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Pre-vegetation, single-thread rivers sustained by cohesive, fine-grained bank sediments: Mesoproterozoic Stoer Group, NW Scotland

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Evidence of an enigmatic and unidirectional shift in fluvial architecture coincides with the proliferation of early vascular plants in the Silurian period. Unlike post-Silurian fluvial deposits, pre-Silurian fluvial strata lack significant alluvial mudrock and are most often characterized by broad sheet-like sandstones. This sedimentary architecture is traditionally interpreted as a pre-Silurian global prevalence of broad, shallow rivers with unstable channel banks, in stark contrast to the modern-day prevalence of low-sloping, meandering rivers. The Silurian stratigraphic shift has been attributed to the profound influence of vegetation on river geometry. Rooted plants are thought to have dramatically increased channel bank strength, decreased the ability of rivers to rework overbank deposits, and increased mud production rates through enhanced chemical weathering. Recent paleohydraulic reconstructions of pre-Silurian channel-bodies from around the world reveal that deep, single-threaded rivers were likely common during the pre-Silurian period, challenging the traditional paradigm. However, the mechanisms that provided pre-Silurian rivers the necessary bank strength to sustain deep-channeled flows have yet to be quantitatively explored using geologic observations. Here, we integrate recent advances in paleohydrological methods with original and published field data to reconstruct paleohydraulics and channel planforms of Mesoproterozoic fluvial deposits in NW Scotland.

Specifically, we combine geological observations of ~1.2 Ga Stoer Group channel fill deposits in NW Scotland with mechanistic theories that describe the formation of river dunes to quantitatively assess the dominant channel planform style. Our results indicate that Stoer Group fluvial strata represent formative channels with 2-6 meters bankfull flow depth and bed slopes ranging from $6x10^{-5}$-$2x10^{-3}$. We combine these estimates with measurements from modern channels to show that the Stoer Group rivers plot alongside modern single-thread, meandering rivers and high-sinuosity, wandering rivers in a quantitative channel-planform discriminant space. Furthermore, using a mechanistic theory that describes the formation of single-threaded rivers without plants, we show that the deep Stoer Group rivers could have been sustained by the cohesive bank strength provided by mixed siliciclastic sediments with 25-40% mud content—a range consistent with field observations of mud content in putative floodplain facies of the Stoer Group. Finally, we relate our findings to modern environments by considering width to depth ratios and bank

cohesion thresholds in a large set of modern rivers, showing that only a small fraction of global rivers requires vegetation to maintain bank stability.