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A holistic view on avulsion dynamics in a dryland river fan based on comprehensive geomorphological analysis

Koen A. van Toorenenburg[1,2*], Marinus E. Donselaar[1,3], Gert Jan Weltje[3]
1. Geoscience and Engineering, Delft University of Technology, Delft, ZH, NETHERLANDS
2. Shell Global Solutions International, Shell, The Hague, ZH, NETHERLANDS
3. Earth and Environmental Sciences, KU Leuven, Leuven, VB, BELGIUM
E-mail: koen.vantoorenenburg@shell.com

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Dryland river fans form by repeated switching (avulsion) of an ephemeral stream as it progrades and accumulates sediment onto a low-gradient alluvial plain. Successive channel belts are organised in a radial pattern through a process of compensational stacking, where each consecutive river path avoids the positive relief left by its predecessors. Several criteria have been proposed for the likelihood of where and when an active channel in such a setting switches its path, including super-elevation, ratio of along-channel slope and cross-floodplain gradient, and hydraulic capacity of crevasses. A key role for the overbank domain is implied in each of these – largely interdependent – parameters for avulsion proneness, but the exact avulsion dynamics remain insufficiently understood.

In this study, we combine differential-GPS measurements and a resampled open-source global digital surface model (DSM) to quantify along-channel changes in hydraulic parameters and reconstruct subtle geomorphology across an undisturbed and non-vegetated dryland river fan. This approach allows us to propose a holistic view on autocyclic avulsion dynamics in prograding dryland river systems.

The results support the idea that the downstream gradient of an active river decreases over time as result of basinward lengthening (by both progradation and increased sinuosity) mirrored by near-channel deposition. This process gradually decreases the drainage effectiveness of the stream profile and elevates the channel belt relative to the surrounding floodplain. Crevasse splays play a key role in determining whether the river switches or not by effectively testing alternative flow paths. Crevasse channels develop along a local path of steepest descent across the floodplain and build out as long as their stream profile is hydrodynamically more favourable than that of their parent channel, after which they heal up. As the river profile lengthens and rises, crevasse splays extend further onto the floodplain until one reaches base level in a shorter distance than the river itself. At this point, it will receive an increasing proportion of total discharge and the parent river is abandoned. The avulsion process is gradual rather than abrupt and its frequency likely increases downstream, resulting in a dendritic pattern of abandoned river paths.

The process proposed here brings together existing criteria for autocyclic avulsion in prograding dryland river systems devoid of vegetation. It incorporates the role of subtle floodplain morphology and the evolution of crevasse splays and explains the resulting depositional architecture. Moreover, our findings enable us to predict when and where a next avulsion will take place, which could help flood risk analysis and mitigation in similar settings.