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Notes

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ABSTRACT

The lack of topographic complexity in ephemeral dryland channels, despite large variations in hydraulic controls and sediment texture, presents an unexplained paradox that limits understanding of their long-term evolution. In dryland basins, spatially and temporally discontinuous channel flow transports and sorts sediment along the bed intermittently and irregularly. The cumulative effect of these processes counterintuitively produces simple topography, manifest in straight longitudinal profiles and symmetrical cross sections, in contrast with perennial channels. This paper presents numerical modeling experiments based on field measurements to investigate dryland channel topographic development through the responses of bed-material flux and net sediment storage to variations in channel hydrology. We show that spatially variable flow creates and subsequently destroys incipient topography along ephemeral reaches, and that large flood events above a threshold overcome hydraulic and grain-size controls to dampen fluctuations in longitudinal sediment flux through a smoothing of the incipient channel bar forms. The results provide a physical explanation for emergent topographic simplicity in ephemeral dryland channels despite higher variability in streamflow and sedimentary characteristics compared to perennial systems.

INTRODUCTION

Interactions between streamflow, sediment supply and transport, and valley constraints create topography in alluvial river channels, which may be simply expressed in the downstream direction by the longitudinal (long) profile and laterally by the cross section. Thus, long-profile curvature or cross-sectional shape may differ depending on the balance between streamflow, bed material transport, and boundary conditions. Perennial streams, for example, tend to have concave-up long profiles (Snow and Slingerland, 1987), asymmetrical cross sections (Knighton, 1981), and well-developed bar forms. In contrast, ephemeral streams commonly have straight long profiles (Powell et al., 2012; Vogel, 1989), nearly symmetrical cross-stream profiles (Leopold et al., 1966), and poorly developed bar forms (Hassan, 2005), thus indicating a higher degree of topographic simplicity than in perennial streams.

Such contrasts in channel topography between perennial and ephemeral streams (Tooth, 2000) are paradoxical given that prior work has shown that dryland basins have high spatial variability in channel hydrology and sedimentary characteristics relative to perennial systems. In particular, streamflow (Q) in dryland channels is short lived, episodic, and spatially discontinuous because it is generated by brief rainstorms that are typically much smaller in area than the drainage basin, and reach-wide floods are infrequent (Wolman and Gerson, 1978). These channels also display large longitudinal fluctuations in bed-sediment grain-size distributions (GSDs) with no clear downstream fining trend (e.g., Frostick and Reid, 1980). Because sediment flux (Q_s) in alluvial river channels is controlled by the interplay between hydraulics and bed texture, in dryland channels the high longitudinal variability in Q and bed-sediment GSD, along with spatial variations in hillslope sediment supply (Michaelides and Singer, 2014) and channel width (Leopold et al., 1966), might be expected to produce great spatial differences in Q_s. Furthermore, if these spatial variations in Q_s persist, they should tend to produce alternating eroding and non-eroding reaches, and thus undulating downstream topography and potentially cross-sectional asymmetry. However, simple topography prevails in ephemeral dryland channels (e.g., Fig. 1A), suggesting that there is a set of unexplained processes that maintain relatively smooth channel morphology despite large variations in the hydrology and other controlling factors.

Based on the Exner equation of sediment mass balance (Paola and Voller, 2005), the longitudinal variance in total cross-sectional Q_s is a measure of topographic simplicity. Low variance in Q_s along a reach is reflective of smaller changes in storage and thus more simple longitudinal and cross-stream topography, while high variance in Q_s suggests more dramatic topographic change and hence higher propensity for constructing sedimentary architecture along a channel (topographic complexity). In this paper, we conduct a set of modeling experiments using longitudinal variances in Q_s and in net sediment storage along the channel ($\Delta Q_s/\Delta x$) as metrics to investigate the controls on topographic development in ephemeral dryland channels for a range of flows. The topography of such channels is particularly relevant to water resources, flash-flood risk, and the lifespan of reservoirs in these marginal climatic regions, which are subject to increasing water stress. The results of this research have broad relevance to the understanding of sediment supply-transport relations, time scales of ephemeral channel filling and evacuation, landscape evolution, and sedimentary geology.

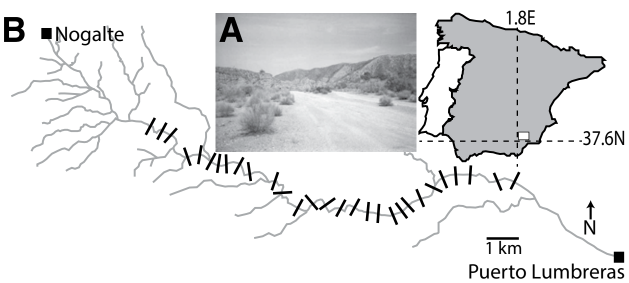

Figure 1. A: Photo of Nogalte channel, Spain, illustrating simple topography. B: Study area map with cross sections, modified from Michaelides and Singer (2014).

STUDY SITE AND METHODS

The analysis presented is based on data collected from the Rambla de Nogalte, southeast Spain (Fig. 1B), a 33-km-long ephemeral, sand and gravel–bed channel bounded by convex hillslopes, draining a 171 km^2 basin. The area has semiarid climate with mean annual rainfall of ~350 mm yr^{-1} that occurs during convective rainstorms, producing large floods with 7–11 yr recurrence (Bull et al., 1999). Topographic valley cross sections and channel GSDs were collected at 29 locations along a 15 km Nogalte reach. GSDs were measured at regular intervals across the channel by Wolman counts for grain size classes between 2 mm and 512 mm. The long profile is straight (Fig. 2A) with a reach-averaged slope of 0.019 ± 0.001 (standard error, SE). Significant cross-channel topography and bar forms were absent (Fig. 1A). GSDs of channel sediments were analyzed to

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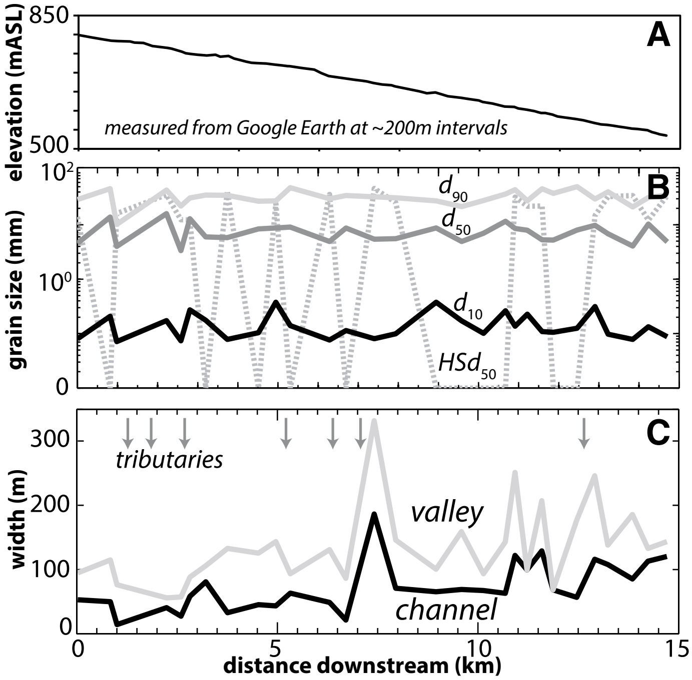

Figure 2. Long profile (A) modified from Michaelides and Singer (2014), measured characteristic channel (d_{90}, d_{50}, d_{10}) and hillslope (HSd_{50}) cumulative grain size percentiles (B), and width (C) versus distance along Nogalte channel. mASL—meters above sea level.

obtain characteristic size percentiles—10, 50, and 90 (d_{10}, d_{50}, and d_{90})—for each cross section (Fig. 2B). GSDs representing hillslope sediment supply at each cross section were obtained as output from a runoff-driven, particle-based model (Michaelides and Martin, 2012) for an ensemble of rainstorms of varying intensity and duration (Michaelides and Singer, 2014). Modeled hillslope-supplied gravel was added to a 32% sand bed at each cross section (Table DR1 in the GSA Data Repository[1]) to obtain a metric of hillslope contribution to channel GSD (HSd_{50}; Fig. 2B).

Our aim was to assess the relative controls on variability in longitudinal Q_s and $\Delta Q_s/\Delta x$ as measures of topographic simplicity over the reach via a set of numerical experiments in which we vary the spatial distribution and magnitude of channel Q. We modeled fractional, instantaneous unit gravel flux (≥2 mm), Q_s, by the surface-based Powell equation (Powell et al., 2003) developed for drylands, which includes a particle hiding function and thus allows for selective transport: $q^*_{s_i}/f_i = 11.2\,(\tau^*_i - \tau^*_{ci})^{4.5}/\tau^{*3}_i$, where q^*_s is dimensionless unit sediment flux, i denotes the grain size class, f is the fraction in that class, τ^* is dimensionless shear (Shields) stress $\{\tau^* = \rho gRS\,/\,[(\rho_s - \rho)gd_{50}]$, where R is hydraulic radius, which approximates flow depth, h, for wide channels, S is slope, ρ is water density, and ρ_s is sediment density$\}$, and τ^*_c is its critical, size class–dependent value at entrainment $[\tau^*_{ci} = 0.03(d_i/d_{50})^{-0.74}$, where d_i is the characteristic grain size for class i]. This flux equation is inverted to calculate volumetric flux: $q_{s_i} = q^*_{s_i} f_i\,(\mathrm{t}^*/\mathrm{r})^{1.5}/[g(\mathrm{r}_s - \mathrm{r})/\mathrm{r}]$. To compute shear stress (ρghS), we assumed S is equal to bed slope, which is reasonable for steep channels where backwater effects are insignificant (Moramarco and Singh, 2000). Channel hydraulics for particular values of instantaneous flow were computed using a simplified integration of flow for unit widths across the cross section and an empirical fit of the grain-scale Darcy-Weisbach friction factor, ff $[1/\sqrt{ff} = 0.82\log(4.35R/d_{90})]$ (Knighton, 1998), used to calculate mean velocity: $U = \sqrt{8gRS/ff}$. Total gravel flux, $Q_s = \sum_{i=2mm}^{512mm} q_{s_i} w$, was calculated based on local measured GSD, channel width (w), and computed mean hydraulics for each cross section (Fig. 1B).

The flux simulations were built upon on two simplifying assumptions to investigate longitudinal patterns in Q_s under different forcing conditions. (1) Q is considered steady; because water was not explicitly routed through the channel, we accounted for cross-sectional differences in flow mass conservation, but did not explicitly compute the effect of the spatial acceleration terms on τ. (2) Q_s is considered instantaneous based on Q such that no scour or fill is explicitly represented. The first assumption obviates routing Q and Q_s, which is challenging in ephemeral systems due to transmission losses and shock waves within flood bores. The second simplification represents Q_s potential, or long-term ephemeral channel behavior under stationary climatic forcing and sediment supply.

To investigate the impact of channel hydrology, we (1) varied the spatial distribution of Q through the reach, and (2) modified the magnitude of uniform Q. The spatially varying Q simulations (maximum $Q = 50$ m³ s⁻¹) are: (1) increasing Q along the reach; (2) decreasing Q along the reach; and (3) mid-reach–peaking Q (Fig. 3A). In the simulations varying flow magnitude, Q was 25, 50, 75, 100, 200, and 2000 $m^3\,s^{-1}$ (Q_{25}, Q_{50}, etc.). For all hydrological simulations, we used measured channel GSDs and topographic valley cross sections. All other variables were kept unchanged in each run. Experimental parameter values are presented in Tables DR2 and DR3. We define our control experiment, against which we compare all other simulations, as spatially uniform $Q = 50$ $m^3\,s^{-1}$, measured valley cross sections, and measured channel GSDs. We compared coefficients of variation (CV) in longitudinal Q_s and net sediment storage along the channel (x) between cross sections ($\Delta Q_s/\Delta x$) that were generated from each experiment as normalized indices of topographic simplicity. Based on the Exner equation, simulations with small CVs of longitudinal Q_s and $\Delta Q_s/\Delta x$ reflect low spatial variation in topography (i.e., simple topography).

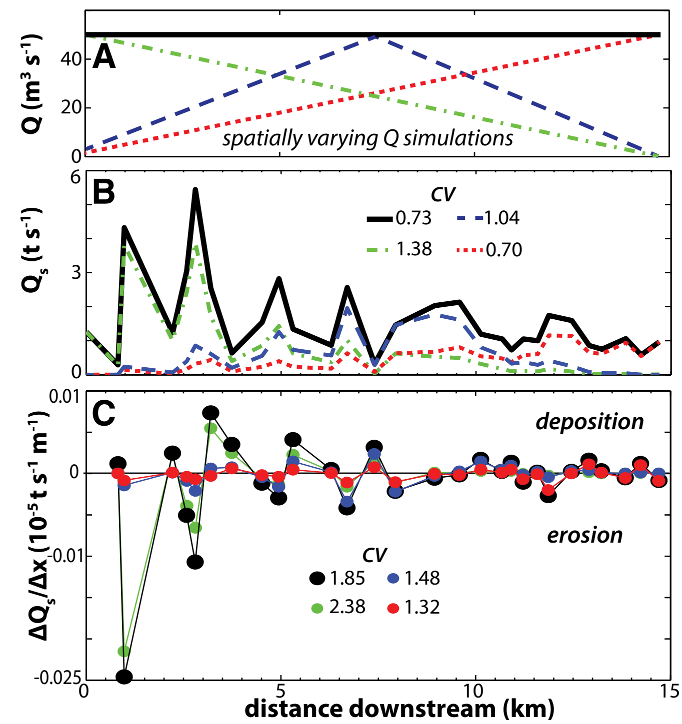

Figure 3. Modeled streamflow (Q) scenarios (A) and corresponding sediment flux (Q_s) (B) and sediment storage ($\Delta Q_s/\Delta x$) (C) versus distance. CV—coefficient of variation.

[1]GSA Data Repository item 2014373, Tables DR1–DR4, is available online at www.geosociety.org/pubs/ft2014.htm, or on request from editing@geosociety.org or Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301, USA.

RESULTS AND DISCUSSION

The field data reveal aperiodic longitudinal fluctuations in GSD, as well as in valley and channel width, which have been shown to impact depositional behavior and grain-size sorting (Pelletier and DeLong, 2004; Toro-Escobar et al., 2000). Our previous Nogalte work demonstrated that channel d_{90} is statistically similar to the hillslope-supplied d_{50} (Michaelides and Singer, 2014), so the hydraulic grain roughness in the Nogalte is likely derived from hillslopes. However, local hillslope-channel correspondence in grain size is poor (Michaelides and Singer, 2014), and there is no systematic relationship between GSD and width (Fig. 2). These factors suggest that channel GSD is derived from winnowing and downstream sorting of nonuniform hillslope-supplied sediment (HSd_{50}) by variable channel flow, wherein stream hydraulics fluctuate with downstream width variation. The following modeled scenarios provide insight into this sorting and longitudinal topographic development.

Spatially Varying Flows

The model simulation of uniform Q_{50} produced aperiodic fluctuations in Q_s and $\Delta Q_s/\Delta x$ (Fig. 3), apparently inherited from a combination of longitudinally varying GSD and channel width (e.g., high Q_s and erosion in narrow section with fine GSD at 1 km; Fig. 2). More importantly, large modeled spatial differences in Q, which generally occur in drylands due to short-lived and spatially discontinuous rainstorms, had a minor impact on spatial patterns of Q_s. In spite of nonlinear relationships between Q and Q_s, spatial differences in Q along the reach merely augmented or attenuated longitudinal fluctuations in Q_s (Fig. 3B). These factors suggest that downstream variations in width and grain size exert strong controls on longitudinal Q_s variation and thus on bed topography in dryland channels.

The simulations with downstream-decreasing Q and mid-reach–peaking Q both produced higher CV in Q_s than the control experiment, yet only the former simulation produced higher CV in sediment storage, $\Delta Q_s/\Delta x$ (Figs. 3B and 3C). Thus, downstream-decreasing Q, which represents a common dryland phenomenon of large transmission losses along the reach, actually produces more topographic complexity than uniform flow, whereas downstream-increasing Q reduces the CV in $\Delta Q_s/\Delta x$ and thus simplifies topography along the reach (Fig. 3C). Interestingly, total net sediment storage along the reach, $\Sigma\Delta Q_s$, is positive (i.e., net accumulation) for downstream-decreasing Q, while it is negative and nearly the same order of magnitude for downstream-increasing Q (Table DR2). The spatial pattern of topographic change for downstream-decreasing Q is one of substantial sediment storage change in the upper reach driven by strongly varying hydraulics (e.g., high Q in the upper part of the reach interacts with a narrow channel) and very little topographic change in the lower reach (Figs. 2, 3B, and 3C; Table DR3). In contrast, downstream-increasing Q, rare in most dryland channels (Tooth, 2000; Wolman and Gerson, 1978), modulates the magnitude of storage differences along the channel by reducing erosion in the upper reach (Fig. 3C). $\Sigma\Delta Q_s$ for the mid-reach–peaking Q is approximately zero, which indicates nearly equal sediment redistribution between sections (Fig. 3C), thus reinforcing topographic simplicity by discontinuous channel Q. In summary, incipient topography created along the Nogalte reach by downstream-decreasing flows may be destroyed by downstream-increasing Q or mid-reach–peaking Q. We therefore suggest that spatial variability in streamflow generation and transmission losses are important drivers for maintaining topographic simplicity in dryland ephemeral channels.

Geomorphic Thresholds

The model runs of spatially varying Q provide insight into controls on flux and storage behavior, but how persistent are longitudinal fluctuations in Q_s and $\Delta Q_s/\Delta x$ for higher or lower flows? We found that longitudinal variation in modeled flux and storage diminishes with higher Q (Figs. 4A and 4B; Table DR2). Most importantly, there appears to be a threshold of Q above which the CVs of longitudinal Q_s and $\Delta Q_s/\Delta x$ decline precipitously; in our simulations this occurs between Q_{100} and Q_{200}. Crossing this threshold produces a marked decline in CVs of channel hydraulic variables and corresponding Q_s (Fig. 4C; Tables DR2 and DR3). The threshold occurs at $\tau^* > 40\tau_c^*$, or ~10 times greater than the ~$4.5\tau_c^*$ value found to be required to entrain all bed material grain sizes with equal mobility in unarmored ephemeral channels (Powell et al., 2003). This suggests that there are three separate quantifiable Q_s thresholds in dryland channels: (1) a low critical value is required to entrain any grain sizes; (2) a value of ~$4.5\tau_c^*$ is needed to move all grain sizes within a cross section with equal mobility; and (3) a value of ~$40\tau_c^*$ is required to entrain gravel at nearly equivalent rates at all sections along a reach. The latter may be called the channel-smoothing threshold because it reduces longitudinal variability in Q_s and $\Delta Q_s/\Delta x$, thus smoothing reach-wide topography. Such a channel-smoothing event resets topography, and can thus be construed as the threshold for geomorphic effectiveness in dryland channels (Wolman and Gerson, 1978), where longitudinal differences in Q_s (e.g., due to varying GSD and width; Fig. 2) are dampened by flows large enough to mobilize available gravel in approximately equal measure.

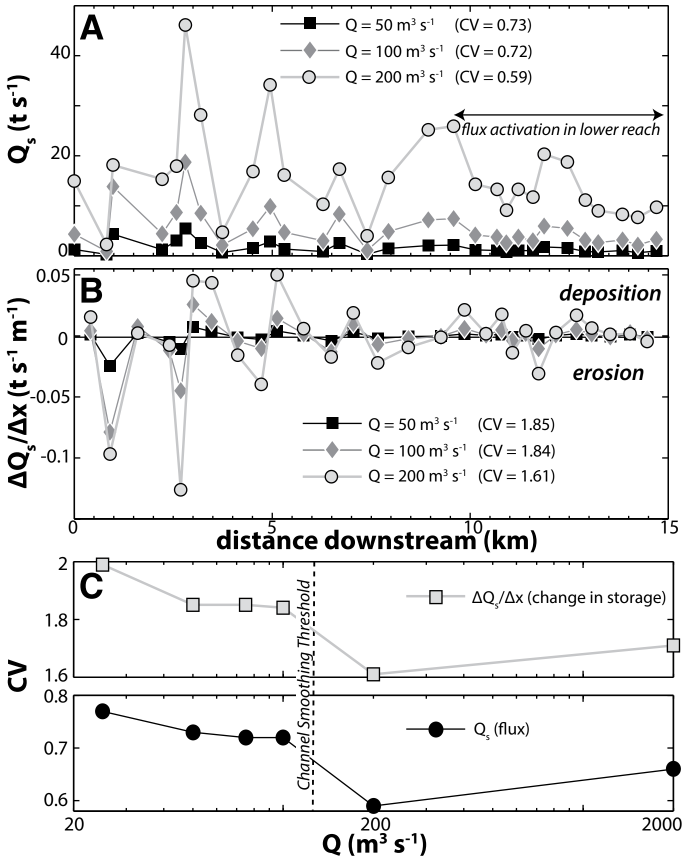

Figure 4. Sediment flux (Q_s) versus distance (A), mean-normalized sediment storage ($\Delta Q_s/\Delta x$) versus distance (B), and coefficient of variation (CV) of Q_s and $\Delta Q_s/\Delta x$ versus streamflow (Q) (C) for simulations of uniform Q.

The abrupt difference in net sediment storage patterns between Q_{100} and Q_{200} is produced by more spatially uniform hydraulics along the reach, evidenced by relatively low variance in U, h, τ, and τ^* for the Q_{200} run (Tables DR2 and DR3). The decline in CV for $\Delta Q_s/\Delta x$ between these two uniform Q values further emphasizes the importance of the channel-smoothing threshold in modulating differences in transport and storage along the reach (Fig. 4C). Notably, CV for Q_s does not significantly change once the channel-smoothing threshold is crossed, even for the extreme case of Q_{2000}, which actually produces a slight increase in CV (Fig. 4C). Generally, crossing this threshold produces larger-amplitude patterns of $\Delta Q_s/\Delta x$, but more regular downstream variation. In particular, it increases transport and storage in the lower part of the Nogalte reach, which is essentially inactive for sub-threshold values of Q. This indicates that Q above this geomorphic threshold produces reach-scale redistribution of sediment.

Controls of Width and Grain Roughness

Longitudinal Q_s fluctuations were prominent for most simulations, suggesting the importance of inherent controls of width and grain roughness (derived from hillslope sediment supply) on sediment flux and net sediment storage along the reach. Therefore, we investigated relationships between $\Delta Q_s/\Delta x$ and downstream changes in width ($\Delta w/\Delta x$) and in grain roughness ($\Delta d_{90}/\Delta x$) for various values of uniform Q. We found that sediment storage is well correlated with $\Delta d_{90}/\Delta x$ and $\Delta w/\Delta x$ for sub-threshold flows, but these correlations decline with progressively higher Q (Table DR4). This finding supports the hypothesis that spatial patterns of storage are strongly affected by grain-size and width controls along the reach for flow below the channel-shaping threshold. Once this threshold is crossed, however, the variability in flux and storage declines (Fig. 4C) because Q is large enough to overcome the inherent channel constraints on hydraulics and sediment flux. We find that different spatial configurations of Q have distinct controls on flux and storage. Specifically, $\Delta Q_s/\Delta x$ is highly correlated with longitudinal differences in hydraulic roughness ($\Delta d_{90}/\Delta x$) for flows that decline downstream, whereas it is well correlated with $\Delta w/\Delta x$ for flows that increase downstream, but these latter flows are poorly correlated with $\Delta d_{90}/\Delta x$ (Table DR4). In other words, patterns of sediment storage during typical dryland channel flows with high transmission losses are sensitive mainly to variations in grain roughness, whereas during rare reach-wide flows, $\Delta Q_s/\Delta x$ is mostly sensitive to variations in channel width. These results suggest that the spatial configuration of prevailing flows in dryland channels may be fundamental to the long-term geomorphic evolution of these channels because of the selective interaction of Q with varying hydraulics and roughness within channel sub-reaches.

IMPLICATIONS AND CONCLUSIONS

It appears then that in dryland basins, spatially heterogeneous Q interacts with fluctuating width and hillslope-supplied GSD to sort sediment along the channel into relatively coarse and fine sections that persist between floods (Fig. 2; Yuill et al., 2010). Our modeling results suggest that sediment may accumulate into incipient bar forms during some flows, but that this topography may be subsequently eroded during different spatial distributions of flow. This is consistent with empirical observations that streamflow-driven changes in sediment storage between cross sections do not generate significant long-term topography over dryland channel reaches (e.g., Leopold et al., 1966). Our results demonstrate that during the even more infrequent reach-wide floods, a geomorphic threshold is exceeded whereby sediment is redistributed longitudinally from incipient bar forms, reducing divergences in flux and storage, and thereby smoothing topography along the entire reach (Figs. 4B and 4C). Thus, these channels contain undeveloped bar forms due to progressive topographic smoothing by the prevailing nonuniform channel flow. These factors, coupled with net sediment accumulation, provide plausible explanations for why, despite spatially heterogeneous Q and varying hydraulics and roughness, ephemeral dryland channels maintain topographic simplicity in the form of straight long profiles and symmetrical cross sections.

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REFERENCES CITED

Bull, L.J., Kirkby, M.J., Shannon, J., and Hooke, J.M., 1999, The impact of rainstorms on floods in ephemeral channels in southeast Spain: Catena, v. 38, p. 191–209, doi:10.1016/S0341-8162(99)00071-5.

Frostick, L.E., and Reid, I., 1980, Sorting mechanisms in coarse-grained alluvial sediments: Fresh evidence from a basalt plateau gravel, Kenya: Journal of the Geological Society, v. 137, p. 431–441, doi:10.1144/gsjgs.137.4.0431.

Hassan, M.A., 2005, Characteristics of gravel bars in ephemeral streams: Journal of Sedimentary Research, v. 75, p. 29–42, doi:10.2110/jsr.2005.004.

Knighton, A.D., 1998, Fluvial Forms and Processes: London, Edward Arnold, 218 p.

Knighton, A.D., 1981, Asymmetry of river channel cross-sections: Part I. Quantitative indices: Earth Surface Processes and Landforms, v. 6, p. 581–588, doi:10.1002/esp.3290060607.

Leopold, L.B., Emmett, W.W., and Myrick, R.M., 1966, Hillslope processes in a semiarid area, New Mexico: U.S. Geological Survey Professional Paper 352-G, 61 p.

Michaelides, K., and Martin, G.J., 2012, Sediment transport by runoff on debris-mantled dryland hillslopes: Journal of Geophysical Research, v. 117, F03014, doi:10.1029/2012JF002415.

Michaelides, K., and Singer, M.B., 2014, Impact of coarse sediment supply from hillslopes to the channel in runoff-dominated, dryland fluvial systems: Journal of Geophysical Research, v. 119, p. 1205–1221, doi:10.1002/2013JF002959.

Moramarco, T., and Singh, V.P., 2000, A practical method for analysis of river waves and for kinematic wave routing in natural channel networks: Hydrological Processes, v. 14, p. 51–62, doi:10.1002/(SICI)1099-1085(200001)14:1<51::AID-HYP909>3.0.CO;2-Z.

Paola, C., and Voller, V.R., 2005, A generalized Exner equation for sediment mass balance: Journal of Geophysical Research, v. 110, F04014, doi:10.1029/2004JF000274.

Pelletier, J.D., and DeLong, S., 2004, Oscillations in arid alluvial-channel geometry: Geology, v. 32, p. 713–716, doi:10.1130/G20512.1.

Powell, D.M., Laronne, J.B., and Reid, I., 2003, The dynamics of bedload sediment transport in low-order, upland, ephemeral gravel-bed rivers: Advances in Environmental Monitoring and Modelling, v. 1, p. 1–27.

Powell, D.M., Laronne, J.B., Reid, I., and Barzilai, R., 2012, The bed morphology of upland single-thread channels in semi-arid environments: Evidence of repeating bedforms and their wider implications for gravel-bed rivers: Earth Surface Processes and Landforms, v. 37, p. 741–753, doi:10.1002/esp.3199.

Snow, R.S., and Slingerland, R.L., 1987, Mathematical modeling of graded river profiles: The Journal of Geology, v. 95, p. 15–33, doi:10.1086/629104.

Tooth, S., 2000, Process, form and change in dryland rivers: A review of recent research: Earth-Science Reviews, v. 51, p. 67–107, doi:10.1016/S0012-8252(00)00014-3.

Toro-Escobar, C.M., Paola, C., Parker, G., Wilcock, P.R., and Southard, J.B., 2000, Experiments on downstream fining of gravel. II: Wide and sandy runs: Journal of Hydraulic Engineering, v. 126, p. 198–208, doi:10.1061/(ASCE)0733-9429(2000)126:3(198).

Vogel, J.C., 1989, Evidence of past climatic change in the Namib Desert: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 70, p. 355–366, doi:10.1016/0031-0182(89)90113-2.

Wolman, M.G., and Gerson, R., 1978, Relative time scales of time and effectiveness of climate in watershed geomorphology: Earth Surface Processes and Landforms, v. 3, p. 189–208, doi:10.1002/esp.3290030207.

Yuill, B., Nichols, M., and Yager, E., 2010, Coarse bed material patch evolution in low-order, ephemeral channels: Catena, v. 81, p. 126–136, doi:10.1016/j.catena.2010.02.002.

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