Microbialite Biohermal Facies Architecture, Basinal Distribution, and Deposition: The Eocene Green River Formation Analog to the South Atlantic Pre-Salt Carbonate Reservoirs

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Abstract

The Green River Formation covers an area of 77,000 km2 in the states of Wyoming, Colorado, and Utah, USA, and is nearly 2000 meters thick. It accumulated in three major lake systems during the Eocene: Fossil Lake, Lake Gosiute, and Lake Uinta. These lake systems developed during the waning phases of the Laramide orogeny when thrust-faulting dominated tectonic mountain uplift to the west in an area once occupied by a foreland basin (the Cretaceous Interior Seaway).

The formation contains what may be the richest record of lacustrine microbialites. Stromatolites dominate, but oncoids, thrombolites, microbial shrubs, and tufa-like microbialites are not uncommon. Most microbialites are in laterally extensive biostromes; however, the recent discovery of multi-meter-size bioherms in the northwest corner of Green River Basin in the Wilkins Peak Member at Little Mesa provides an important analog to pre-salt carbonate reservoirs. The microbialite bioherms occupy an area of over 2000 km2. The bioherms are composed of clusters of meter-scale columnar and domical stromatolites, and tufa-like microbialites. The 10-30 m thick bioherms co-occur in a succession of stacked, 1-3 m-thick units composed of oolite and grainstone, microbialites, wackestone, and carbonate mudstone. They grew offshore, parallel to lake margin and were associated with long-shore and barrier bars.

Bioherms grade laterally into adjacent fine-grained lake facies over a distance of 100 meters into a logoonal facies composed of wackestone, carbonate mudstone, and isolated groups of smaller bioherms or “patch reefs”. Basinward into deeper water, over a distance of 15+ km, the biohermal facies grades into a wackestone-carbonate mudstone facies with small isolated individual microbialite bioherms. Further basinward this facies is replaced by dolomitic kerogen-rich mudstones (“oil shale”). Evidence of spring activity associated with these bioherms includes tufa-filled fractures, “sand-tufa” stratigraphically below some of the bioherms, and tufa-like microbialites.

Important to the development of the biohermal “reefs” was a critical balance of calcium-rich input (via rivers and springs), precipitation/ evaporation ratio, subsidence, and clastic input. Eventually high volcaniclastic deposition drowned out microbial growth and carbonate sedimentation.
In addition to the large microbialite bioherms at Little Mesa and vicinity, individual, 1 to 5+ meter bioherms occur along an estimated 350 km of lake margin on the western and south-ern margins of the Green River Basin. At some locations, along the Uinta Mountain front, individual isolated bioherms become so abundant that they form biostromes, rather than isolated bioherms.

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So what can we learn from the Green River analog? Certainly we have a clearer understanding of the conditions favoring microbialite biohermal development, including stable lake-levels and water depth during balanced to overfilled lake conditions, high-calcium input via surface and spring inflow, limited clastic input and removal of fines by waves and lake currents. In addition, these strata record a change to frequent open-hydrology conditions that arose from the interaction of structurally mediated landscape development and climatic regimes. These factors provide an exploration-scale tool for predicting the occurrence and distribution of high-relief lacustrine microbial bioherms. The importance of lacustrine microbialites as hydrocarbon reservoirs appears to be significant and their potential for exploration in lacustrine basins should not be underestimated.