Interplay of Eustasy and Tectonics on High-Frequency Sequence Development and Facies Distribution in the Marcellus Shale of the Northern Appalachian Basin, USA

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Abstract

The Marcellus Shale was deposited in the tectonically active Appalachian foreland basin during the Middle Devonian. It is composed of three mixed siliciclastic, carbonate, and source rock sequences that were produced by a complex interplay of eustasy and tectonics. Mountains to the present-day east were the source of silt, sand and clay and perhaps nutrients to the basin. Thrust-loading led to development of a rapidly subsiding foreland basin in the east and a rising forebulge to the west. Forebulge development mainly occurred on pre-existing basement highs called the Cincinnati and Findlay-Algonquin Arches. In the outcrop belt in the east, the Marcellus is up to 1500 feet thick and to the west it is less than 10 feet thick on the Findlay-Algonquin Arch and completely pinches out on the flank of the Cincinnati Arch. Organic-rich shales and limestones of the Marcellus are primarily deposited on the western side of the basin in relatively shallow water on the flanks of the uplifted forebulge where nutrient levels and productivity were high and dilution from the clastic source was low. To the east of the basin axis, the Marcellus has a much higher siliciclastic component and the shales that are present have much lower organic content. The Onondaga Limestone underlies the Marcellus Shale. In the proximal areas near the clastic source where subsidence rates were high, the contact between the Onondaga and the Marcellus is gradational. To the west where uplift occurred an erosional unconformity developed on top of the Onondaga

and the contact with the Marcellus is disconformable. The Marcellus shale onlaps this unconformity to the west and high TOC mudstones commonly sit directly above the unconformity. Along with tectonic control, there were low- to moderate-amplitude eustatic sea-level changes that produced three high-frequency sequences within the Marcellus. The first sequence includes the Onondaga Limestone in the east with the maximum flooding surface near the base of the Marcellus. The organic-rich lower Marcellus is largely regressive and shallows up to a regional limestone with shallow open marine fauna and a well-developed hardground that could possibly be an exposure surface. The second sequence has limestone at the base and again has the maximum flooding surface near the base of the organic-rich shale and is regressive up to a second limestone unit that has common shallow marine corals. The third sequence has a similar pattern with the maximum flooding surface near the base of the organic-rich shale and capped by the regional Stafford Limestone which marks the top of the Marcellus. There are several more limestone black shale sequences above this that continue to onlap to the west. All three of these sequences onlap the unconformity on the Onondaga Limestone and the Marcellus is completely absent over the crests of the arches which may have remained emergent throughout.