A refined model of Quaternary valley downcutting emphasizing the interplay between tectonically triggered regressive erosion and climatic cyclicity.

We focus on the drainage system of the Ourthe River, the main tributary of the Meuse River in the Ardennes (Fig. 1). Its catchment extends over 3500 km² of central and NE Ardennes, with a 130-km long main stem flowing from south to north (Fig. 3). The Ourthe River flows into the Meuse River at Liège, which, at 55 m asl, makes a regional base level located approximately at the border of the uplifted massif.

As a consequence of a middle Pleistocene increase in uplift rate, valleys in the Ardennes display a typical cross section that opposes a narrow, steep-sided young valley nested into a broader older valley with gently sloping sides (Fig. 2). Dated ~0.73 Ma north of the massif (Rixhon et al., 2011), the extended lower level of the Main Terrace Complex (YMT) clearly separates the two units and marks the beginning of the middle Pleistocene incision episode. Cosmogenic age data of the YMT and knickpoint data are used to decipher the incision history of the Ardennian valleys since 0.73 Ma.

New data

Cosmogenic 10Be/26Al ages have recently been calculated for the abandonment of the YMT (Rixhon et al., 2011) in the valleys of the lower Meuse, the lower Ourthe, and the Amblève (Fig. 3). These ages show that the terrace has been abandoned diachronically as the result of a migrating erosion wave that started at ~0.73 Ma in the Meuse catchment just north of the massif, soon entered the latter, and is still visible in the current long profiles of the Ardennian Ourthe tributaries as knickpoints disturbing their upper reaches (Beckers et al., submitted). This diachronism is further confirmed by the identification of another stage of the erosion wave progression along the Eau Rouge River, a tributary of the Amblève. Until the end of the Eemian, the Eau Rouge valley was occupied by the Rouge River, whose upstream head was then captured by a small tributary of the Amblève (Stavelot, Fig. 3). The reconstructed long profile of the Paleowarche displays a prominent convexity (Pissart & Juvigné, 1982) that marks the place the post-YMT knickpoint had reached at ~50 ka, the approximate time of the capture.

Table 1. Time range of the migrating erosion wave triggered by the pulse of uplift of the massif at 0.73 Ma. The format: (Maastricht km) is at the northern margin of the uplifted massif.

<table>
<thead>
<tr>
<th>Time Range</th>
<th>Maastricht km</th>
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<tbody>
<tr>
<td>0.73 Ma</td>
<td>~100</td>
</tr>
<tr>
<td>~0.73 Ma</td>
<td>~50</td>
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<tr>
<td>~0.73 Ma</td>
<td>~15</td>
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</table>

Figure 3. New data about the migration of the post-YMT erosion wave within the Ourthe catchment (dotted white). Stars indicate sites of cosmogenic 10Be/26Al ages dated in ka. Large black dots denote knickpoints that clearly mark the passage of the post-YMT erosion wave in the present-day river profiles, outside while arcs denote pre-YMT knickpoints, either eroded or buried in the abandoned valleys. The circled star locates the buried knickpoint of the Paleowarche in its pre-capture stage. Small dots denote post-YMT knickpoints dated in ka. The stars denote the age of the profiles dated by cosmogenic 10Be/26Al ages in the Eau Rouge and the Amblève. The dashed line marks the ancient course of the Ourthe River, a tributary of the Amblève. In the abandoned valleys, the reconstructed long profile of the Paleowarche displays a prominent convexity (Pissart & Juvigné, 1982) that marks the place the post-YMT knickpoint had reached at ~50-78 ka, the approximate time of the capture.

Discussion

At first glance, our data contradict the common belief that the terraces of the Ardennian rivers were generated by a climatically triggered stepwise incision of river profiles. However, several details of the terrace staircases (larger than average vertical spacing between the YMT and the next younger terrace, decreasing number of post-YMT terraces from trunk stream to tributaries and subtributaries) show that a combination of the climatic and tectonic models of river incision is able to satisfactorily account for all available data.

We thus propose a mixed model of valley incision. The transient response of the drainage system to an uplift pulse around 0.73 Ma operated longitudinally by knickpoint migration rather than vertically by ubiquitous profile incision. However, once a knickzone had travelled up stream reaches, the latter kept on deepening, and the climatic conditions were progressively fluvial erosion, but then after the climatic simulation of simultaneous vertical incision in the whole part of the drainage network situated downstream of the positions reached by the erosion waves, returning there progressively to a new steady state.

Consequently, at every time since the onset of the middle Pleistocene uplift, the Ardennian drainage network has been divided in three parts of distinct erosional behavior (Fig. 6): (1) the knickzones travelling up the branches of the drainage network and representing the transient response to uplift, where incision results from the longitudinal displacement of the erosion wave. (2) The regions downstream of the knickzones, where the river profiles progressively achieve equilibrium by ubiquitous vertical incision, and (3) the upstream regions not yet attained by the knickzones, where the whole landscape is still in steady state condition under very low denudation rates.

In this scheme, the glacial-interglacial cycles still impose the temporal frame determining the periods favorable to incision. During glacial, the whole drainage system, up to the smallest streams, was churned up with hillslope material, so that bedrock-channel incision, including knickpoint propagation, was temporarily impeded. Incision episodes mainly took place at the warm-climate transitions.

References


