

Paleoenvironments of the Mississippian Heath Formation (Big Snowy Trough, central Montana) and their Relevance to Understanding late Paleozoic Paleoenvironmental Change and Low-Accommodation, Unconventional Petroleum Systems

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ABSTRACT

The late Mississippian Heath Formation is a paleotropical, cyclothemic succession that is an emerging tight oil play in the Big Snowy Trough of central Montana. More than 100 MMBO of oil produced from regional reservoirs are sourced from organic-rich Heath rocks. In 2013, oil production directly from Heath intervals confirmed it as a stand-alone petroleum system. The Heath Formation is also notable for preserving a record of numerous sea-level fluctuations that may be related to Gondwanan glacial ice growth and decay cycles at the onset of the late Paleozoic Ice Age. Despite recent exploration efforts, robust facies and sequence stratigraphic models, as well as a detailed paleoenvironmental analysis, are not yet available for the Heath Formation. This study focuses on the record of late Paleozoic paleoenvironmental change and paleo-water depth variability preserved in the Heath Formation in order to elucidate their influence on Heath petroleum system elements in the Big Snowy Trough. Wireline logs and cores from subsurface intersections are combined with outcrop data and 125 thin-sections to yield a robust depositional model for the Heath, in addition to an analysis of stacking patterns and stratigraphic changes in petroleum system elements within the succession. Two recurrent stratigraphic motifs were observed in the Heath Formation, each composed of repetitive successions of facies. The motif in the lower Heath consists (from base to top) of: fossiliferous black laminated mudstone, fossiliferous calcareous siltstone with irregularly dispersed fine sandstone, wackestone, and packstone, calcareous siltstone with plant fragments, slickensides, pedogenic fabrics, and coal (overlain by the next black shale). The motif in the upper Heath consists of: fossiliferous dark grey laminated mudstone, fossiliferous, calcareous siltstone, sandstone, wackestone and packstone (as above), biolaminated micrite and dolomudstone, nodular to chicken-wire anhydrite, and a cap of fossiliferous black laminated mudstone. Observed facies are consistent with a muddy, homoclinal carbonate ramp. Fossiliferous laminated black mudstones settled from suspension in offshore, basinal waters. Poorly fossiliferous, laminated and normally graded calcareous siltstones are outer ramp deposits, alternating fossiliferous siltstone, fine fossiliferous sandstone, wackestone, and packstone are mid ramp deposits. Biolaminated micrite and dolomudstone with variable proportions of anhydrite are inner ramp subtidal to peritidal deposits. Calcareous siltstones with plant fragments, slickensides, pedogenic fabrics, and coals are coastal plain and mire deposits. Laterally persistent, repetitive vertical cycles of alternating marine and nonmarine facies (cyclothems) are interpreted as depositional sequences bounded by sequence boundaries that are represented by paleosols, and later by evaporites. Cycles record up to eight 3rd to 4th order sequences, with sea-level excursions up to 10s of meters that are likely a paleotropical, eustatic response to Gondwanan ice growth and decay cycles. Deposition of marine facies over coals and anhydrites in sequences as thin as ~2m suggests these units were formed in both a low accommodation and low sediment supply setting. The upward transition from paleosols and coals to limestone- anhydrite associations records a known paleotropical humid to arid climate shift, here identified as Serpukhovian in age, earlier than suggested by previous studies.