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THE GEOCHEMICAL PATHWAY BETWEEN OPTIMAL ORGANIC ACCUMULATION AND DESICCATION IN A CYCLICAL PLAYA LAKE-MUDFLAT SYSTEM; GREEN RIVER FORMATION, WYOMING

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The Wilkins Peak Member of the Green River Formation represents an underfilled lacustrine system consisting of hypersaline playa lake and salt pan-mudflat facies with sporadic detrital incursions. Compared to the “deep” perennial lake systems associated with paleolake Gosiute, this setting was extremely responsive to changing climatic, tectonic and paleogeographic conditions. Depositional oscillations in this basinal setting produced the long-recognized cyclicity consisting of oil shale-mudflat doublets or oil shale-trona-mudflat triplets that average about 4 meters. An approximate 5:1 bundling of these cycles, and a rise and fall in oil-yields of individual oil shales over a 20 cycle interval indicates longer-term cyclicity. Time-series analysis and correlation of this cyclicity with published argon-argon dates of Wilkins Peak interbedded tuffs defines the precessional (21 Ky), and short- and long-term eccentricity (100 and 400 Ky) cycles. Because the Earth’s precession and eccentricity modulates climate, the origin of this cyclicity was strongly influenced by orbital-driven changes in net moisture. The cyclical conditions produced climatically sensitive lithologies, oil-yields and geochemical signatures that occur over a short, well-defined temporal interval.

Geochemical reconstruction of these cyclical doublets and triplets, which represent “rainy and dry” precessional phases, reveal lacustrine highstands, sharp isotopic and other geochemical excursions, desiccation events, and various microfacies. Geochemical signatures associated with individual oil shales correspond to the limnology and sedimentation dictated by the playa lake expansion and contraction history. Thin, organic-rich zones in oil shales represent optimal organic accumulation events that equate to maximum net moisture, nutrient availability, productivity, organic flux, stratification and preservation. The mudflat is dominated by variable amounts of benthic and terrestrial input, desiccation, and chemical and detrital sedimentation. Variations between “wet and dry” mudflat microfacies respectively correspond to organic-bearing versus organic-lean assemblages, which were derived from small changes in net moisture related to orbital, tectonic and regional paleoclimatic effects. In most cycles, lake contraction and desiccation corresponds to a ^{13}C-enriched mudflat kerogen of up to 9 ‰ that occurs directly above the oil shale. This ^{13}C enrichment results from a combination of: (1) a greater proportion of terrestrial input, (2) increased organic degradation, and (3) a reduced CO_2 concentration in the mudflat lake that lowered the isotopic fractionation factor and possibly altered the carbon-assimilatory pathway.

The well-defined temporal and spatial pathway between optimal organic accumulation and desiccation provides “geochemical signposts” that define different processes of organic accumulation. In contrast to stable “deepwater” source rock systems, a combination of continuous changes in lake geometry, chemistry, ecology and sedimentation simultaneously controlled productivity, preservation and organic dilution. Reconstruction of the Milankovitch cyclicity explains the occurrence of end-member lithologies consisting of organic-rich, desiccated, detrital, and chemical-derived sediments. Characterization of these “short-lived” climatic-driven lacustrine processes complements longer term tectonic and/or climatic mechanisms to explain the dynamic Green River deposition. These geochemical signposts also define mechanisms by which orbital and non-orbital signals were transferred into the sedimentary record.