Observations on Fluid/Fracture Pressure Coupling Ratios*

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Abstract

Observations on the variation of fracture pressure with fluid pressure reduction associated with hydrocarbon production yielded fluid/fracture pressure coupling ratio values as large as 0.8 (Teufel et al. 1991) and as small as 0.36 (Salz, 1977). Sedimentary basin-scale studies of fluid and fracture pressures, expressed as gradients, yielded estimates of the fluid/fracture pressure coupling ratio values between 0.59 (Tingay et al.,2003) and 0.76 (Hillis, 2000). Basin scale coupling was interpreted as a poroelastic response by Engelder and Fischer, 1994. Reexamination of the basin-scale data without use of pressure gradients and without the direct use of fluid and Sv pressures as limits on the calculated fracture pressures yielded fluid/fracture pressure coupling ratio values between 0.28 and 0.43 for 11 basins examined (Swarbrick and Lahann, 2016). Swarbrick and Lahann (2016) concluded that poroelasticity can be excluded as an explanation for most basin-scale coupling.

Discussion

Uniaxial strain models indicate that fluid/fracture coupling ratios can be related to stress ratio and Poisson’s ratio (Hillis, 2000). With this model, low coupling values would be associated with high Poisson’s ratios (plastic). Poisson’s ratio values obtained from Leak Off Tests (LOT) and fluid pressure over a wide depth range from 11 basins are compared with Poisson’s ratio values derived from shallow, near-hydrostatic LOTs for the same basins. The two approaches yield similar, but not identical coupling values. In most cases, the coupling values derived from LOT and fluid pressure data over a large depth range was greater by values ranging up to 0.10. Calculated Poisson’s ratio values ranged from 0.40 to 0.45, with slightly larger Poisson’s ratio values derived from the shallow, near-hydrostatic LOTs.

Published laboratory-measured Poisson’s ratio values near 0.5 (plastic/very low coupling values) appear to be restricted to samples associated with very low effective stress and shallow burial (Hamilton, 1971). Reduction in porosity is associated with reduced Poisson’s ratios (Zhang and Bentley, 2005). These observations imply a model of reducing Poisson’s ratios with burial depth/compaction, a model that contradicts some existing models of Poisson’s ratio behavior. For example, Eaton and Eaton, (1997) show Poisson’s ratio values increasing from near 0.25

at the seabed (brittle) to approaching 0.5 (plastic) at 20,000 feet below mudline, which contradicts the expected trend based on reduction of porosity.

A sedimentary sequence with normal compaction to the top of overpressure and a lithostatic-parallel fluid pressure profile with depth below the top of overpressure, (constant shale porosity/vertical effective stress) is typical of mud-dominated succession found along continental margins (Swarbrick et al., 2011). Such a sequence would be expected to have decreasing Poisson's ratio from seabed to the top of overpressure and constant Poisson's ratio (and coupling values) in the portion of the overpressured interval not affected by chemical diagenesis. The onset of chemical diagenesis and cementation, most likely at temperatures beginning between 100° and 120°C, would be expected to decrease the Poisson's ratio and have the effect of increasing the coupling coefficient (Figure 1).

Summary

The model of Poisson's ratio displayed in Figure 1 could be used to generate fracture/fluid pressure coupling values in a procedure similar to the method described by Swarbrick and Lahann (2016) and Lahann and Swarbrick (2017).

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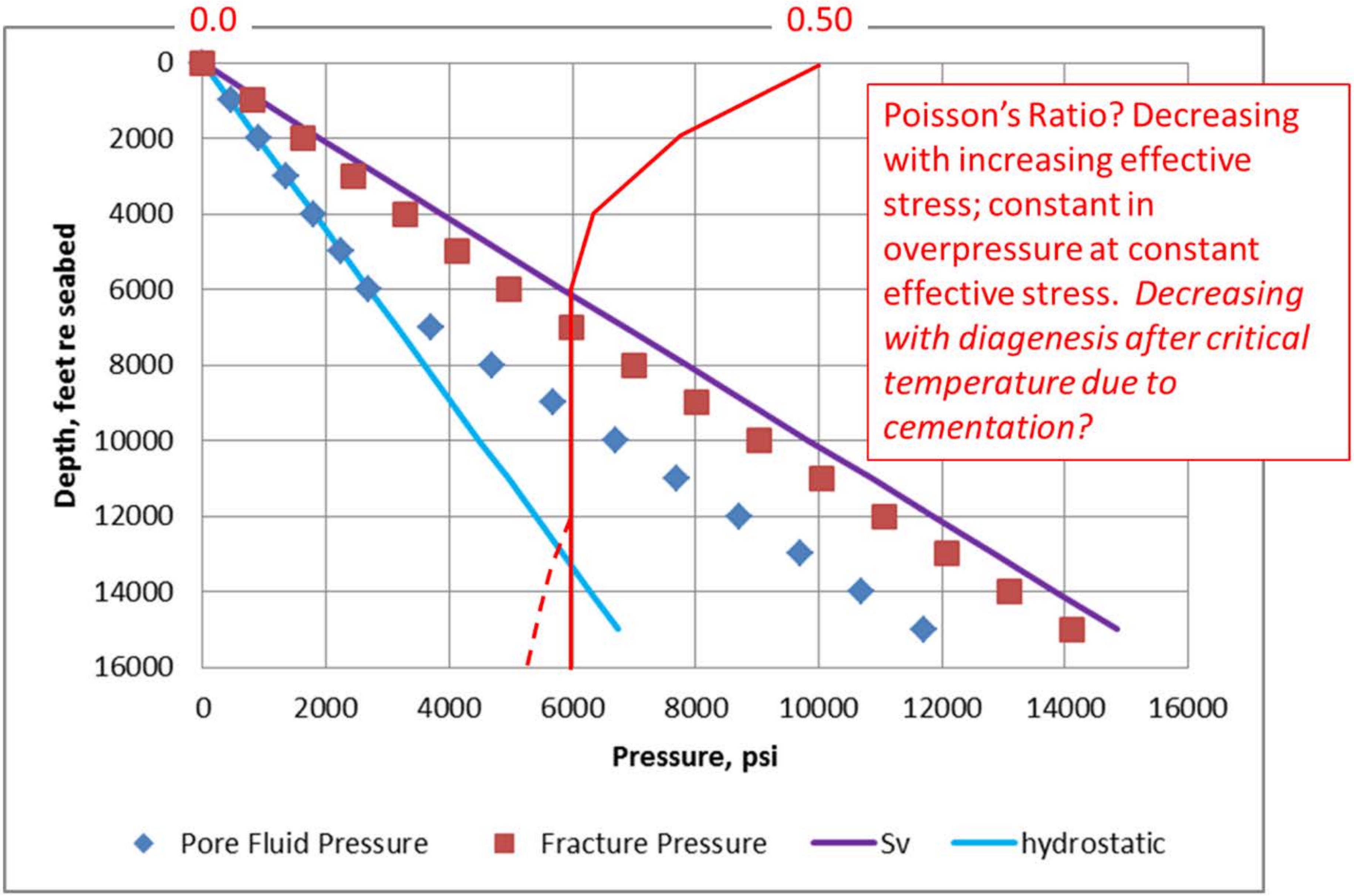

Figure 1. Expected Poisson's Ratio variation for typical mud-dominated sedimentary sequence.