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Quantifying the morphology of dunes in big rivers

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Dunes are ubiquitous morphological elements in rivers of all grain sizes and are the principal agents of bedload transport. Through the interactions between flow dynamics and dune morphology, dunes can migrate, change shape, and amalgamate leading to the formation of larger bedforms, which can also create hydraulic heterogeneity and potentially lead to river morphologic change. Additionally, dunes are the major building block in many alluvial successions in the rock record. Many interpretations of dunes in the ancient record have relied on analogies with dunes that have been well documented in experimental studies and examination of smaller natural channels, in which dunes possess a leeside angle at the angle-of-repose of the sediment. However, research over the past 20 years has shown the presence of dunes that possess a lower leeside angle, and which may have more complex leeside morphology. Recent research has also documented the flow associated with such low-angle dunes, both in the laboratory as well as in the field. Laboratory models have demonstrated the presence of an intermittent zone of flow separation in the leeside of low-angle dunes, and suggested an angle of 15° is required to promote the onset of permanent flow separation. Furthermore, interpreting big rivers from the sedimentary record is typically thought to be dependent on recognizing deposits that are related to the large scales of dune morphology and dynamics.

This work utilizes a dune morphological analysis method to compile data from seven of the World's big rivers – the Amazon, Brahmaputra, Columbia, Mekong, Mississippi, Missouri, and Paraná rivers – and investigates dune size and shape through morphologic parameters including dune height, wavelength, leeside angle, leeside shape, and flow depth. This method decreases analysis time from a few days to a few hours and increases data output to 105 data points. This research highlights that low-angle dunes are common in big rivers. However, in addition, the analysis reveals that even in many cases where dunes have high angle leesides, the steepest slope on the dune leeside is often located at the bottom half of the leeside. This has important implications for estimating flow resistance, and also suggests that such steeper cross-stratification may not be representative of the entire dune leeside profile. Investigation of dune size also reveals that while large dunes do exist in deep flows, an overwhelming number of small dunes also exist in deep flows.

This analysis demonstrates that dune shape and size are complex in big rivers and care is required when estimating flow resistance, interpreting low-angle stratification in fluvial deposits, and producing paleohydraulic reconstructions that rely on relationships between dune size and flow depth.