Controls of Preexisting Basin Morphology on Facies, Depositional Environments, Geochemistry, and Petrophysical Properties in the Upper Jurassic Haynesville and Bossier Shales of East Texas and West Louisiana

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The Late Jurassic (Kimmeridgian to Tithonian) was one of the most prolific times for organic-rich source-rock production, ranging from the Gulf of Mexico across the proto-Atlantic to the Tethys. Many important source-rock intervals are associated with eustatic, second-order, relative sea-level rise that flooded many of the shelves along these basins in the process depositing marine transgressive black mudstones. However, not all of these black mudstones accumulated organic matter-rich sediments and source rocks that would ultimately generate many of the shale-gas deposits that are currently under investigation worldwide. This talk will address controls on formation of shale-gas deposits using the western Gulf of Mexico Upper Jurassic Haynesville and Bossier shale-gas plays as an example.

The Haynesville and Bossier Formations in East Texas and West Louisiana have evolved into two of the most prolific shale-gas plays in North America, with estimated recoverable resources in the hundreds of trillion cubic feet, high initial production rates of up to 30 MMcf/d, high pressure gradients of 0.9 psi/ft, and steep decline rates of 80%. These economically viable plays (at gas prices of >$4/Mcf) have generated a lot of interest in industry and academe, facilitating research in disciplines from geochemistry and basin modeling to shale diagenesis. However, few publications on the regional understanding of the depositional setting, facies, diagenesis, pore evolution, petrophysics, or geochemical characteristics of the Haynesville and Bossier shales exist. Our work represents new insights into Haynesville and Bossier Shale facies, deposition, geochemistry, and stratigraphy in light of paleographic setting and regional tectonics, as well as broader implications for shale-gas formation.

Haynesville and Bossier Shale deposition was influenced by basement structures, local carbonate platforms, and salt movement related to the opening of the Gulf of Mexico. During Haynesville time, the basin was surrounded by carbonate and evaporite shelves of the Smackover/ Haynesville Lime Louark sequence in the north and east and local platforms within the basin. The basin periodically exhibited restricted environment and reducing anoxic conditions, as indicated by variably increased molybdenum content, presence of framboidal pyrite, and TOC-S-Fe relationships. These organic-rich intervals are concentrated along and between platforms and islands that provided restrictive and anoxic conditions during Haynesville times (Figure 1). Nutrients were provided by surrounding carbonate platforms, clay was shed into the basin from siliciclastic shelves, and organic production was facilitated by overall rapidly rising sea level.

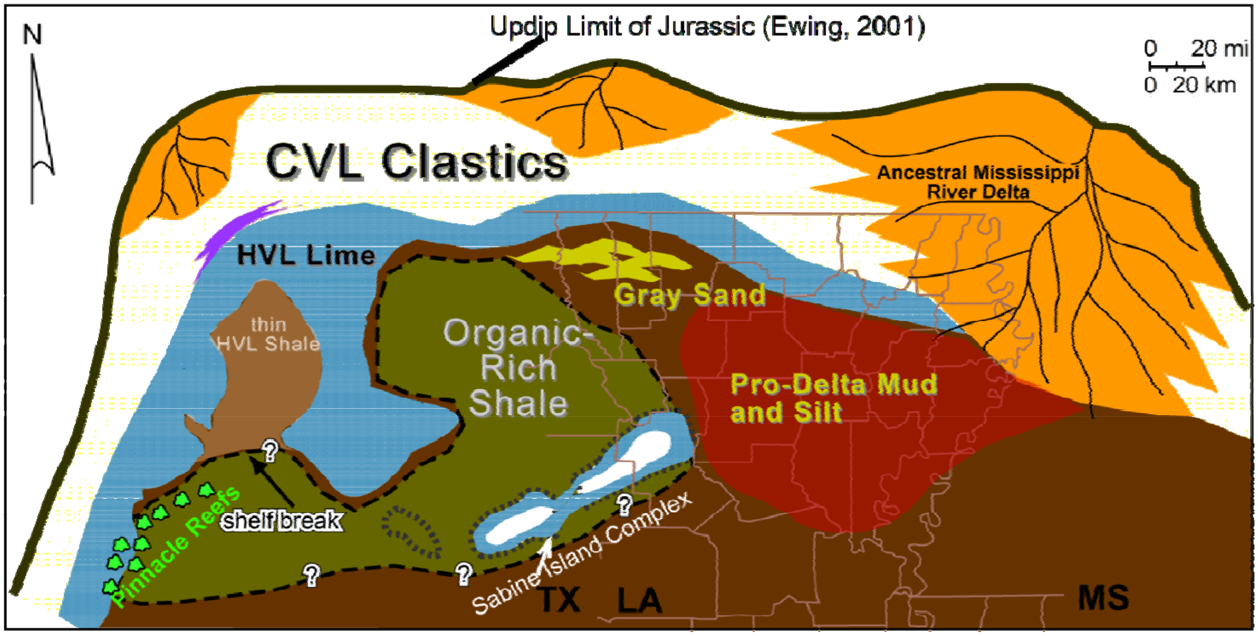

Figure 1: Depositional model and paleogeography during Haynesville Shale deposition showing carbonate platforms (blue), organic-rich shale (olive), shallow-water clastic (yellow), fluvial (orange), and prodelta (red-brown) environments.

Several rivers supplied sand and mud from the northwest, north, and northeast into the basin, contributing to a variety of mudrock lithology changes across Haynesville depositional areas. Haynesville mudrocks range from calcareous-dominated facies near the carbonate platforms and islands to siliceous-dominated lithologies in areas where deltas prograded into the basin and diluted organic matter (e.g., northern Louisiana and northeast Texas). These facies are a direct response to a second-order transgression that lasted from the early Kimmeridgian to the Berriasian. Haynesville and Bossier shales each compose three upward-coarsening cycles that probably represent third-order sequences within the larger second-order transgressive systems and early highstand systems tracts, respectively. Each Haynesville third-order cycle is characterized by unlaminated mudstone grading into laminated and bioturbated mudstone (Figure 2). Most of the three Bossier third-order cycles are dominated by low organic content and varying amounts of siliciclastics and clays. However, the third Bossier cycle exhibits higher carbonate and an increase in organic productivity in a southern restricted area (beyond the basinward limits of Cotton Valley progradation) that was created by paleohighs of the Sabine Island and submerged carbonate platforms toward the north, forming a NE-SW-striking trough. These facies are petrophysically similar to the Haynesville mudstones in grading upward from unlaminated to laminated to bioturbated organic-rich mudstones (Figure 2). The facies are dominated by calcareous mudstones, particularly in the Sabine Island area, creating another productive gas-shale opportunity with total organic contents of between 4 and 8% and maturities of >2% Ro.

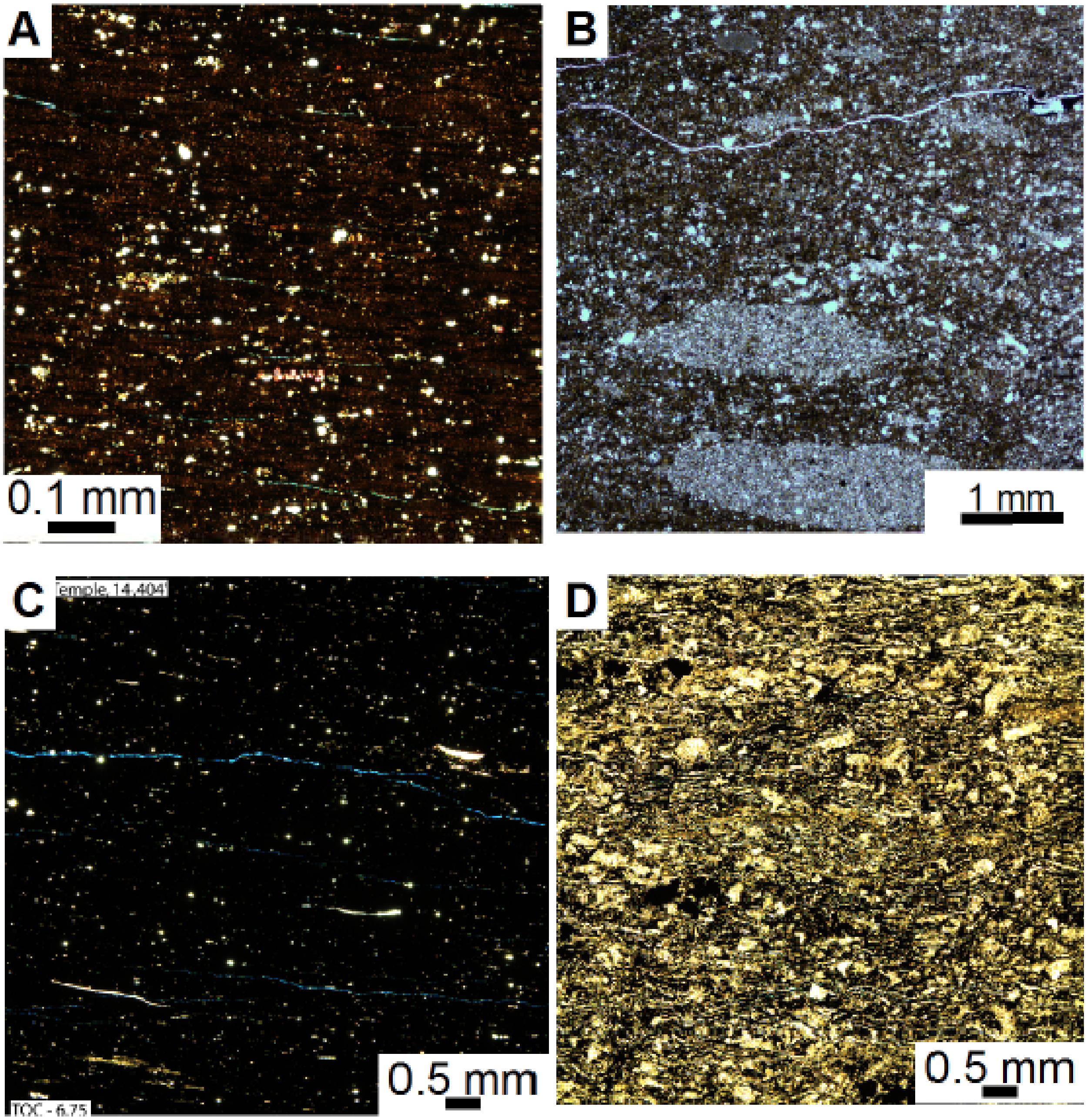

Figure 2: A. Haynesville unlaminated mudstone facies showing silt-sized siliceous and carbonate grains, pelleted matrix, and organics (brown). B. Haynesville burrowed mudstone facies showing carbonate and siliceous grains, peloids, and burrows filled with calcite (B). C. Organic-rich Bossier unlaminated mudstone facies showing fillibranch mollusks and silt-sized siliceous and calcareous grains. D. Bioturbated calcareous mudstone showing abundant calcitic bioclasts in organic-rich matrix. Haynesville samples are from Louisiana and East Texas. Bossier samples are from the Shell Temple and Jones cores of Sabine Island, Texas.