Morphology, bedload and sedimentology of active gravel bed rivers

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Fluvial systems: dynamics and interactions across scales

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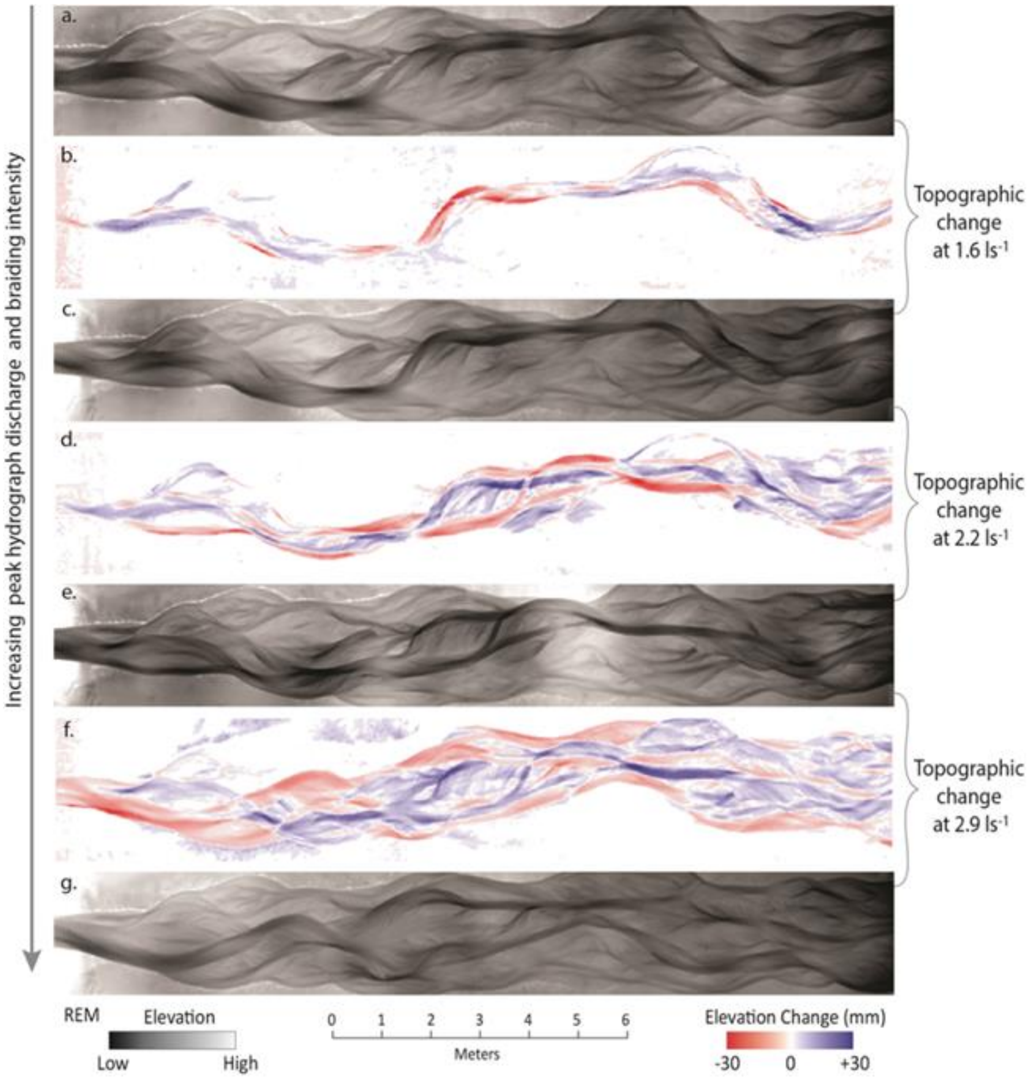
The paper integrates ideas about gravel river dynamics and sedimentology built around the idea of the "morphological active layer", its variability and relation to stream power, and its control of bedload transport rate and bed particle mobility, as well as deposit geometry. The summary generalizations are based on quantitative analysis from a series of physical model experiments, supported by field observations (references on final slide)

- Fundamental to the idea is that bedload is closely connected to the short-term local patterns of erosion and deposition associated with channel-scale processes (bar formation and development, channel migration and avulsion, local bed scour)
- These processes occur continuously and rapidly in very active gravel-bed rivers once bed material is mobilized. (This is the basis for morphological approach to bedload measurement).
- *Bed load and bed dynamics are essentially the same thing* and all bedload exchanges with the morphological change over distances of the order of the length scale of the bed morphology (e.g. bar spacing).
- This differs from 'textbook' concepts of bedload as a grain-scale phenomenon driven by local hydraulics under equilibrium transport over a stable plane bed.

Morphological active layer



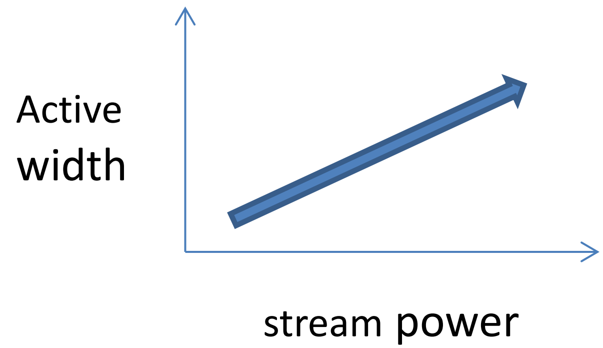
A morphologically active gravel river bed (braided in this case) undergoes constant morphological change at mobilising flows. This can be seen as intricate patterns of positive and negative elevation change over a defined time period (minutes in this case of active braiding in a flume)

The morphological active layer is then the layer of bed sediment involved in morphological change and bedload over the defined time period. The lateral extent and vertical amplitude of the morphological active layer depends on river type and size, and therelative magnitude of the forcing flow.

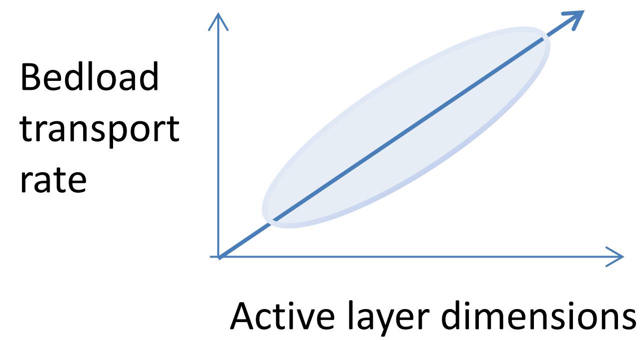
See Leduc et al 2015; Ashmore et al., 2018

Morphological active layer and bedload

Active layer dimensions (area, width, depth, volume) increase with increased flow forcing (both ‘at a station’ and ‘downstream’)



- Bedload transport is strongly correlated with active layer dimensions – especially width and to lesser extent the depth
- No morphological activity = no bedload. (i.e. no ‘wash load’ over static bed) – so we can define a channel-scale morphological threshold for bedload rather than grain threshold.



See Peirce et al. 2018; Middleton et al. 2019

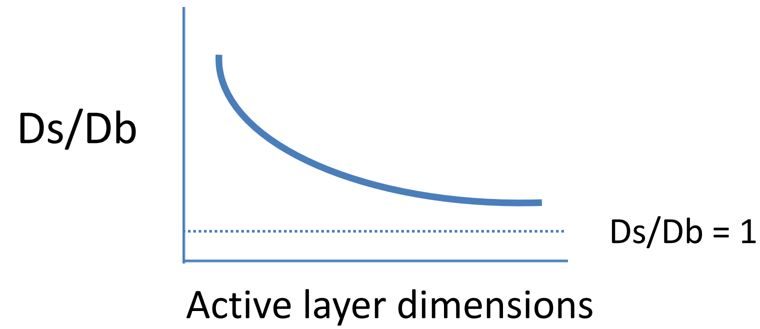
Consequences of morphological control of bedload

- Temporal and spatial variability in bedload relates to channel scale morphological process variation – the dynamic effects of local channel processes on the morphological active layer translate into bedload variability in time and along the channel
- Spatial correlation of bedload transport rate decays rapidly over a few channel widths in relation to spatial scale of variation of the morphological dynamics
- Frequency distribution of active layer dimensions and bedload transport rate co-vary – range and amplitude of variation increase with average active layer dimensions
- Bedload transport rate can be measured from morphological active layer dimensions and correlates strongly with independent direct flux measurement
- Bed particle path length is 'slaved' to channel morphology length and the mean and modal path length is approximately the bar length scale

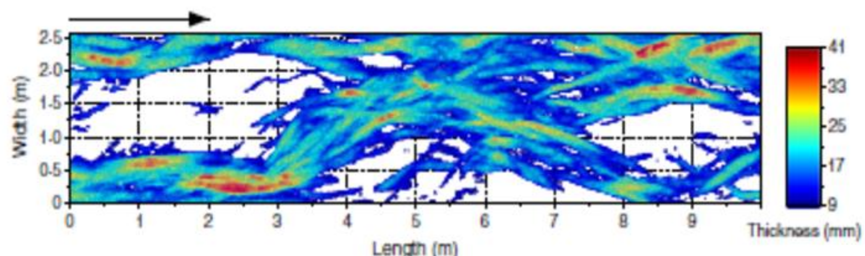
Morphological active layer, bed material mobility and deposit characteristics

- Bedload mobility e.g. ratio of subsurface to bedload particle size (Ds/Db) tied to active layer dimensions – larger scale bed turnover requires mobility of all size fractions.
- Bedload approaches equal mobility at highest morphological active layer dimensions

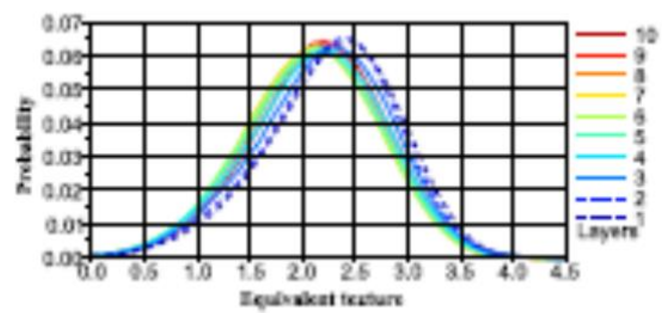
Peirce et al. 2019



Minimum surface elevation of morphological active layer sets deposit geometry thickness and distribution in relation to



Turnover of morphological active layer Morphological dynamics and extensive morphological active layer create homogeneous (on average) mixing of grain sizes within the deposit, consistent with bed material equal mobility (Figure show similar grain size distribution for a series of horizontal slices within the time-integrated active layer)



Leduc et al. 2015; Gardner et al., 2017

Details of experimental and field results supporting the conceptual outline include:

Ashmore, P. , Bertoldi, W. and Gardner, J.T. 2011. Active width of gravel-bed braided rivers. Earth Surface Processes and Landforms. 36, 1510-1521. https://doi:10.1001:esp2182

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Gardner, T., Ashmore, P., Leduc, P. 2017. Morpho-sedimentary characteristics of proximal gravel braided river deposits in a Froude-scaled physical model. Sedimentology, 65, 877-896. https://doi:10.1111/sed.12409

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Peirce, S. E.K 2017. Morphological Bedload Transport in Gravel-Bed Raided Rivers. PhD Thesis, University of Western Ontario. https://ir.lib.uwo.ca/etd/4595/

Peirce, S., Ashmore, P., Leduc, P. 2018. Variability in the morphological active width: results from physical models of gravel-bed braided rivers. Earth Surface Processes and Landforms, 43, 2371–2383. https://doi.org/10.1002/esp.4400

Peirce, S., Ashmore, P., Leduc, P. 2019. Evolution of grain size distributions and bed mobility during hydrographs in gravel-bed braided rivers. Earth Surface Processes and Landforms, 44, 304– 316 https://doi.org/10.1002/esp.4511