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Large Lacustrine Microbialite Bioherms from the Eocene Green River Formation: Stratigraphic Architecture, Sequence Stratigraphic Relations, and Depositional Model

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The Eocene lacustrine Green River Formation in the Uinta Basin is a major source of hydrocarbons in the state of Utah. A large, lacustrine microbialite mound, ~25 m thick and ~4 km long is the reservoir for oil and gas production in the West Willow Creek Field. Analogous bioherms occur in outcrops of the Green River Formation of the Piceance Creek Basin of Colorado and the Green River Basin of Wyoming. The bioherms in Wyoming are particularly well exposed near LaBarge and have attracted attention as possible analogs for the "pre-salt" lacustrine sections of off-shore Santos Basin, Brazil, where microbialites and associated lacustrine facies are reported to form significant reservoirs.

The large microbialite bioherms near LaBarge occur in the Wilkins Peak Member (Green River Formation) in the northwestern Green River Basin and are composed of clusters of domical and columnar stromatolites, some clusters approaching a few hundred meters across and upwards of 9 m thick. Individual stromatolites in the clusters are up to 3 meters in diameter. Bioherms are porous, with ooids, ostracods, intraclasts, calcified caddisfly larval cases, and other carbonate components occurring within and among the stromatolitic domes and columns of the bioherms. Some bioherms also have a component of tufa. Laterally, bioherms are discontinuous (like patch reefs) and they grade laterally into lacustrine wackestone and micrite over a distance of 100 meters and basin-ward into dolomitic kerogenite (oil shale) of the Wilkins Peak Member over a distance of ~15 km. Shoreward, bioherms become progressively smaller and more isolated, and their enclosing fine-grained strata becomes thicker. Although the large bioherms are restricted to the northwestern portion of the basin, they are part of a lake-margin facies tract of microbialites that follows a 250+ km arc across the western, northern, and eastern greater Green River Basin.

Exemplary bioherms occur at Little Mesa, near La Barge, within an association of lithofacies that provide insight into the paleoenvironmental conditions of formation for the large bioherms. These bioherms occur mostly within aggrading fining-upward successions. The lithofacies association consists of four facies. The first is a flat-pebble conglomerate or coarse grainstone or both, deposited on flooding surfaces, typically beneath bioherms. Within this facies, interpreted as a high-energy setting, long-shore and barrier bars developed that provided raised, stable substrates for bioherm growth. The second facies is wackestone containing microbialite fragments, skeletal grains, and intraclasts; and is found lateral to bioherms and

interpreted as deposited in more sheltered waters around the bioherms. A third facies, commonly overlying and lateral to the bioherms, is composed of micrite and mudstone representing deeper, quieter water -- conditions not favorable for stromatolite growth. Basinward, a fourth facies develops, which comprises micrite and kerogenite.

A depositional model is proposed for the bioherm and associated lacustrine facies. Biohermal "reefs" or buildups grew in the higher-energy, nearshore region, parallel to the lake margin, and are associated with long-shore and barrier bars. Lagoonal micrite and mudstone facies with smaller isolated bioherms ("patch reefs") accumulated between the large bioherms and lakeshore. Basinward of the bioherms, wackestone, mudstone, micrite, and kerogenite were deposited in storm-wave-dominated sublittoral to profundal environments. A full parasequence in this unit would record a shallowing upward succession from fine-grained profundal and sublittoral settings, to relatively coarse-grained bars and erosion-resistant bioherms in the nearshore region, through finer-grained lagoonal areas, to mixed coarse- and fine-grained lake-plain and fluvial-floodplain environments. At Little Mesa, due to its relative proximal paleogeographic setting, parasequences mostly span nearshore to lagoonal environments, which are therefore recorded in dominantly fining-upward facies successions. This hypothesis needs to be tested by extending the stratigraphic framework farther across the region.

The succession of bioherms in Little Mesa area is associated with a major flooding surface. The succession spans part of a retrogradational parasequence set that evolved through parasequences successively dominated by fluvial-flood-plain sandstone and mudstone, then littoral grainstone, sublittoral mudstone, and finally profundal kerogenite. This succession is interpreted as a transgressive systems tract. All bioherms were eventually drowned, with subsequent kerogenite deposition during early Laney Member time, at and above the maximum flooding, downlap surface. These facies associations, parasequence development, and stratal stacking patterns are closely analogous to those we observed in strata of the Miocene Lake Idaho volcanically mediated rift system.

The development of Green River Formation bioherms was favored by balanced-filled lake-basin conditions with microbialites restricted to lake margins. Energy conditions, water depth, removal of fines, and a likely high calcium input related to fresh water inflow provided ideal conditions for bioherm development. 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 petroleum reservoirs appears to be significant and their potential for petroleum exploration in lacustrine basins should not be underestimated.