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Linking bed-scale processes to basin-scale architecture in the Lower Triassic Sulphur Mountain Formation (Montney-equivalent)

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Summary

Unconventional siltstone reservoirs exhibit geological heterogeneity across a gradational continuum of scales, from microscopic variations in fabric and composition to basin-scale changes in depositional architecture. Despite the economic importance of the Montney Formation as one of Canada's most significant unconventional plays, the controls on this multi-scale heterogeneity remains poorly understood. This study develops an integrated framework that links bed-scale transport processes to basin-scale stratigraphic architecture through a unifying supply–accommodation approach, based on detailed outcrop analysis of the Sulphur Mountain Formation (Montney equivalent) in the front ranges of southwestern Alberta.

Fourteen measured sections near Canmore and Kananaskis document thirteen sedimentary facies organized into associations representing shoreface, subaqueous platform, slope, and basin floor environments. These facies associations define shallow-water clinoforms recording deposition from wave- and storm-dominated shoreface settings to slope and basin floor deposits dominated by gravity-driven transport and gravitational instability (including turbidites). Three clinothem sets are recognized, distinguished by stacking styles that reflect the evolving balance between accommodation and sediment supply ($\delta A/\delta S$). Clinothem Set I exhibits alternating progradational and retrogradational stacking reflecting a progressive decrease in the rate of accommodation creation. Clinothem Set II is dominantly progradational, suggesting conditions where sediment supply significantly outpaced the rate of creation of accommodation. Clinothem Set III is aggradational to progradational as sediment supply matched and eventually exceeded the rate of accommodation creation.

An extensive paleocurrent dataset (N = 672) demonstrates that sediment dispersal was strongly three-dimensional, driven not by a single dominant process but by the interplay of fair-weather wave reworking, episodic storm-driven flows, gravity-driven transport, overprinted by semi-permanent along-shore and along-slope currents (i.e., geostrophic currents). Numerous paleocurrent measurements from unidirectional current ripples are oblique to, and locally nearly perpendicular to, the dominant direction of shoreline progradation. These findings challenge simplified two-dimensional depositional models commonly applied to fine-grained successions, improve reconstructions of sediment dispersal pathways, and may explain lateral facies changes and "off-trend" reservoir sweet spots in the subsurface.

At the bed scale, the Sulphur Mountain Formation is dominated by bedload transport, and despite compositional uniformity of non-cohesive, silt-sized quartz, feldspar, and detrital dolomite,

bedding planes preserve a diverse suite of small-scale bedforms including starved, barchan, sinuous, and linguoid ripple morphologies. A sediment flux–to–transport capacity (δSF/δTC) framework demonstrates that bedform diversity is controlled by variations in sediment supply relative to flow capacity, independent of grain size and composition. These bedforms create bed-parallel uneven surfaces that develop mechanical bed boundaries and thus serve as preferential planes for bedding-parallel fracture development and fluid migration in the subsurface.

The conceptual ratio frameworks developed here (δA/δS and δSF/δTC) demonstrate that sediment supply operates as a scale-independent control, governing centimeter-scale fabric variability and kilometer-scale depositional geometries. At the basin scale, variations in δA/δS drive systematic changes in clinothem architecture, sedimentary fabric, and associated mechanical stratigraphy, providing a predictive framework for reservoir connectivity and fracture network variability. This integrated approach advances our understanding of fine-grained sedimentary systems and has direct implications for unconventional reservoir characterization in the Western Canada Sedimentary Basin.

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