Merging Sequence Stratigraphy and Geomechanics for Unconventional Gas (and Oil) Shales

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The words "ductile" and "brittle" have emerged as two key descriptors for characterizing unconventional gas shales. The former is usually considered to be relatively organic (TOC)- and clay-mineral rich, while the latter is considered to be more enriched in "silica" (i.e. biogenic and/or detrital quartz)- and/or carbonate (calcite/dolomite) minerals.

Our studies of some gas shales have shown that such ductile and brittle rocks occur as alternating 'couplets' at a variety of scales (Fig. 1). At the largest, sequence stratigraphic scale, ductile beds comprise condensed sections (CS) which lie on or stratigraphically near a combined sequence boundary/transgressive surface of erosion (SB/TSE). Detritus-rich beds prograde over the top of the condensed section (i.e. maximum flooding surface) during the ensuing highstand/regressive (HS/RST) depositional phase. The next smaller, temporally-shorter parasequence scale often consists of a ductile CS shale overlain by a 'cleaning'-upward' (i.e. on gamma –ray log) HS/RST shale. Vertical stacking of repetitive parasequences gives rise to a series of stacked, ductile-brittle couplets, each couplet bound by a marine flooding surface. At a still-finer, sub-parasequence scale, ductile and brittle couplets are often finely interbedded or interlaminated.

It is possible to recognize or predict these different scales of couplets on logs and core, and sometimes on seismic, thus providing a means of predicting and regionally mapping stratigraphic variability in geomechanical and other rock properties. Examples include: (1) Fracture Toughness, Youngs Modulus and Poisson's Ratio vary at the sequence and parasequence scales, (2) Microseismic event-intensities vary at the parasequence scale (Slatt et al., in press), and (3), rock strength varies with amount of laminations/beds per stratigraphic interval at the sub-parasequence scale (Sierra et al., 2010).

It recently has been recognized that the distribution of hydraulically-induced fractures is not as simple or predictable as currently-used theoretical models would suggest (Kui, 2010); this may be due to the different scales of fracturability and fracturing associated with these different scales of brittle-ductile couplets (Fig. 2). Such scale-dependent complexity might also result in differential retention of fracture proppant.

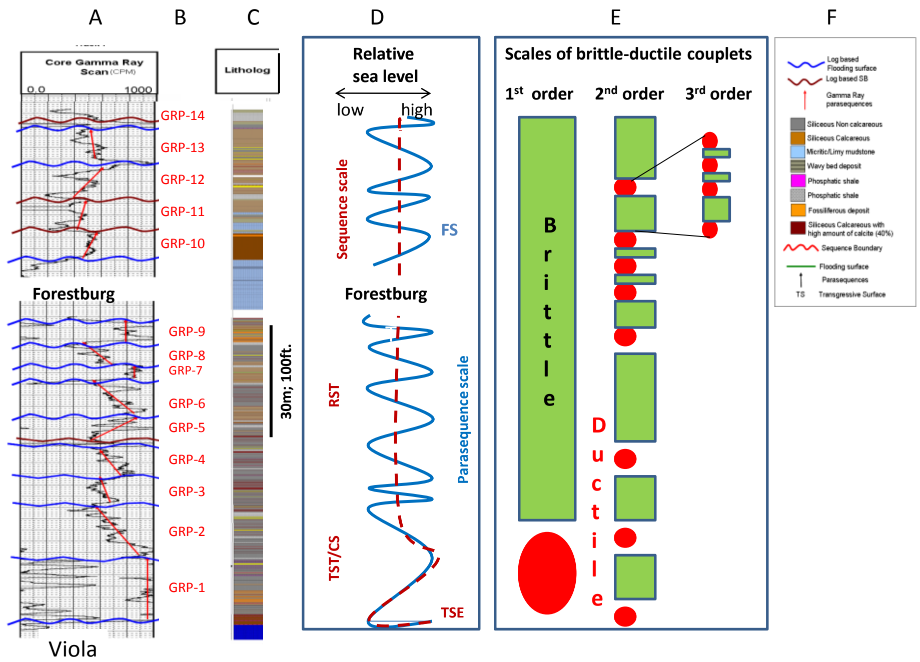

Figure 1. A. Barnett Shale gamma ray log showing parasequence boundaries (wavy blue lines) and parasequence patterns (red arrows), B. 14 gamma ray parasequences (GRP) for the well; C. core facies description and explanation (F.) (from Singh, 2008), D. Delative sea level curve for the complete Barnett Shale sequence (brown dashed line) and the 14 parasequences listed alongside the gamma ray log (solid blue curve). FS=flooding surface. E. Three scales of ductile-brittle couples (Sequence = 1st order, Parasequence = 2nd order and Bedset = 3rd order.

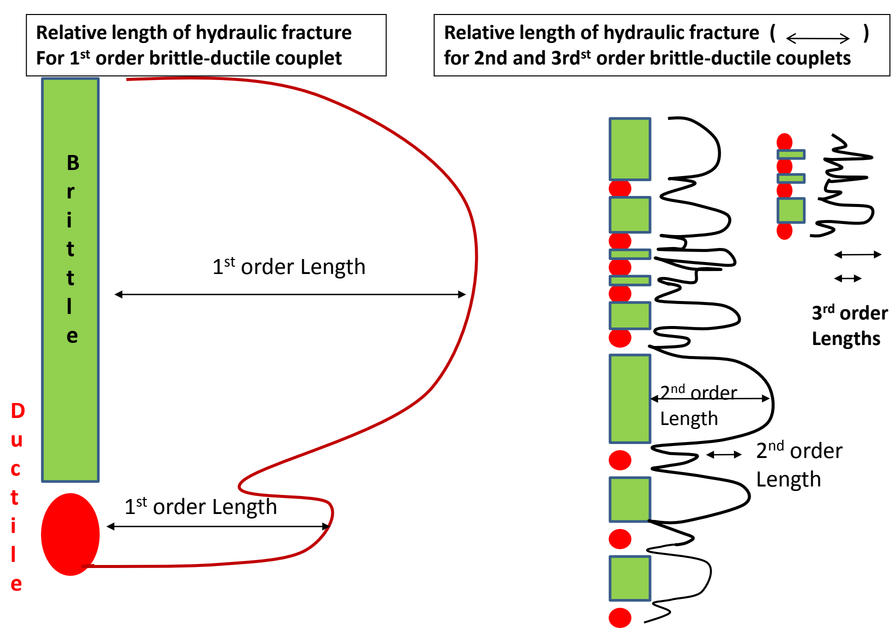

Figure 2. Schematic illustration of multi-hydraulic fracture lengths in gas shale brittle-ductile couplets.

References

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