AAPG Datapages/Search and Discovery Article #90308 ©2017 AAPG Eastern Section 46th Annual Meeting, Morgantown, West Virginia, September 24-27, 2017

Deposition, Diagenesis and Hydrocarbon Generation in the Ordovician Point Pleasant Limestone and the Devonian Marcellus Shale: Comparing and Contrasting Two Appalachian Basin Unconventional Reservoirs

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ABSTRACT

Appalachian Basin shale gas has now become a well-known component of U.S. natural gas production. Indeed, as of 2015 Pennsylvania accounted for 18% of domestic dry natural gas production, driven largely by the Devonian Marcellus Shale, and to a lesser extent, the Ordovician Point Pleasant Limestone. While these two shale plays display similar production mechanisms, the conditions under which these deposits accumulated were markedly different. Vertical chemostratigraphic profiles and pyrite morphology trends were developed on core taken from both formations. The Marcellus exhibits enrichments in redox sensitive trace elements, a framboid population detailing abundant small, <5 µm framboids, with subordinate large framboids, and occasional bioturbation. These observations suggest that sediments accumulated under dominantly anoxic to euxinic bottom waters that were occasionally subjected to periods of (dys)oxia. The high total organic carbon content of the Marcellus is the result of increased preservation due in part, to favorable oxygen-depleted conditions, while concentration was controlled by dilution from clastic influx. Conversely, the Point Pleasant comprises mudstones and marls largely devoid of redox sensitive trace elements, with minimal pyrite, a paucity of iron, and a number of in situ shell bed horizons. These observations suggest the Point Pleasant accumulated under oxic to dysoxic bottom water conditions. Further, the lack of biolimiting iron, and lower preservation potential due to oxidation of organic matter, yielded a formation of lower organic carbon concentration, where preservation occurred via rapid burial. It is noteworthy that, despite the lower organic carbon content, the Point Pleasant hosts a pore pressure gradient far in excess of that observed in the Marcellus. While expulsion fractures, including Mode I vertical catagenic fractures, are common to the Marcellus, they are infrequent to absent in the Point Pleasant study area. One explanation is that the pressure needed to overcome the compressive stress carried by higher modulus, carbonate-rich sediments was never achieved, thus limiting fracturing and hydrocarbon expulsion and preserving its high pressure. Conversely, stress build-up from pore pressure resulting from hydrocarbon generation in lower modulus, more clay-rich Marcellus sediments achieved the tensile strength of the rock causing it to fracture and release hydrocarbons, subsequently lowering its pressure.