Microseismic Estimates of Surface Seismic Brittleness Estimates: Application to a Barnett Shale Survey

Roderick Perez-Altamar[1], John Henry Alzate[1], Amanda Trumbo[1], and Kurt Marfurt[1]

[1]University of Oklahoma

ABSTRACT

Generation of permeability through the completion process requires that the target formation be more brittle than its neighbors, and that the induced fractures do not ductilely close about the injected proppant. Brittleness in unconventional reservoirs is mainly controlled by mineralogy, increasing with quartz and dolomite content, and decreasing with clay and calcite content. Using core and electron capture spectroscopy, P-wave sonic, and dipole sonic logs from nearby wells, we construct a brittleness index template and use it to predict the brittleness from surface seismic elastic parameter estimates of $\lambda\rho$ and $\mu\rho$. We apply the workflow to a 3D seismic survey acquired in an area where more than 400 wells were drilled and hydraulically fractured prior to seismic acquisition.

Although six microseismic experiments show clouds that are roughly aligned with the NE-SW regional stress field, they are no way symmetrically aligned about the well bore. Instead, microseismic events “find” neighboring brittle rock to fracture, and “avoid” fracturing nearby ductile rocks. Diagenesis also appears to play a role. Microseismic events “avoid” fracturing structural ridges which are thought to be tightly cemented, and “favor” fracturing structural bowls which are thought to be more loosely cemented.

While increased TOC should theoretically make the rock more ductile, in the Barnett Shale high TOC and elevated levels of biogenic quartz resulting in a TOC-rich brittle rock are depositionally coupled, forming in deeper, anoxic parts of the basin. Not surprisingly, production logs show that wells completed in more brittle, TOC-rich zones produce better than those in more ductile, TOC-poor zones. Such observations raise more questions than they answer. Fractures associated with microseismic events in brittle zones are not necessarily connected to the borehole. Wells landed in a ductile, TOC-poor zone can produce from neighboring brittle, TOC-rich zones while at least one stage landed in a brittle, TOC-rich zone exhibited low gas flow. Furthermore, the generation of fractures is a nonlinear phenomenon. Examining the Mohr-Coulomb failure curve shows that for a given effective stress level, some rocks break, while others do not, suggesting that failure, and hence the number of fractures, is not a linear function of brittleness.