

Thermal Maturity of Devonian Black Shale-Gas Reservoirs, Northwestern Pennsylvania - Evidence from Organic Petrology, Geochemistry and Mineralogy

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Reliable interpretations of thermal maturation indicators (geothermometers) provide critical data needed for resource estimates in thermogenic shale-gas reservoirs. In the Appalachian basin, vitrinite reflectance (R_o) is one of the most commonly measured geothermometers used for mapping regional maturity patterns in the Devonian black shales. R_o values from distal Catskill delta mudrocks suggest that organic matter in these shales is immature. This observation contradicts hypotheses suggesting that regional joint sets in these rocks formed as natural hydraulic fractures induced by abnormal fluid pressures during catagenesis. Some workers suggest that the R_o values are suppressed. Analyses of several different geothermometers in cores of Huron through Marcellus shale recovered from the EGSP-PA #3 well in Erie County, Pennsylvania indicate that the rocks actually are in the early to peak stage of catagenesis. The mean conodont alteration index (CAI) is 1.5. The mean illite crystallinity factor is 0.10, a value that approximates the observed CAI values. T_{max} and production indices, from Rock-Eval pyrolysis, range from 439°C to 442°C and 0.05 to 0.10, respectively. The ratios of bitumen to TOC are 0.06 to 0.072. Several biomarker maturity indicators also imply that these shales are in the oil window. These include C_{31} homohopane isomerization, the $Ts/Ts + Tm$ ratio, C_{29} sterane isomerization, and the ratio of $5\alpha 20S/5\alpha 20R$ (C_{29}). Carbon preference indices of 1.10 and isoprenoid/n-alkane ratios are consistent with catagenesis. Crossplots of the stable isotopes of methane ($\delta^{13}C$ and δD) indicate that oil-associated gas was generated in the black shales. The $\delta^{13}C$ of methane, ethane, and propane correlate to thermal alteration indices (TAI) consistent with wet gas generation in the upper oil window. Burial modeling shows that the rocks entered the oil window approximately 190 Ma and were exposed to temperatures as high as 120°C over a period of 50 million years before uplift retrogressed organic maturation in the rocks.