Geomorphology 313 (2018) 13–26

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

The effects of lithology and base level on topography in the northern alpine foreland

Sebastian Baumann[a], Jörg Robl[a,*], Günther Prasicek[b], Bernhard Salcher[a], Melanie Keil[a]

[a] Department of Geography and Geology, University of Salzburg, Salzburg, Austria
[b] University of Lausanne, Institute of Earth Surface Dynamics, Lausanne, Switzerland

ARTICLE INFO

Article history:
Received 26 June 2017
Received in revised form 6 April 2018
Accepted 11 April 2018
Available online 16 April 2018

Keywords:
Molasse basin
Channel metrics
Fluvial erosion
Hillslope processes
Lithology-dependence
Base level
Landsliding
Channel metrics

ABSTRACT

The evolution of topography is driven by climate and tectonics, and strongly influenced by substrate properties and different base levels. The contributions of these factors may vary in space and time and are thus difficult to disentangle. Our study area, the Hausruck-Kobernaußerwald range, has a rather uniform climatic and tectonic history but is drained by rivers with different base levels and consists of contrasting sedimentary rocks, mainly due to different sedimentation environments. This makes them an ideal location to study the effects of lithology and base level on topography.

To decipher the roles of these influences, we used a high-resolution digital elevation model and performed a series of morphometric analyses. Longitudinal river profiles indicate that all channels in the study area, independent from base level, bed rock and overall morphological expression, are well graded. Hypsometry shows no evidence for base level effects on the present topography, while variations in the hypsometric curves coincide with lithological differences. This is also reflected in contrasts of mean elevation and slope distributions. Lithology-dependent variations in channel concavity and catchment-wide hypsometric integrals show that lithology controls both channel incision and hillslope processes in the study area. Our results further indicate that variations in channel and catchment metrics are not linked to the prevalence of different rock types alone, but to different successions of lithological units along the channels and within the catchments. Variations in channel slope and geomorphological mapping suggest that lithology-dependent landsliding is the dominant process causing the observed large-scale landscape diversity in the Hausruck-Kobernaußerwald range.

1. Introduction

The topography of mountain ranges worldwide represents the competition between uplift and erosion driven by tectonics and climate (e.g. Bishop, 2007; Roe et al., 2008; Champagnac et al., 2012). Furthermore, rock properties influence erosional processes in rivers (Moglen and Bras, 1995; Duvall et al., 2004; Jansen et al., 2010) and hillslopes (Schmidt and Montgomery, 1995; Kühni and Pfiffner, 2001) and thus landscape geometry (Montgomery, 2001; Willett and Brandon, 2002; Whipple, 2004; Robl et al., 2015, 2017b). During transient states, lithology controls the response time to changes of the base level, uplift rate, or precipitation (e.g. Bishop and Goldrick, 2010; Yanites et al., 2017) so that rates of landscape transformation are lithology-dependent (e.g. Scharf et al., 2013). Most major mountain ranges such as the European Alps are characterised by large spatial variations in tectonic (e.g. uplift rate) and climatic (e.g. precipitation rate, temperature) forcing and in their lithological inventory. This is in general reflected by diverse topographic patterns representing a mixture of tectonic-, climatic- and lithologic conditioning (Kühni and Pfiffner, 2001; Robl et al., 2008a; Salcher et al., 2014; Robl et al., 2015; Dixon et al., 2016; Robl et al., 2017a).

Temporal changes in tectonics or climate such as progressive shortening in zones of plate convergence (Robl et al., 2008b; Bartosch et al., 2017) or glacial-interglacial periods (Salcher et al., 2014), respectively, force erosional surface processes to adjust as indicated by a transient landscape state (e.g. Schlunegger and Hinderer, 2003; Norton et al., 2008, 2010; Korup and Schlunegger, 2009). Although constructive and destructive processes and their feedbacks in mountain ranges are intensively studied (e.g. Champagnac et al., 2012, and references therein), their various contributions in shaping alpine topography are difficult to constrain as drivers (i.e. climate and tectonics) and controlling factors (e.g. lithology) may vary in space and time.

* Corresponding author.
E-mail address: joerg.robl@sbg.ac.at (J. Robl).

https://doi.org/10.1016/j.geomorph.2018.04.006

The Hausruck-Kobernaußerwald range (HKR) is a small mountain range located in the northern foreland basin of the Eastern Alps (Fig. 1). The HKR features the highest relief within the Molasse Basin in Austria and is characterised by a smooth and hilly landscape with elevation differences of 400 m and peaks up to 800 m above sea level (Fig. 1). Despite similar peak elevations at around 800 m, the landscape characteristics differ significantly. In the field, the Kobernaußerwald in the west appears less incised than the Hausruck in the east.

In contrast to large, tectonically active mountain ranges at mid-latitudes, the HKR was (a) not affected by glacial carving in the Pleistocene (Van Husen, 1987; Ehlers and Gibbard, 2004), (b) is characterised by uniform climatic conditions and (c) did not experience faulting or any other form of tectonic deformation (e.g. Genser et al., 2007; Gusterhuber et al., 2012). This lack of spatial differences in tectonics and climate makes the HKR an ideal natural laboratory to study the other major controls on mountain topography, namely lithological variations and different erosional base levels. Indeed, both influences may affect the evolution of the HKR. The eastern Hausruck domain and the western Kobernaußerwald domain consist of different sedimentary rocks (e.g. Kuhlemann and Kempf, 2002; Gusterhuber et al., 2012) and erosion is driven by several small rivers with three different local base levels: the Inn-, Innbach and Traun base level (Fig. 1). The simple geological and climatic setting of the range allows to define two contrasting hypotheses to explain these spatial variations of landscape characteristics:

1. The diverse topographic expression of the range results from spatial variations in rock type and thus resistance to erosion with different prevailing surface processes and rates.
2. The increasing landscape dissection from west to east results from various evolutionary states of relief formation or destruction controlled by different local base levels.

In this study we use the HKR as a natural laboratory and test these two major influences on topography, which affect most mountain ranges worldwide. Both potential controls (i.e. lithology, base levels) are linked to the geodynamic evolution of the Molasse Basin including subsidence, sediment deposition and uplift in response to basin inversion.

2. Study area

In this section we briefly describe the drainage system characteristics of the range and review conditions of deposition and related sedimentary sequences of the Molasse Basin.

2.1. Configuration of the present-day drainage system

Similar to large mountain ranges such as the European Alps, the HKR features a drainage divide, which follows the main crest of the range (Fig. 1). In absence of glacial erosion (Van Husen, 1987; Ehlers and Gibbard, 2004), the topographic evolution of the range has been solely driven by fluvial incision and corresponding hillslope processes, which are controlled by three different local base levels (i.e. Inn River, Innbach River, Traun River). Although the range was not directly affected by glacial erosion, glacial scouring, ice damming and the deposition of terminal moraines may have influenced local base levels and redirected the course of rivers in the southern Vöckla/Traun- and the western Inn catchment (e.g. Salcher et al., 2015).

The Inn River and Traun River drain the largest part of the HKR (Fig. 1). The watershed separating the Inn catchment from the Traun catchment follows the main crest of the range from southwest to northeast. Only a small region in the northeast of the HKR is drained by the Innbach. The Danube River at the northern margin of the Molasse Basin is the receiving stream and thus the common base level of the HKR drainage systems. However, the confluence of the Inn River with the Danube River is located upstream of the Danube gorge, while the Innbach River and the Traun River enter the Danube River several tens of kilometers further east and downstream of the Danube gorge. The Danube gorge is a narrow channel segment with

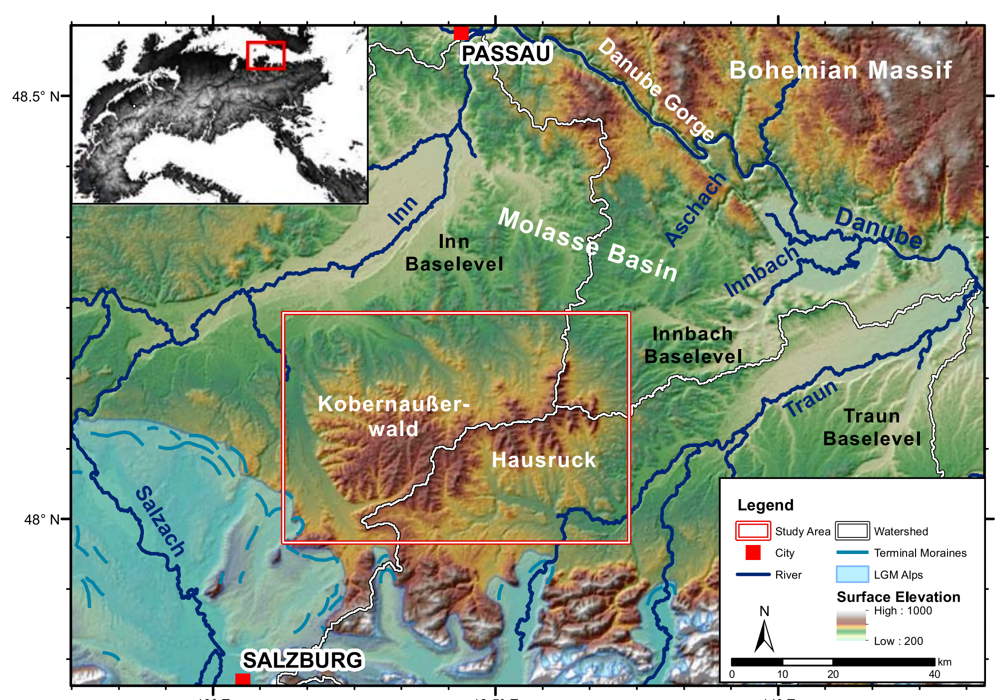

Fig. 1. Topographic map showing the position of the study area within the northern foreland basin. The inset shows the position of the topographic map within the European Alps. Extent of the last glacial maximum (LGM) taken from Ehlers and Gibbard (2004).