Capillary tension and imbibition sequester frack fluid in Marcellus gas shale

In a recent issue of PNAS, Warner et al. (1) interpreted local ground water chemistry in the Appalachian Basin as a signal for cross-formational pathways where natural migration of brine from the deep formations may be ongoing today. The implication of this paper is that the Marcellus is leaking now naturally, without any human assistance, and that if water-based fluid is injected into these cross-formational pathways, that leakage, which is already "contaminating" the aquifers with salt, could be made much worse.

During large-scale tectonic events more than 250 million years ago, deep-basin brine migrated into fractures of the Marcellus (2). Despite brine penetration during tectonics, the Marcellus pore space has so little free brine that water saturation is ~23 ± 10% (1 SD) based on regional wireline analysis, calibrated to core, for >340 wells. Such low water saturation leads to capillary binding that will not allow entrained brine to leak upward naturally into shallow groundwater thousands of feet higher in the stratigraphic section.

This brine bound within the Marcellus by capillary tension serves as the tight seal over very large Oriskany gas storage fields in New York and Pennsylvania. The Marcellus maintains an initial pressure head of >0.7 psi/ft. Such high gas pressure means that even if natural fractures within the Marcellus contain brine, they remain sealed.

Further, natural gas is buoyant, and therefore far more mobile and likely to migrate than deep-basin brine. The gas in the Marcellus today is highly overpressured (>0.85 psi/ft in places), as can happen when trapped firmly by a capillary seal. Evidence that gas is not leaking upward at a meaningful rate comes from the difference in isotope geochemistry of Marcellus gas and that from the Upper Devonian section in this area of the basin.* If gas were leaking even a little over the past 200 million years, it would now be all gone.

Introducing 10^4 m^3 of fracking fluid per horizontal well seems sizable, but only less than half of it returns after drilling, and this half is gradually salinized by what little free brine from the Marcellus comes in contact with the frack fluid. Drawing brine into a Marcellus well from the Onondaga Limestone below can cause extreme salinization in flow-back. Where does the rest of the frack fluid go if not returned to the surface during flow-back and production? With natural fractures commonly 1 m apart, imbibition of water by capillary forces driving just 5 cm of matrix penetration could sequester the remaining charge of fracking fluid in a matrix porosity of about 1%, only a fraction of the porosity in gas shale.† Not only is the Marcellus unlikely to leak natural brine through capillary seals, but imbibition ensures that fluids left in the Marcellus will be sequestered permanently.

For those concerned that stimulation by hydraulic fracturing could reopen deep-seated fractures and then move either gas or liquid up thousands of feet on a human time scale, the operation of capillary tension causing imbibition in the Marcellus makes this unlikely.

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