Factors of knickpoint migration on the moderately uplifted Ardennes Plateau, Western Europe

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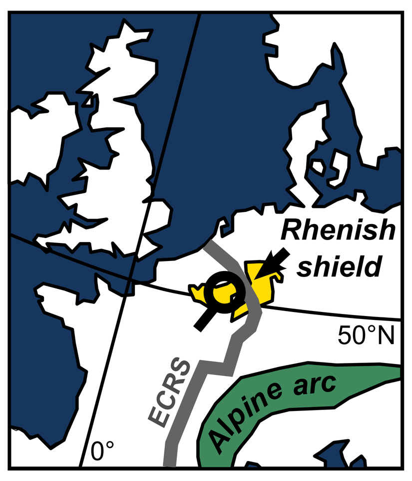

In the last two decades, much research has been devoted to the development and refinement of numerical models of river incision. In settings of prevailing bedrock channel erosion, numerous studies used field data, notably knickpoint data, to calibrate the widely acknowledged stream power model of incision and to discuss the specific impact of various variables (e.g., sediment load, channel width) not appearing explicitly in the model's simplest form.

However, most of these studies were conducted in areas of very active tectonics and high relief, thus displaying an exacerbated geomorphic response to the tectonic signal. Here, we analyze the traces left in the drainage network 0.7 My after the NE Ardennes region (western Europe) underwent a moderate 100-150 m uplift.

Data set

We identified a set of 18 knickpoints that have travelled far upstream in the River Ourthe catchment and that can be correlated to the Younger Main Terrace (YMT) level (fig. 1). This terrace level separates two units in the cross section of many Ardennian valleys : (1) a narrow, steep-sided young valley nested into (2) a broader older valley with gently sloping valleysides. The beginning of the abandonment of this terrace level in the River Ourthe catchment has been dated at ~700 ka (Rixhon et al., 2011).

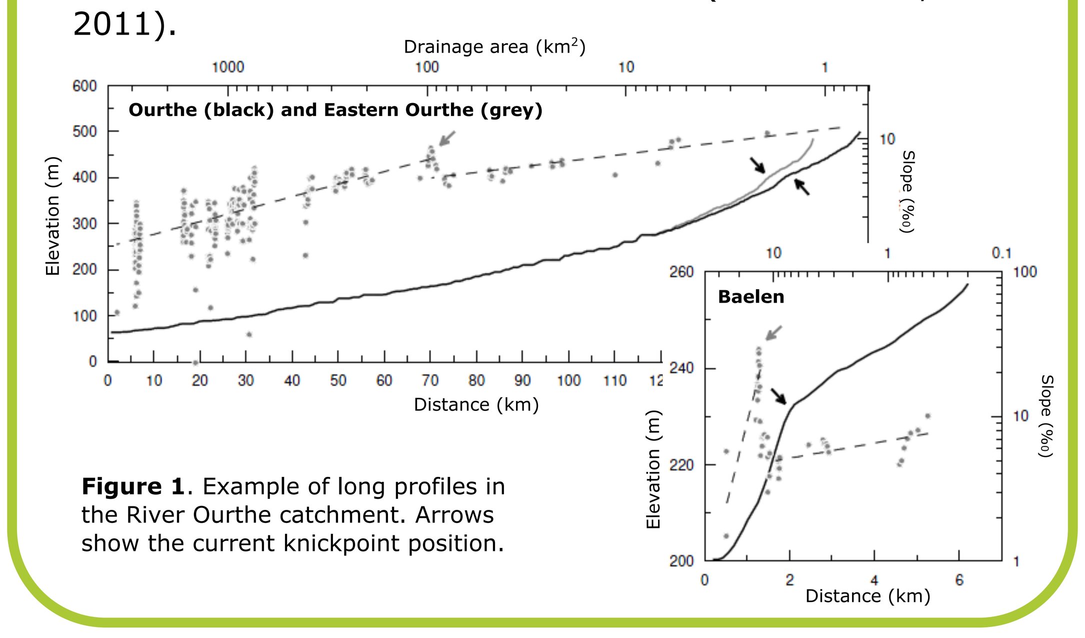

Figure 1. Example of long profiles in the River Ourthe catchment. Arrows show the current knickpoint position.

Modelling the knickpoint migration

We used the following equation, coming from the stream power law, to model the knickpoint migration, assuming that discharge is the main factor controling the celerity :

$c = K A^{m/n}$

where c is the knickpoint celerity, A the drainage area and K and m/n parameters of the stream power law. Because time becomes a more sensitive variable than distance near the headwaters, we fit the model to the data by minimizing time residuals (i.e., the differences between 0.7 My and the modelled times for the knickpoints to reach their actual location) rather than distance residuals. Our best fit of the stream power model parameters yields m/n = 0.75 and K = 4.63 10^{-8} $m^{-0.5}$ y^{-1}. Time residuals are showned on fig. 2.

Their value proove that, in the River Ourthe catchment, the upstream evolution of the drainage area considered in the modelling is not able, alone, to precisely explain the present day location of the 18 knickpoints. Some other factors have to be studied to better understand the controls on knickpoint migration.

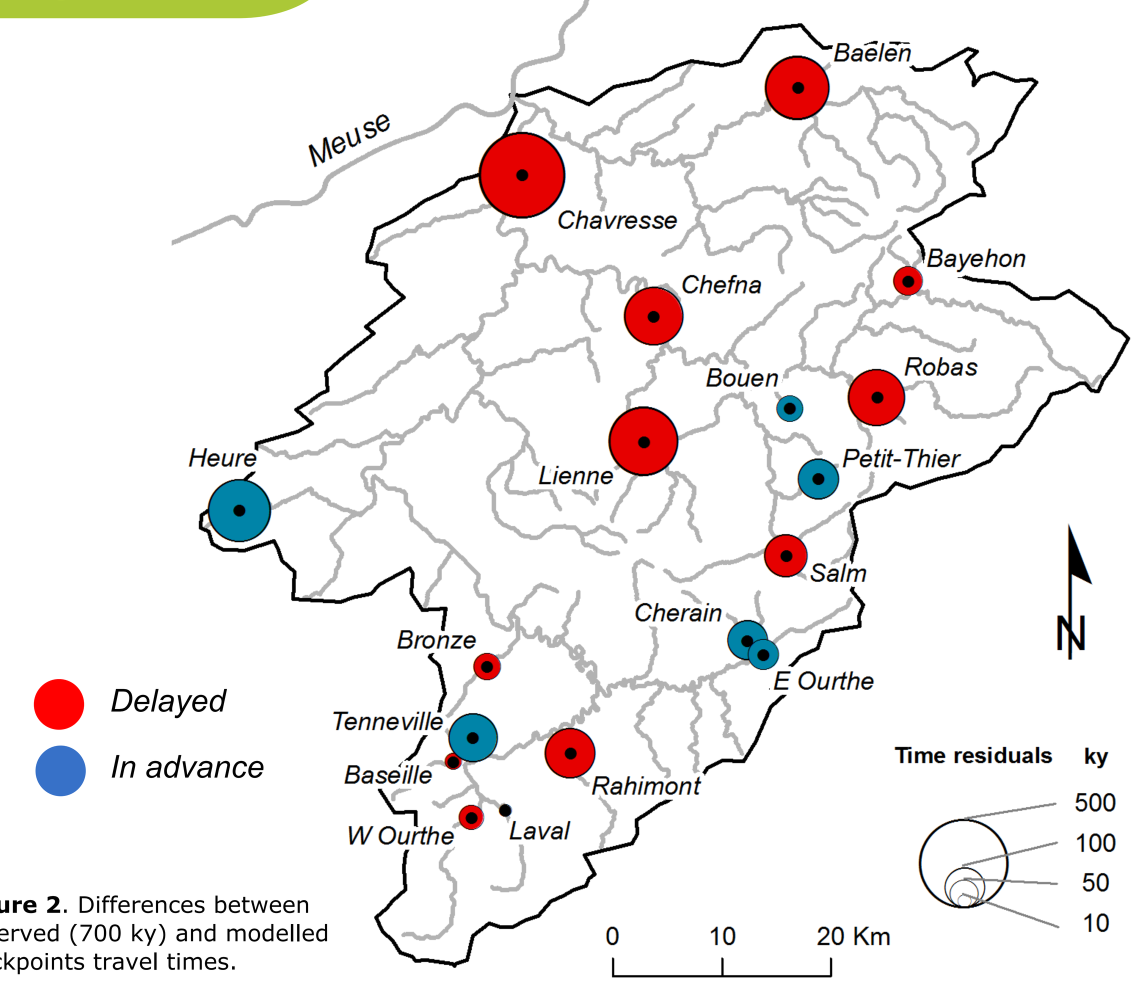

Figure 2. Differences between observed (700 ky) and modelled knickpoints travel times.

Analysis of residuals

Influence of rock erodibility variability (K ≠ cst) ?

To test this hypothesis we developed parameters of rock erodibility (R_i) based on the eroded volumes under the YMT level by 200m-length river sections. To remove the gradual increase of eroded volume with increasing distance to the source, the measured eroded volumes V_{obs} were divided by their estimation V_{calc} using the relation :

$V_{calc} = 291938 * \exp^{(-0.0000159 * D)}$ ($R^2 = 0.39$)

fitted on our data, where D is the distance to the outlet. The cube root of the ratio between V_{obs} and V_{calc} is schown on fig. 3.

The parameter of rock erodibility R providing the best correlation with time residuals is the following one : for each knickpoint, the value of R is given by

$$R = \frac{\sum_{i=1}^{n} \sqrt[3]{\frac{Vobs_i - Vcalc_i}{Vcalc_i}}}{n}$$

where *n* is the number of 200m-length river sections crossed by the knickpoint during its migration.

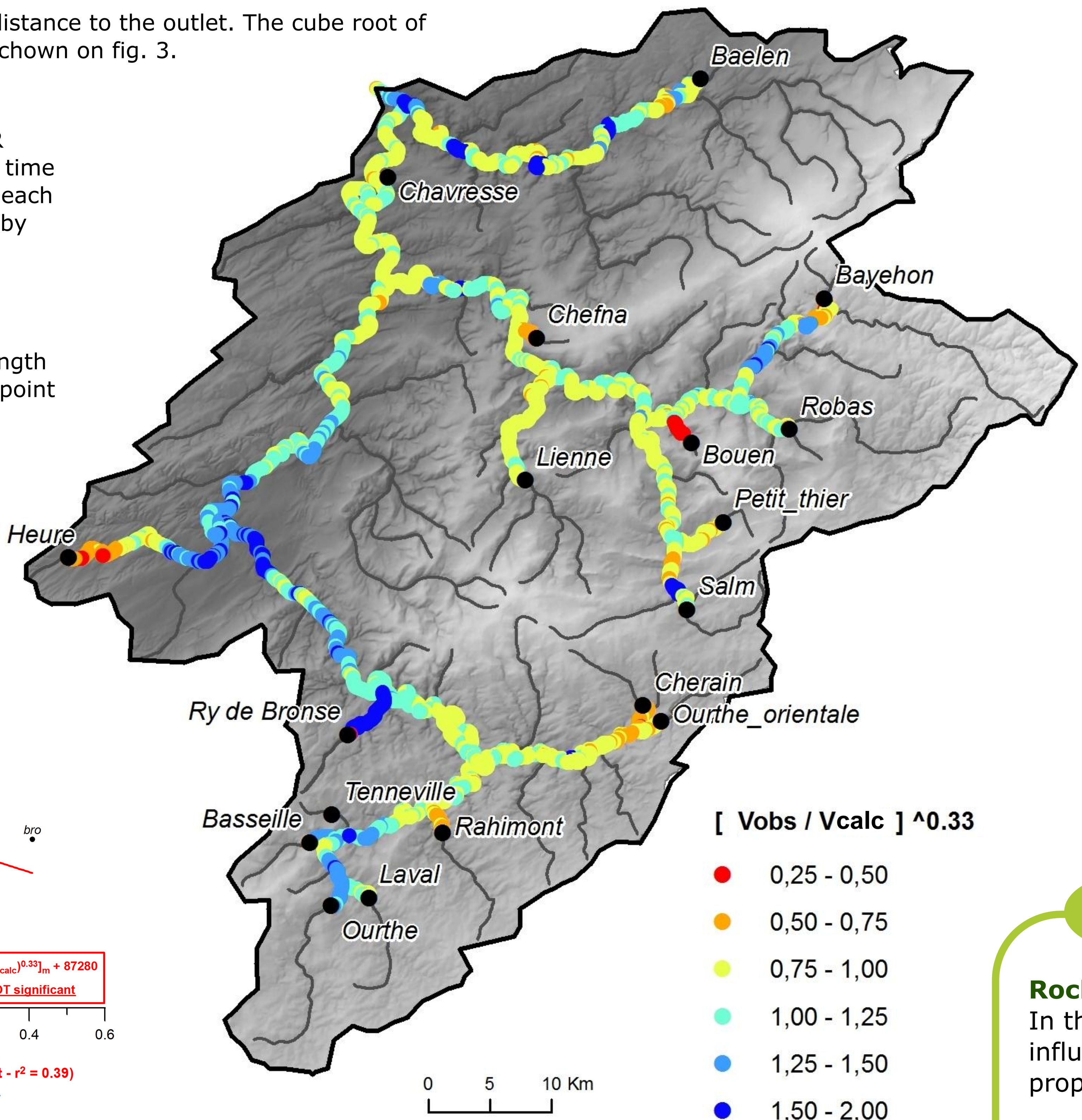

Figure 3. Cube root of the ratio between observed and calculated eroded volumes under the YMT.

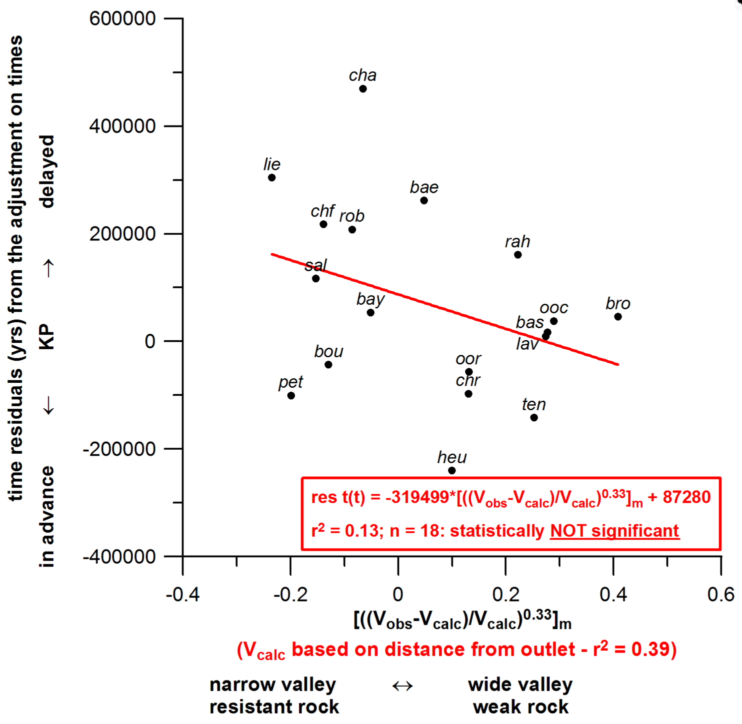

Figure 4. Absence of correlation between time residuals and the parameter of rock erodibility.

As shown on fig. 4, **no significant correlation** has been found between knickpoint time residuals and rock erodibility.

Delays at junctions ?

This hypothesis stems from absolute dating of Rixhon et al. (2011) who showed unexplained delays of the knickpoint migration in the River Ourthe catchment at two major junctions. Therefore, our hypothesis is that junctions might be critical points in the propagation of an erosion wave.

Several parameters were developed to quantify this potential effect of junctions. The one providing the best correlation is the value of vertical incision since the YMT level where each knickpoint leaved the main stem for a tributary for the last time (fig. 5a).

This correlation highlights probably more **the role of the knickpoints position in the river network**, as shown on fig. 5b, rather than any role of junctions.

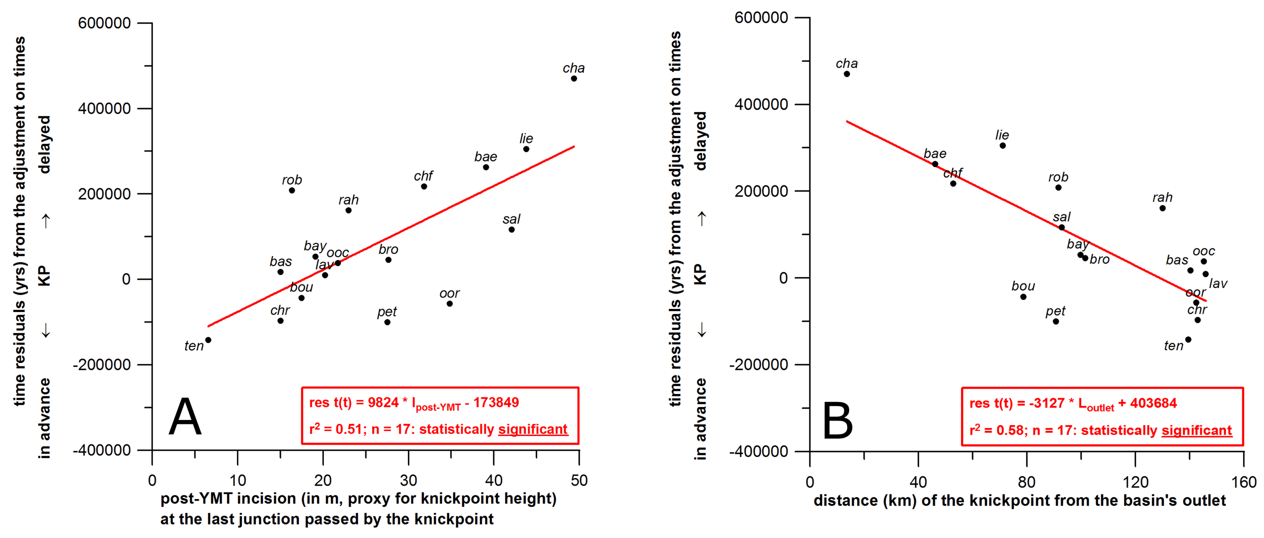

Figure 5. Correlation between time residuals and : (a) post-YMT incision at last junction, (b) distance of the knickpoint from the basin's outlet.

Preliminary conclusions

Rock erodibility ?
In the River Ourthe catchment, this factor seems to not significantly influence the knickpoint celerity at the level of the whole knickpoint propagation (high erodibility sections seem to offset low erodibility one)

Delay at junctions ?
No parameter really representative of a potential role of junctions have permitted to explain a significative part of the variance of residuals.

Position in the river network !
We find that this factor seems to control the effectiveness of the stream power law. The sooner the knickpoint enters in a small stream, the larger the delay.

Overestimation of the knickpoint celerity in small streams where sediment supply increases ?

Reference
Rixhon G., Braucher R., Bourlès D., Siame L., Bovy B., Demoulin A., 2011. Quaternary river incision in NE Ardennes (Belgium) - Insights from 10Be/26Al dating of river terraces. Quat. Geochronol. 6, 273-284.