FAULT-SEAL CALIBRATION USING IN-SITU BUOYANCY PRESSURE

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The sealing properties of fault zones are strongly dependent on their compositions, which may be estimated using the Shale Gouge Ratio (or SGR) algorithm. SGR can be calibrated with in-situ pressure data to derive a measure of the 'strength' of the fault seal. The strength of the seal has been defined as the maximum across-fault pressure difference that could be supported for the lowest SGR value.

A compilation plot of SGR against across-fault pressure data for a large number of fault datasets permits a general trend of increasing SGR value supporting increasing across-fault pressures to be defined for different burial depths. The equation defining the seal-failure envelope is: AFPD (bars) = $10^{(SGR/27 - C)}$. C is 0.5 for burial depths less then 3.0 km (ca. 9,850 feet), C is 0.25 for burial depths between 3.0 and 3.5 km (ca 9,850 to 11,500 feet), C is 0 when the burial depth exceeds 3.5km (11,500 feet). The seal-failure envelopes provide a method to estimate the maximum height of a hydrocarbon column that can be supported by the fault. Leakage of hydrocarbons occurs when the buoyancy pressure exceeds the capillary entry pressure of the fault.

Ideally, SGR values should be calibrated against the difference in pressure between the hydrocarbons trapped at the fault and water in the fault zone (buoyancy pressure) rather than across-fault pressure difference. In general, the buoyancy pressure can be obtained by measuring the pressure difference between the hydrocarbon and water phases in the same reservoir. Calibration diagrams based on buoyancy pressure have been derived for a number of datasets. They show that gas and oil data exhibit a correlation between increasing SGR and increasing buoyancy pressure but only between SGR values of 20% and 40%. There is no increase in the strength of a seal, as reflected by an increase in maximum buoyancy pressure, at SGR values greater than about 40% both for gas and for oil data. The implication is that column heights do not continue to increase over the SGR range 50 to 100%. However, more data are still required to define individual seal-failure envelopes for oil and gas. Existing compilations of capillary pressures for fault gouge samples are consistent with the subsurface calibrations based on buoyancy pressure.

The key input for the SGR algorithm is the volumetric shale fraction (Vshale) of the intervals adjacent to the fault. Vshale is a derived product, typically from gamma ray or neutron-density logs, and is not necessarily the same as the actual volumetric clay content (Vclay or %phyllosilicates) of the rock. We have re-analysed data for the Oseberg Syd area (Fristad et al 1997) using a revised estimate for Vshale that incorporates mica and kaolin. For 'Fault 1' the minimum SGR value using Vshale that includes mica and kaolin is 30% compared with 18% based on the original estimate for Vshale. Buoyancy pressure-depth plots obtained from SGR values using the revised Vshale estimate gives a very good prediction of the observed downthrown gas/oil contact on Fault 1.

Calibration of fault-seal attributes should be a two-stage process. First, the seal-attributes are calibrated using buoyancy pressure to derive the capillary entry pressure along the fault plane, using existing depth-dependent seal-failure envelopes. Second, buoyancy pressure-depth profiles are derived as an additional constraint to ensure that the calibration provides a good prediction of the observed hydrocarbon contacts.