Examination of Inferred Third-Order Structural Features of the Marcellus Shale Using Wireline Logs in the Broadtop Synclinorium, Virginia and West Virginia

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The Middle Devonian Marcellus Shale extends from central Ohio in the west to eastern Pennsylvania in the east, and central New York in the north to southwest Virginia in the south. Its thickness varies from zero along its western pinchout to perhaps as much as 900 feet (275 m) thick in its eastern extents. The thickness of the Marcellus Shale varies from 350 to 570 feet (100 to 175 m) thick within the Broadtop Synclinorium in Virginia and West Virginia. Thickness variations in the eastern portion of the Appalachian Basin appear to be caused by third-order features, specifically apparent thickening related to folds and thrust faults within the formation. Published studies in the Valley and Ridge Province illustrated a direct relationship of third-order faults, folds, and “disturbed zones” to the regional tectonic framework. During recent field work within the Valley and Ridge Province, we observed intraformational deformation in the Marcellus Shale. In an attempt to determine if this outcrop-scale deformation is discernible in the subsurface, we examined conventional gamma-ray and density logs from nine wells in a 30-mile by 30-mile (50-km by 50-km) area in eastern West Virginia and western Virginia.

We used the Correlator 5.2 computer program designed to correlate geophysical well logs in extensional regimes such as the U.S. Gulf Coast. This represents the initial use of the Correlator program in a contractional tectonic regime. We used this program to statistically evaluate the continuity of the Marcellus Shale and, in turn, to interpret discontinuities in the subsurface that may be the roots of the “disturbed zones” evident in outcrop. Using formation top depths submitted by well operators as a starting point, we used visual pattern recognition to correlate digital logs from nine wells. The tops of the Marcellus Shale, the Needmore Shale, and the Oriskany Sandstone were entered into the Correlator 5.2 program to initiate this study. Using an iterative process of measuring the similarity in shale content between two wells within user-defined correlation and search windows, then measuring the similarity in bulk density between the same two wells, the program calculates a weighted correlation within the search window. We subdivided the Marcellus Shale into three intervals based on correlation strength and gamma-ray log character. We calculated average gamma-ray and average bulk density values for each of these intervals.

Our analysis of all of these calculations suggests that some zones within the Marcellus Shale are more prone to disharmonic folding and small-scale thrust faulting than others. Recent presentations by natural gas producers have suggested that faults and fractures in the Marcellus Shale have a negative impact on completion operations in horizontal wells. The ability to delineate these features in the subsurface will aid in designing completion techniques and enhancing natural gas production from the Marcellus Shale.