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Glaciation cycles, sediment production, isostasy, and fluvial response: are the valleys in the Eastern Alps deep enough?

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The multitude of processes affecting the Eastern Alps has always been challenging for geoscientists. The picturesque relief as a combined result of the long-lasting orogeny and the Quaternary glaciation and can only be explained by complex models accounting for isostatic and erosional effects, and recent surface processes.

The current relief of the major Eastern Alpine valleys is a young feature: the extremely high erosive power of the wet-based temperate glaciers are not only erasing the first-order tributary valleys reshaping the valley profiles but creating a vast amount of loose, poorly sorted sediments ready to be evacuated from the orogen. During the glaciation, the buttressing effect of the glacier prevents the large-scale slumping; after the deglaciation these slopes become unstable and hanging valleys represent retreating knickpoints in the reborn drainage system. The glaciation cycles therefore effectively enhance the (over)deepening of the valleys.

According to our calculations, the missing volume from the valleys considering an envelope of the current peak level would be equal to some 700 m sediment thickness for the whole area. Comparing this volume with the sediment balance of the neighbouring depocentres, one can conclude that the missing volume is a bit larger than the volume of sediments produced in the Quaternary. In other words, the data are in congruence with the assumption that the presently observable high relief of the area can be attributed almost exclusively to the Quaternary erosion.

On the other hand, the loose material and the possibility of overdeepenings along the long-profile of a glacier during the glaciation provide internal storage capacity for lacustrine sedimentation. According to our vertical electrical soundings (VES) in the lower Salzach valley such overdeepenings can host several hundred meters of poorly sorted sediments. This type of Quaternary sedimentation decreases the local relief at the knickpoint: only the fine-grained and dissolved sediments can travel over this sediment trap. The process can continue to act until the complete filling of the depressions or, typically at the orogenic front, the emptying of the lake due to the incision of the river in the end moraine of the molten glacier. The latter process implies a sudden base level drop for the river. In the long-profile view a new knickpoint appears retreating upstream, if the transport capacity is provided.

In the light of these processes it is interesting to recognize that the LGM nunatak pattern derived from LGM trimlines and other glacial features correlate with results of low temperature thermochronology (e.g. fission track ages). This correlation advocates the theory that (1) most of the relief existed pre-LGM times, and (2) the present surface, despite the glaciation, has a topographic memory determined by long-term orogeny.

For test purposes some runs of surface processes modelling (SPM) have been carried out on a smaller region of the current topography modelling fluvial erosion and landsliding. The assumption was a pure fluvial regime (ca. 1000 mm/yr precipitation) without glaciation for some 100-200 ka. Because of the scale of the modelling the (internal) isostatic effects are negligible. The “forecast” of the modelling is that local relief in the valleys starts to balance (in the beginning via landslides), while some tectonic features in the elevated regions are enhanced by the erosion. The sediment production at the model boundary varies strongly due to the varying internal storage capacity of the larger valleys.

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