dependence of texture in kaolinitic shales than in smectitic shales. Oxygenated waters tend to favor clay deposition in biogenic pellets. Anoxic depositional environments favor laminae, because benthic burrowing organisms will be scarce. Anoxic waters are more likely than are oxygenated waters to be sites for accumulation of clays that are coated with organic films, which inhibit flocculation.

Even if there were only one "true" shale and even if it were monomineralic, its mechanical properties would be dependent on the interplay of **rates** (especially of strain rates and of fluid-pressure equilibration rates). The dependence on those rates is a direct consequence of the effective-stress dependence (Terzaghi, 1936; Hubbert, 1951) of rock-response (elastic, brittle, or ductile). As an example, small variations in volumetric strain within a shale reservoir (low matrix-permeability) can potentially cause significant variations of local fluid pressure and thus of local effective stress and therefore in rock response to both natural and anthropogenic deformation.

Searching for the ideal conditions under which to stimulate a fractured-shale reservoir should include consideration of possible long-term, post-stimulation ductile flow of the matrix around grains of proppant.

The complicating factors mentioned above suggest that a major hindrance in understanding the fracturing of shales is the variability of shale composition and texture. That variability gives each shale reservoir unique mechanical facies. The **methodology** of analyzing the mechanical facies, though, should be common across multiple reservoirs.