An Integrated Geological and Petrophysical Study of a Shale Gas Play: Woodford Shale, Permian Basin, West Texas

Nicholas B. Harris [1], Cheryl A. Mnich [2], Nikki T. Hemmesch [3], Khodir Aoudia [4], and Jennifer Miskimins [4]

[1]Earth & Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada.
[2]ConocoPhillips Inc., Houston, TX.
[3]Geology and Geological Engineering, Colorado School of Mines, Golden, CO.
[4]Petroleum Engineering, Colorado School of Mines, Golden, CO.

We present an integrated stratigraphic, sedimentological, geochemical and petrophysical study logs from the Upper Devonian Woodford Shale Permian Basin, west Texas. Our work, based on long cores and well logs, demonstrates variations in shale lithofacies, mineralogy and rock composition at multiple scales that are associated with 2nd, 3rd and possibly 4th order sea level cycles. The 3rd order cycles are evident in bundles of 'exotic beds', repeated at a scale of approximately 10 meters. Carbonate or siliciclastic sediments derived from the basin margins and transported distances of several tens of kilometers to the middle of the basin. The composition of these beds depends on the composition of the nearest source terrane; adjacent to carbonate platforms, the beds consist of carbonate turbidite and debris flow beds, while elsewhere they form thin siliciclastic turbidite beds.

The total organic carbon (TOC) content displays a high-frequency alternation between high and low values in the Lower and Upper Woodford and consistently high values in the Middle Woodford. We interpret this variability to reflect varying degrees of restriction and nutrient delivery, as sea level cycles affect the degree of connection to the global ocean. High TOC values in the Middle Woodford are accompanied by high Mo/TOC and high TOC/P, suggesting that organic carbon deposition was associated with both redox conditions and organic productivity and that the latter two were linked through a positive feedback relationship.

Formation-scale variation reflects a 2nd order sea level fall and progressively restricted connection between the Permian Basin and the global ocean. The proportion of clay decreased and the proportion of biogenic silica increased upward, resulting from the enhanced delivery of continent-derived dissolved silica as the basin became more isolated from the global ocean; this interpreted is supported by the presence of chert beds in the Upper Woodford. The increased biogenic silica significantly influences rock properties, specifically making the rock more brittle, with major implications for well completion and stimulation design. Clay-rich intervals in the Lower Woodford can act as barrier to hydraulic fracture propagation. Seismic velocities, both Vp and Vs, vary with clay content, while density varies with quartz, carbonate and TOC content.