The importance of lithology and throw rate on bedrock river behaviour and evolution in the Gediz (Alaşehir) Graben, Turkey.

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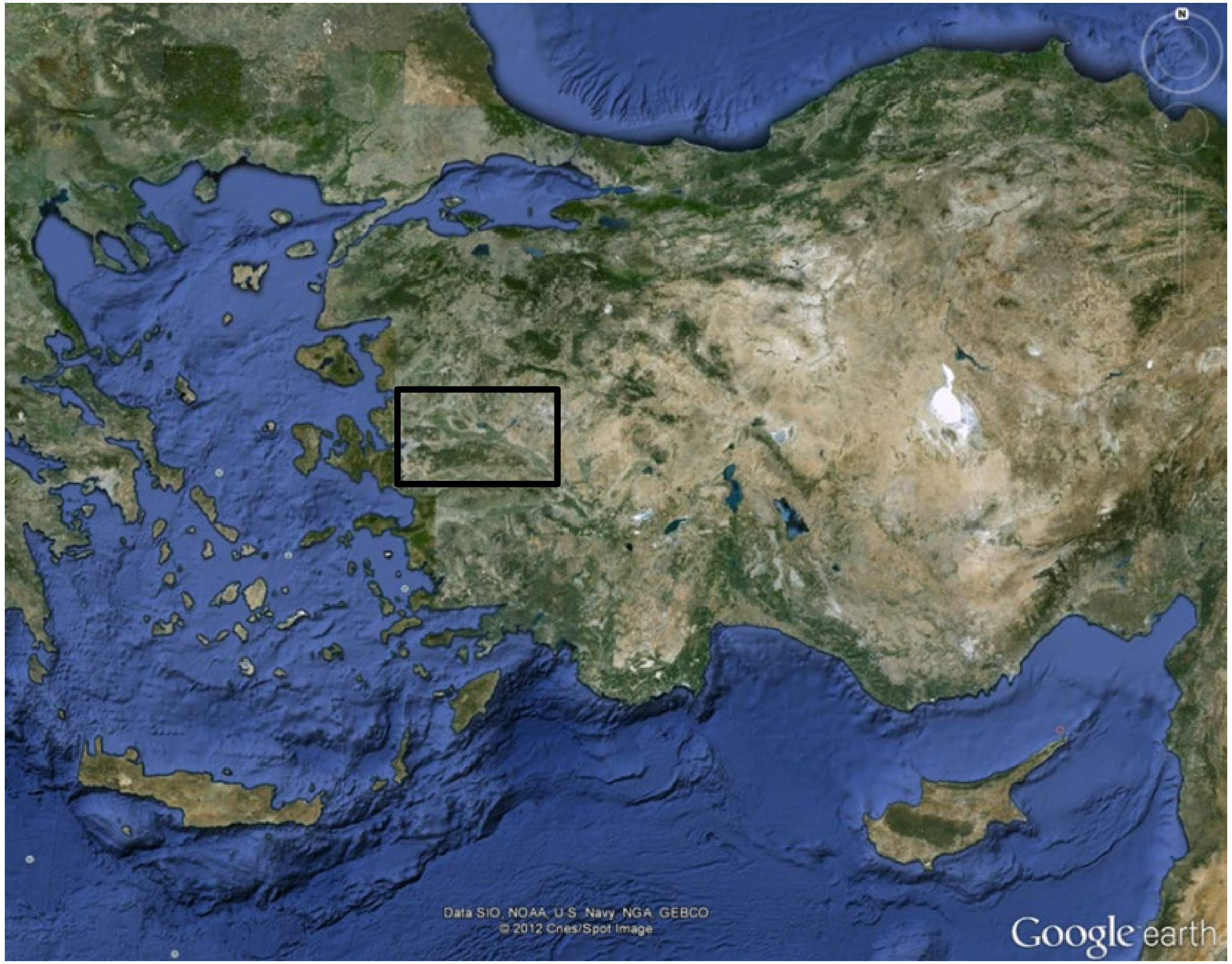
Gediz Graben



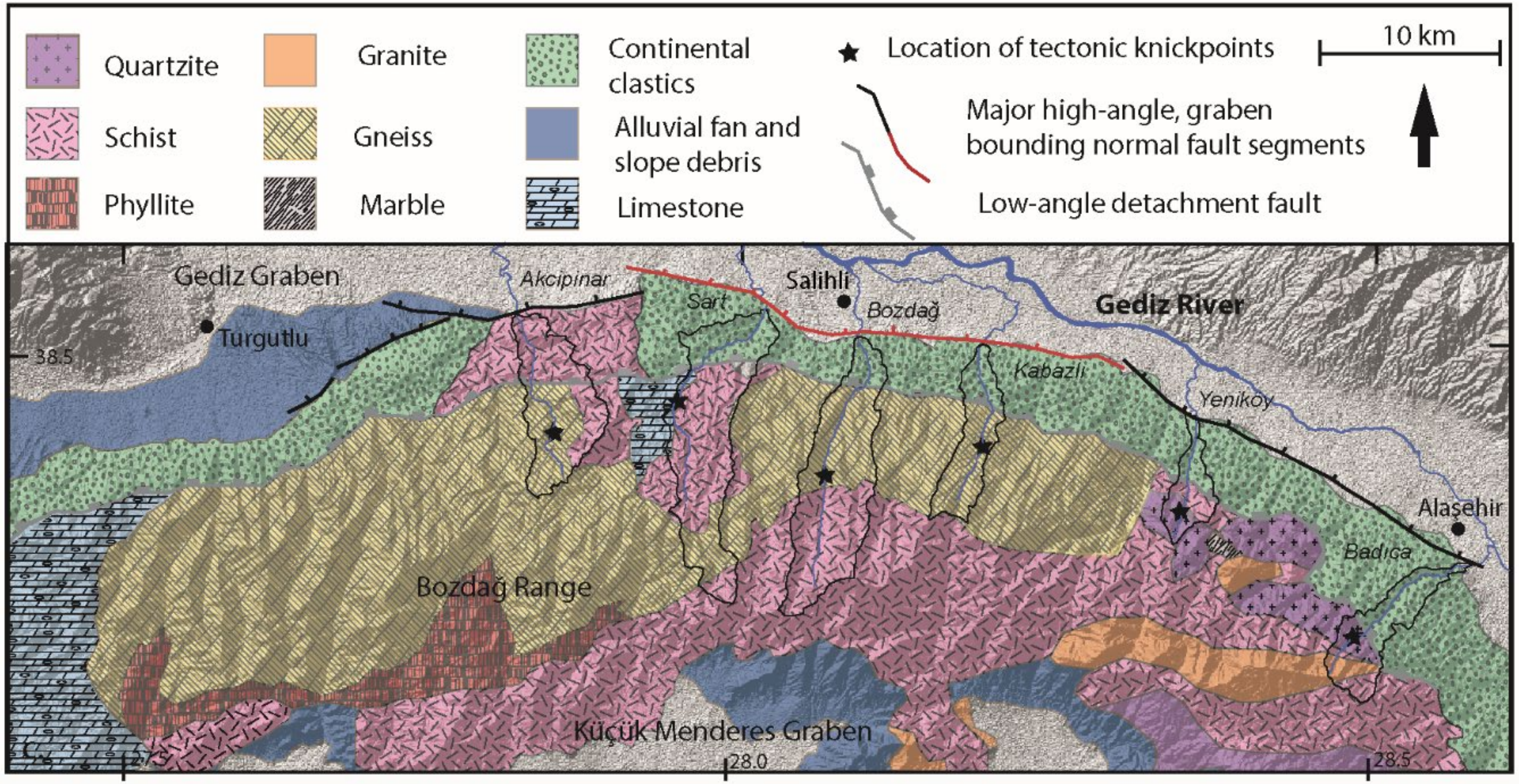
The Gediz Graben is an ideal natural laboratory to study the interplay of active faulting and landscape evolution because:

1. **There is good regional and local mapping of bedrock geology**
2. **Rates of fault movement and evolution are well constrained**
3. **Rivers show a well documented transient geomorphic response to increase in fault slip**

Box indicates location of the Gediz Graben in Western Turkey

1. The bedrock geology of the Gediz Graben

Kent et al. In review



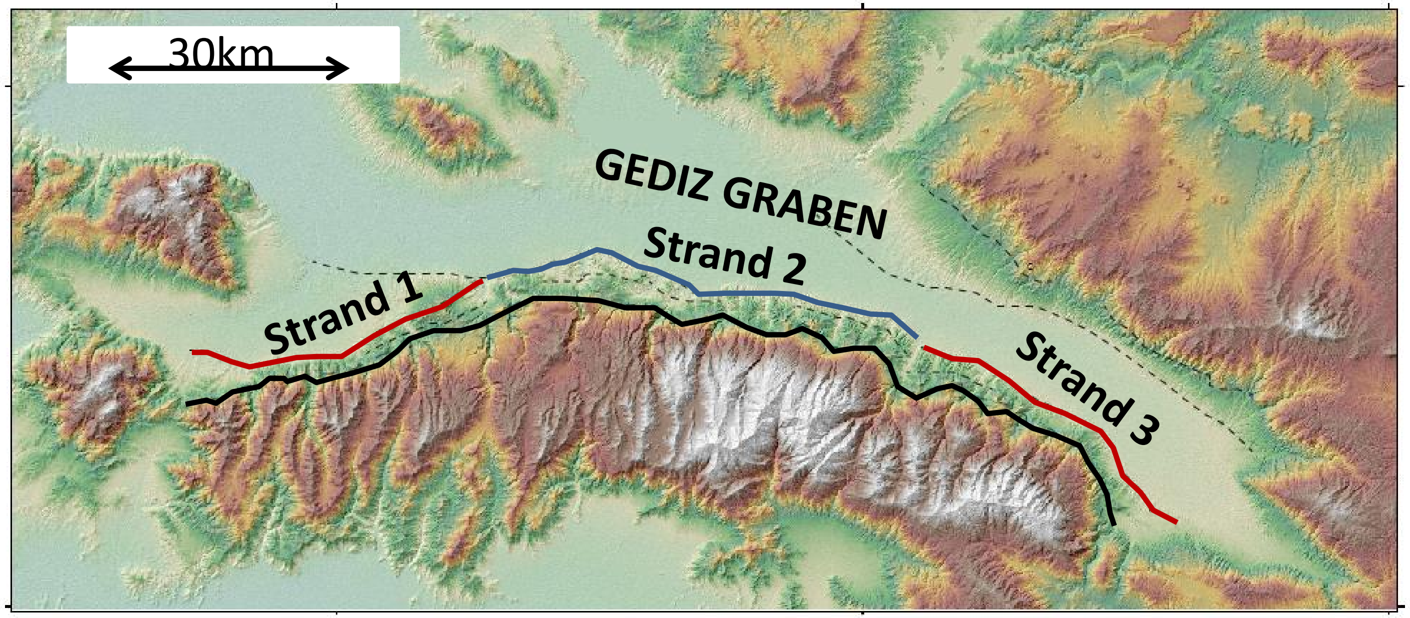
Simplified Geological map of the southern margin of the Gediz Graben, also highlighter are the six rivers surveyed in this study.

The southern margin of the Gediz Graben can simplified into two broad groups:

a) Metamorphic rocks of the Menderes Massif metamorphic core complex, mainly gniesses and schists.
b) Sedimentary rocks deposited syn-tectonically with the activity on the low-angle Gediz detachment of Miocene and Pliocene age, mostly conglomerates and sandstones.

2. Evolution of the boundary fault

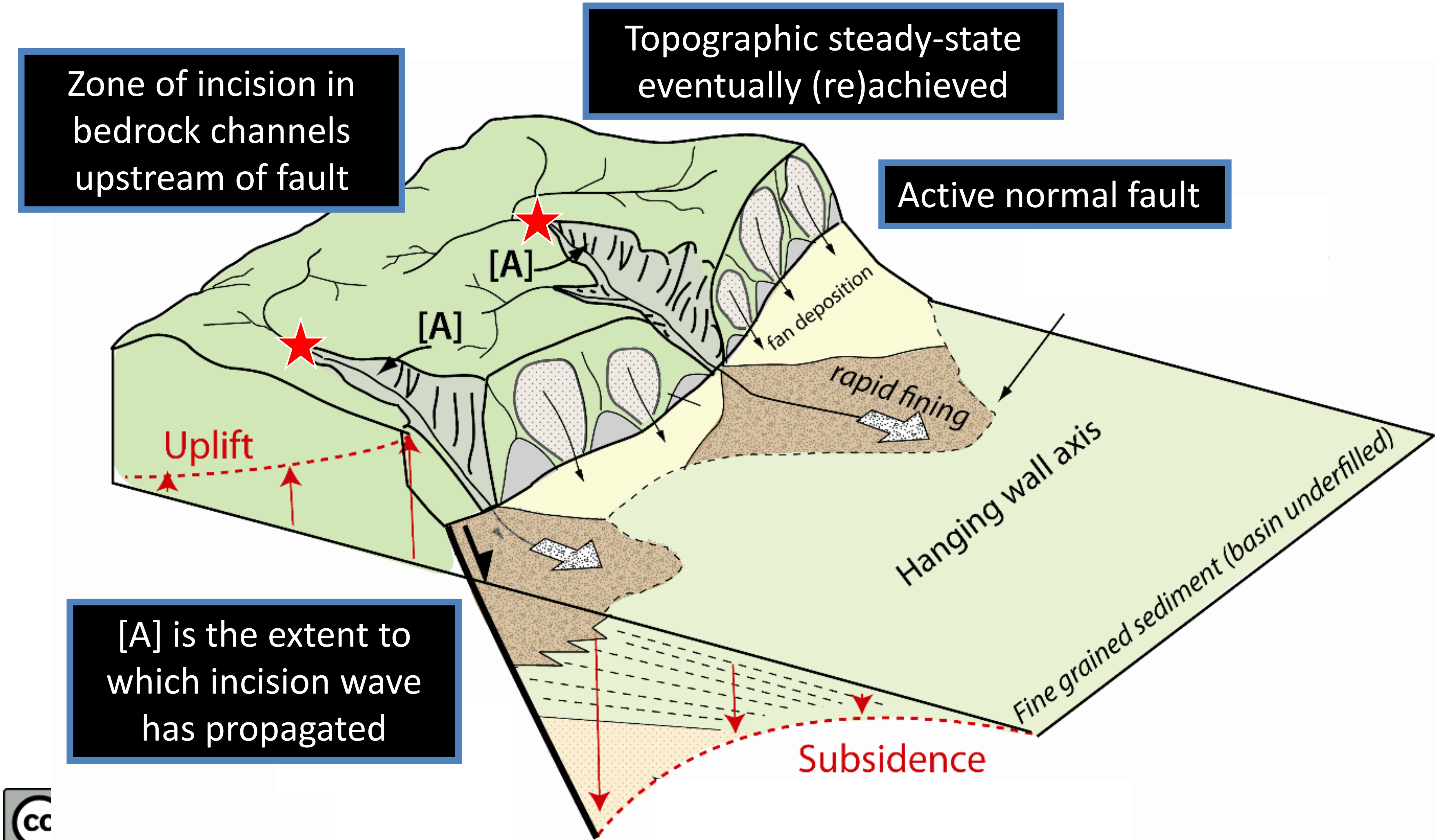
- The Gediz Graben is an asymmetrical graben with an active southern margin, initial low-angle detachment faulting switched to high-angle normal faulting at ~ 2 Ma (Buscher et al., 2013).
- Growth and linkage of high-angle range front faults causes increase in slip rate ~ 0.8 Ma (Kent et al., 2016; 2017).
- Minor post-Miocene faulting of the northern margin



Above: Photograph of the now inactive Gediz detachment fault.
Left: 30 m SRTM DEM of the Gediz Graben showing fault segments (blue and red) now linked to form single normal fault.

3. Landscape response to active faulting

Schematic diagram illustrating an transient landscape response to faulting (Whittaker et al., 2010)



The increase in slip rate at ~ 0.8 Ma caused the rivers to develop a characteristic transient morphology of slope-break knickpoints and channel incision.

3. Landscape response to active faulting

- Low relief landscape incised by dramatic bedrock rivers, gorges and slot canyons.

The scientific questions

- We used this outstanding natural laboratory to investigate the role of bedrock lithology and throw rate on the development of stream power in six selected rivers that could be surveyed in the field.

Key questions:

1. Does the strength contrast in bedrock effect stream power?
2. Can we parameterise k in the stream power 'law'?
3. Does stream power scale with throw rate?
4. Do erosion rates scale with stream power or throw rate?

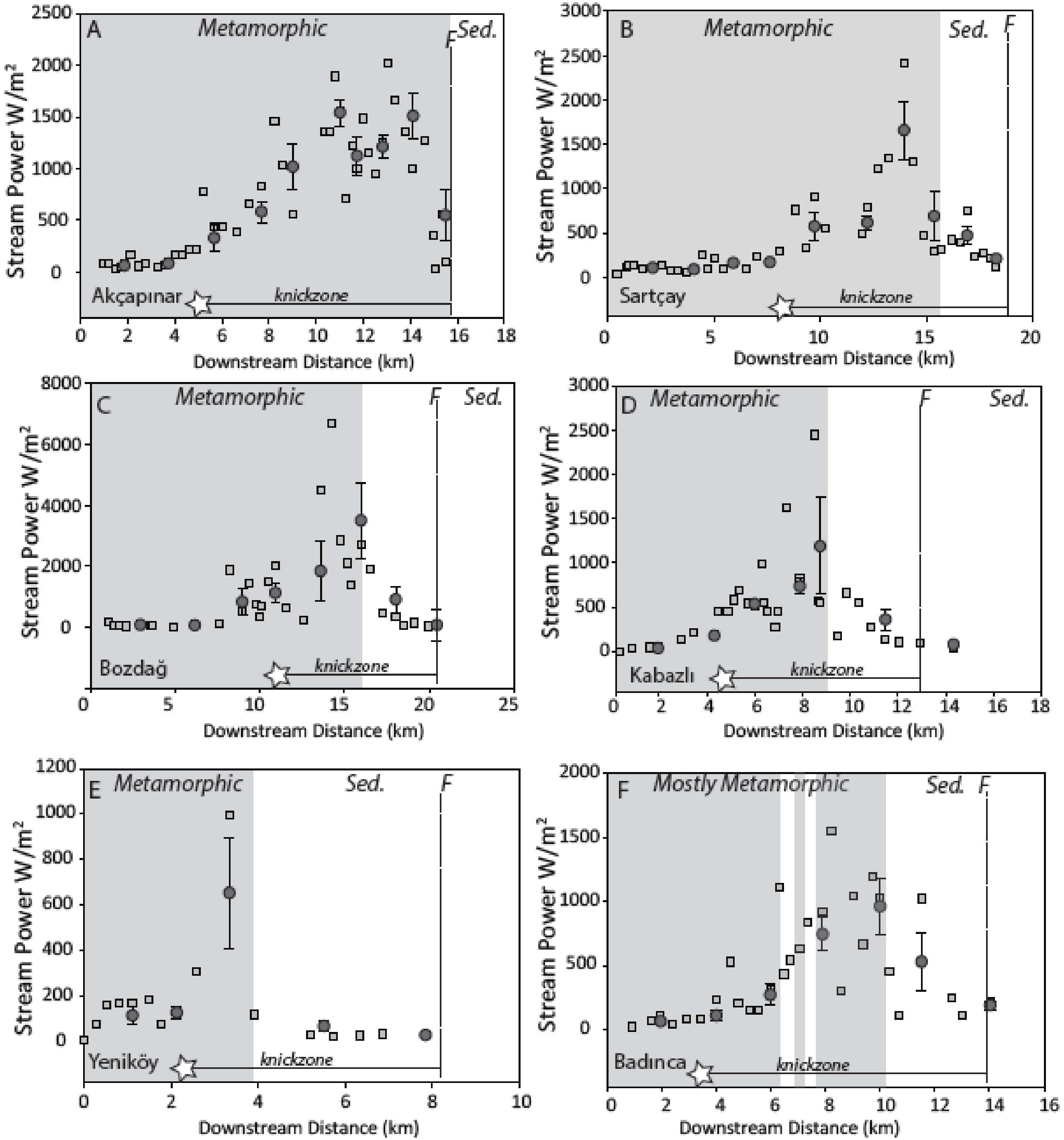
Stream Power Results

Clear increase in stream power in the knickzones upstream of faults.

Stream Power decreases once the metamorphic sedimentary boundary is crossed.

Key to figures

knickpoint location | Active fault | Stream power | reach-averaged stream power



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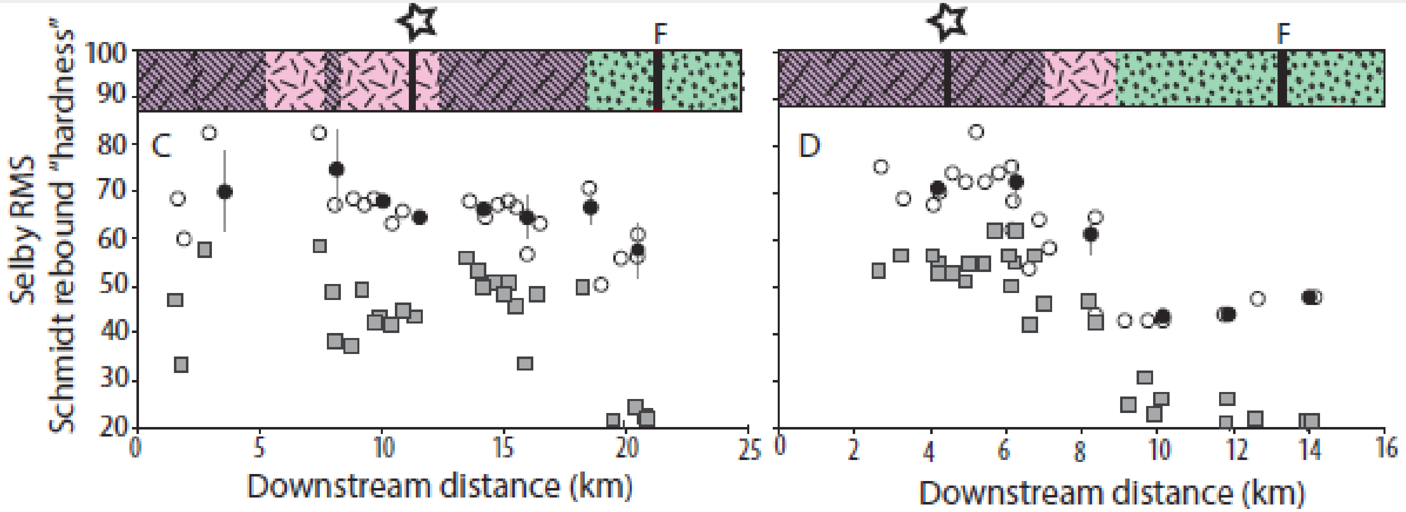
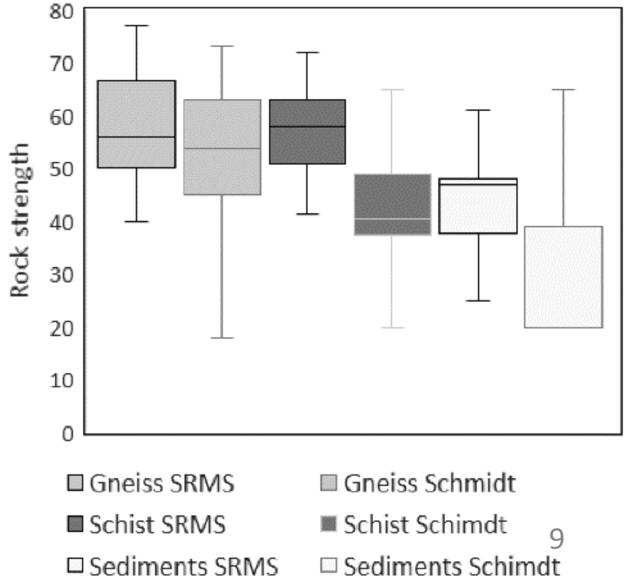
The bedrock strength

Selby rock mass strength and Schmidt hammer rebound tests were used to assess the strength of the bedrock geology.

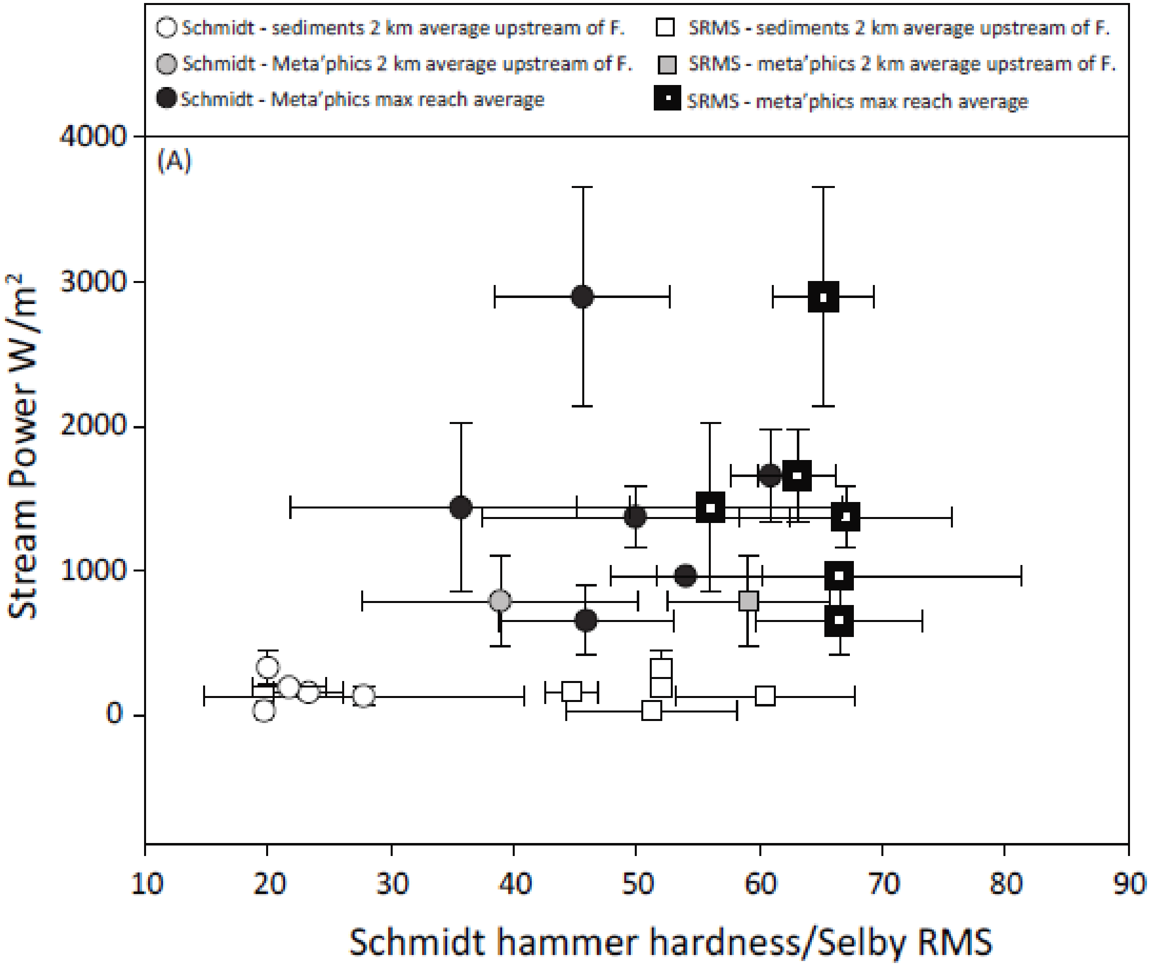
- Metamorphic rocks are ~ twice as strong as the continental clastics.
- Metamorphic rocks show greater strength variability.



Above: Variability in rock strength along two rivers showing transition from metamorphic to sedimentary bedrock. Star indicates position of knickpoint, f = fault.
Right: Box and whisker plot showing all strength data for the study area by major rock type.



1. Does bedrock strength effect stream power?



Yes!

In general, higher stream powers correlate to higher bedrock strength both for Schimdt hammer and Selby data.

Photograph of the weaker and incised sedimentary strata.

2. Can we parametrise k_b in the stream power 'law'?

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- k_b = **2.2 x 10^{-14} to 6.3 x 10^{-14} m s^2 kg^{-1}** in the metamorphic rocks
- k_b = **1.2 x 10^{-13} - 1.5 x 10^{-12} m s^2 kg^{-1}** for the sedimentary units
- Small differences in rock mass strength measurements can translate into very large differences in long-term bedrock erodibility
- But rock strength is not the only factor affecting stream power…

What is k_b?

The standard form of the detachment limited stream power model is:

$$E = KA^mS^n$$

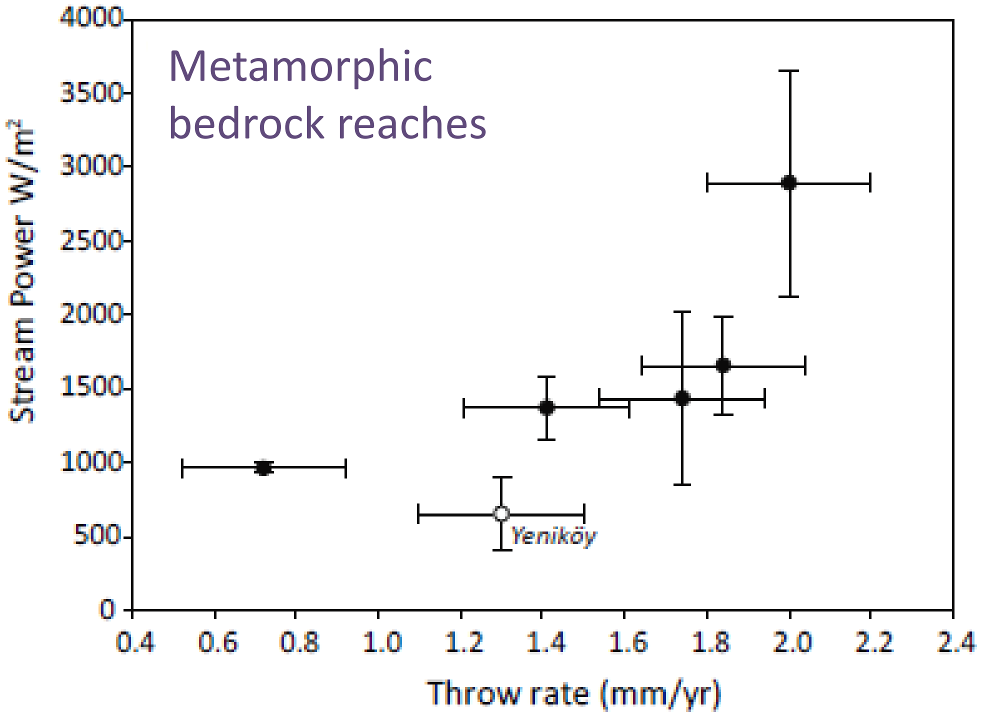
Where K is the erodibility coefficient which encapsulates, alongside additional variables, the important role of bedrock erodibility.

Where field data allow, E can also be determined using :

$E = k_b\omega = k_b(\rho gQS/W)$

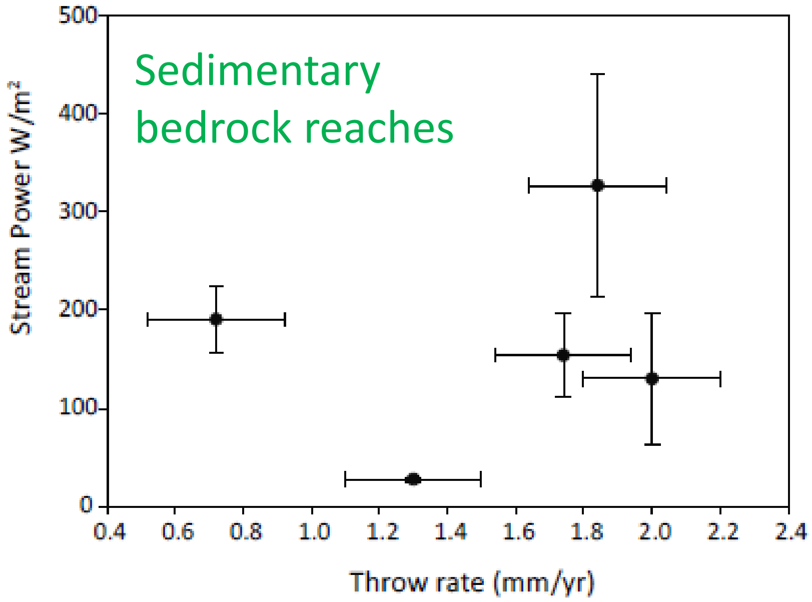
Units of kb represent the inverse of stress and we assume E = U.

3. Does stream power scale with throw rate?



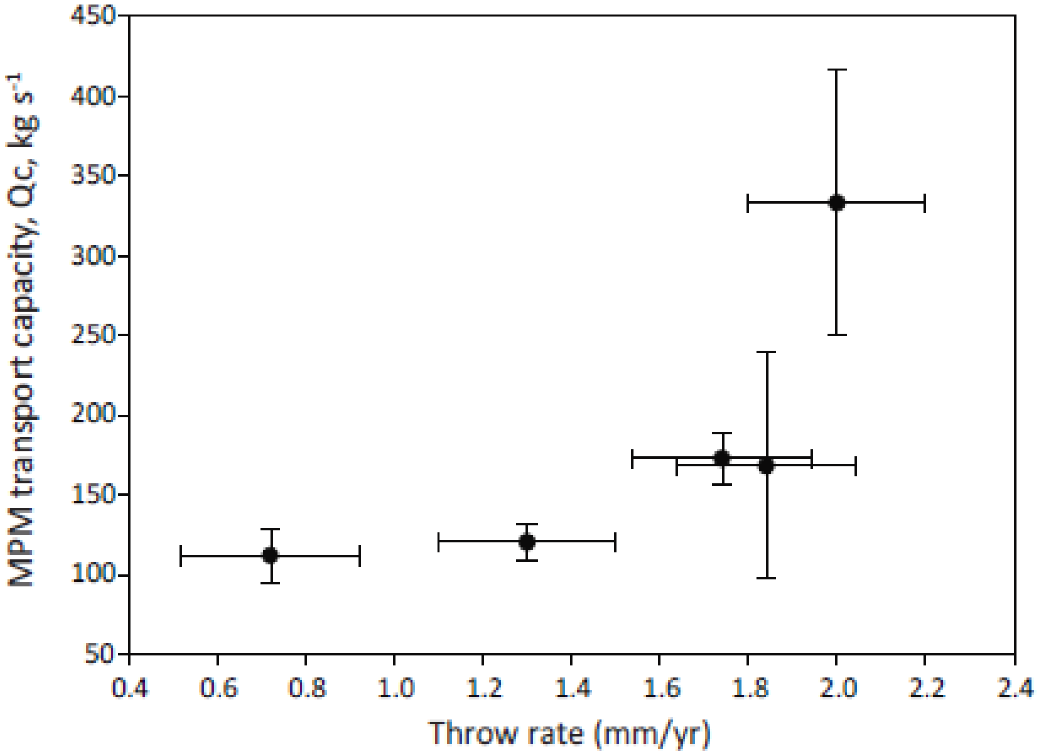
For the metamorphic bedrock – Yes stream power scales with throw rate (since linkage)!

But when the sedimentary reaches are considered scaling is not apparent and stream power is fairly invariant across a range of throw rates…



What is going on the sedimentary reaches?

The downstream reaches of rivers in sedimentary bedrock contain significant volumes of bedload. River behaviour is modified by the transport ability of the rivers to move this sediment, especially in the Yeniköy below.

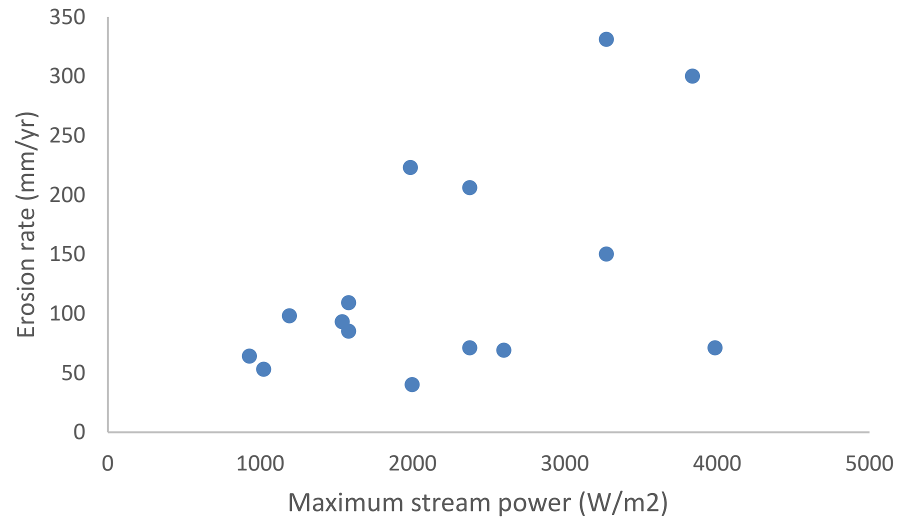


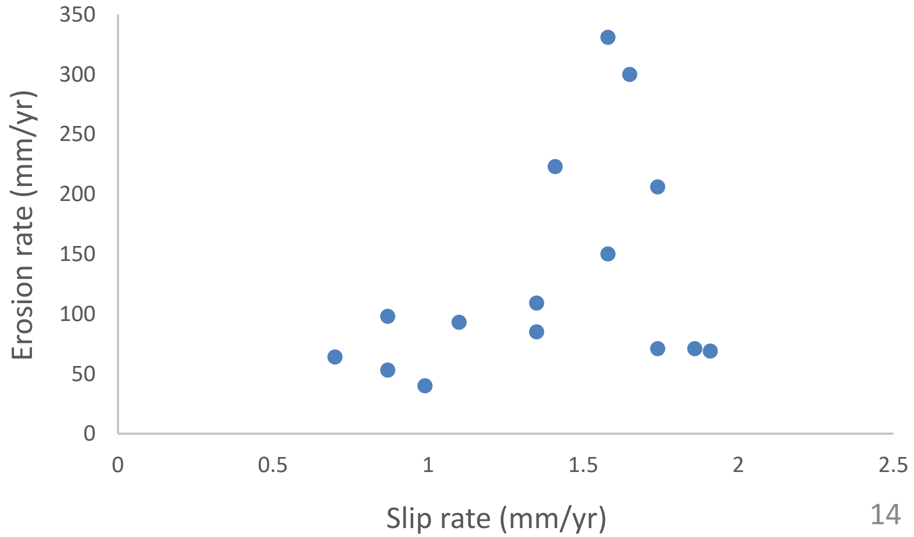
There is an interesting relationship between the river's estimated transport capacity (from the Meyer-Peter-Muller equation) and the throw rate of the active fault, where throw rates are higher so is the transport capacity.

4. Do erosion rates scale with stream power or throw rate?

New ^{10}Be catchment average erosion rate data delayed by the current COVID-19 pandemic ☹

But published data (Buscher et al., 2013; Heineke et al., 2019) from other rivers to the west of our studied rivers indicates that there is a weak relationship between cosmogenically-derived erosion rates and stream power determined from DEM analyses (top). There is also a weak relationship between erosion rate and short term rates of fault motion (bottom).





Summary

1. Does the strength contrast in bedrock effect stream power?
   a) Yes – there is a positive relationship of higher unit stream power where measured rock strength is greater.
2. Can we parameterise k in the stream power ‘law’?
   a) Yes – our values are in line with previously estimated values yet our data are determined from field measurements.
3. Does stream power scale with throw rate?
   a) Yes and no! In the metamorphic reaches stream power scales with fault motion but in the sedimentary reaches bedload also plays an important role in the fluvial response to uplift.
4. Do erosion rates scale with stream power or throw rate?
   a) Watch this space but preliminary analyses are looking good!

References

New research presented here in review as:

Kent, E., Whittaker, A.C., Boulton, S.J., Alçiçek, M.C.

Quantifying the competing influences of lithology and throw rate on bedrock river incision.

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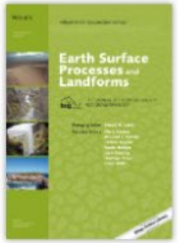

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Normal fault growth and linkage in the Gediz (Alaşehir) Graben, Western Turkey, revealed by transient river long-profiles and slope-break knickpoints

Emiko Kent, Sarah J. Boulton, Alexander C. Whittaker, Iain S. Stewart, M. Cihat Alçiçek

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Journal of the Geological Society, 173, 666-678, 24 March 2016, https://doi.org/10.1144/jgs2015-121

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