Soils as archives of natural and cultural history; examples from the Eastern Alps

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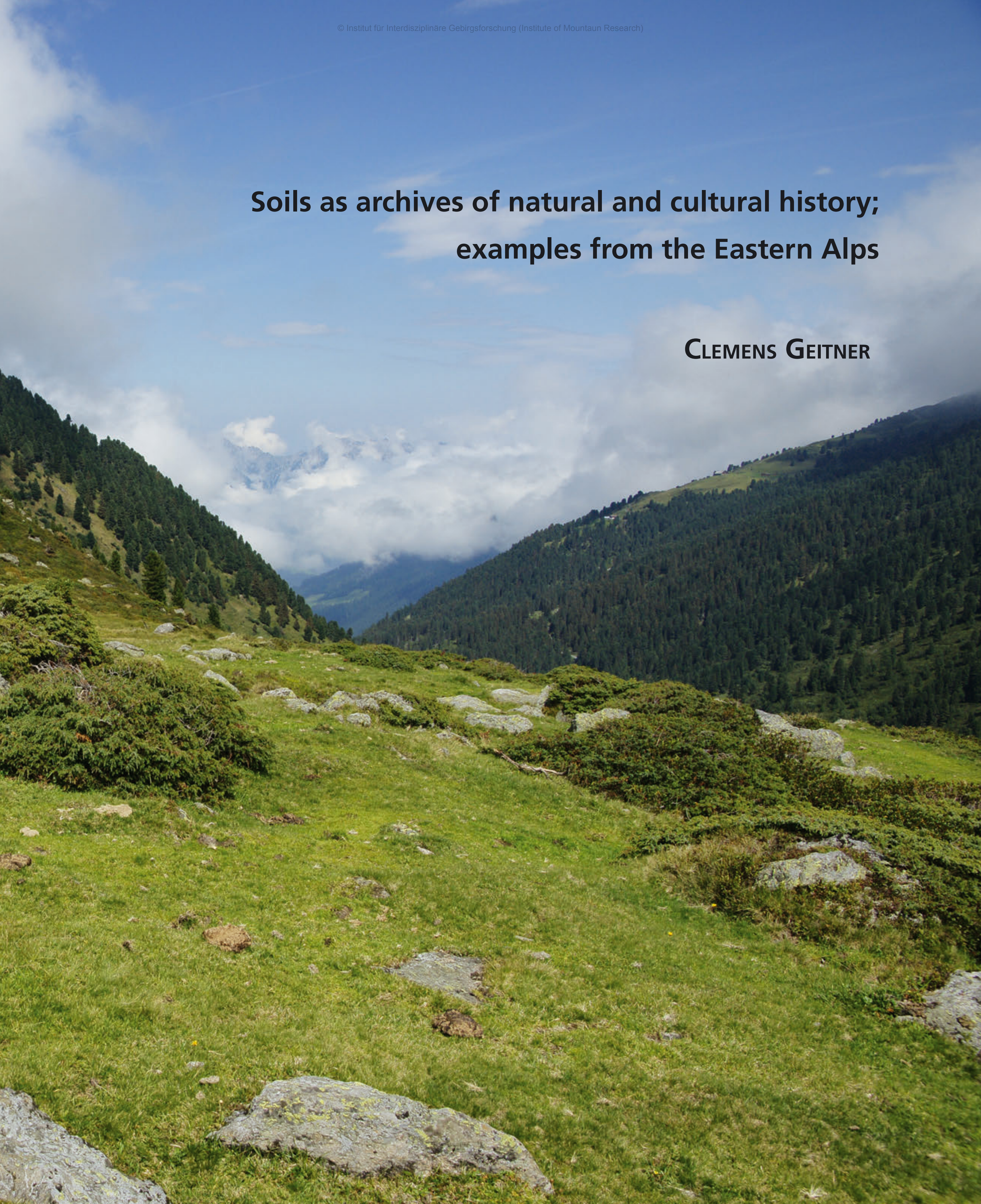

Introduction

Soils fulfil a number of functions that must be taken into account in soil protection (CIPRA 2005; Geitner & Tusch 2009). These include the economic functions of land use as well as ecological functions and the function of soil as an archive of natural and cultural history. This article presents selected soils of the Alps as archives, picking out a few aspects only and exemplifying them on appropriate profiles. As will be shown, the relevant potential of the soils is great and just waiting to be thoroughly investigated by scientists. This is true of soils in the Alps in general.

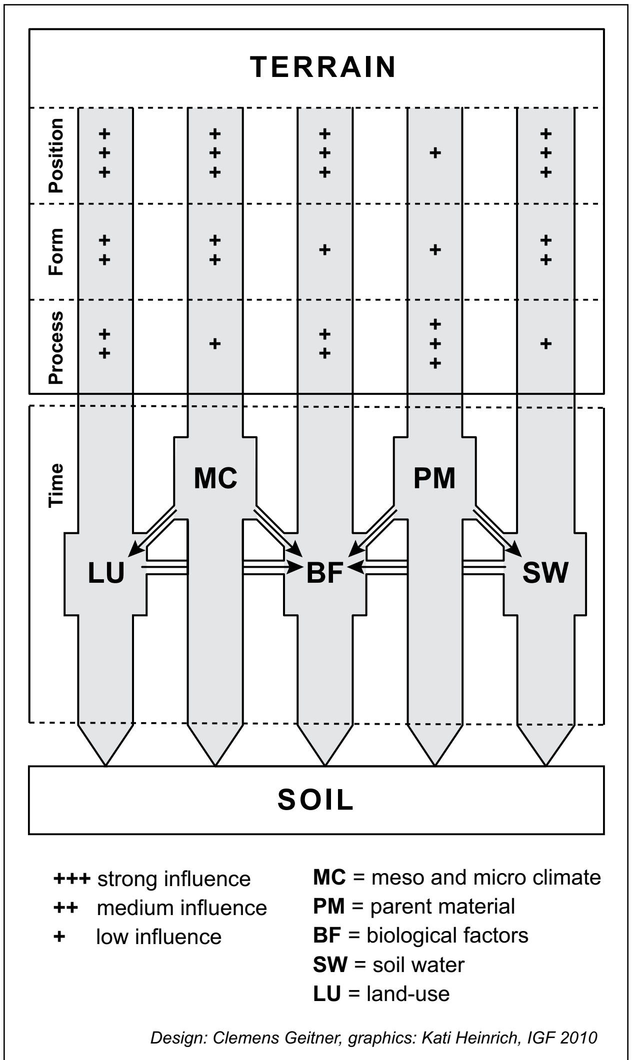

Fig. 1: Schematic illustration of the most important indirect effects of the terrain on soils (Geitner et al., at press a).

Soils as landscape components reaching a meter or more in depth are three-dimensional bodies and subject to changes over time. This makes them potential carriers of information about the past. Deciphering the soil archives, however, means understanding their characteristics as the result of soil formation processes and taking into account the controlling factors of these processes. Figure 1 schematically shows the main interaction of these factors. In mountain regions, the relief is of overriding importance, which is why it is emphasized here (Geitner et al., at press a). Apart from its direct effect on the soil (not represented in Fig. 1), the terrain also influences the soil indirectly by modifying other factors, in varying intensity by its position characteristics, forms and processes. The factors climate, parent material, vegetation, (soil)fauna, soil water and land use interact in a complex manner in space and time, forming the background of soil-genetic interpretation.

The best known soil archives in the Alps as everywhere are the mires. They can be investigated using sedimentological and palaeoecological methods and we owe the reconstruction of climate fluctuations in the Alps during the Holocene period to the information carried in the mires (Patzelt & Bortenschlager 1973). Less well known is the archive function of terrestrial soils that Oeggl et al. (1997), Carnelli et al. (2004), Veit et al. (2004), Küfmann (2008) or Mourier et al. (2008) have exploited using a variety of methods. Moreover, the cooperation of archaeology and soil science holds great potential (Geitner et al., at press b; Geitner & Schäfer 2010). Below, I shall present and discuss three examples of the archive functions of soils in the Eastern Alps. The chosen sites are located in the montane and subalpine altitudinal zone, were covered by glaciers during the Pleistocene and are used today as meadows or pastures. The sites were chosen to demonstrate the breadth of processes of substrate generation. Figure 2 shows the locations of the selected sites.

By far the most soils in the Alps are formed out of unconsolidated Quaternary material. Often this material consists of several layers that differ in composition and formation. This stratified parent material has a major influence on the development and characteristics of soils. It is all the more surprising then that the lithological discontinuities and their significance for soils in the Alps have hitherto only been systematically studied by a handful of authors (e. g. Artmann & Völkel 1999; Veit et al. 2002), in contrast to numerous comparable studies done in uplands (cf. overview in Raab et al. 2007). In the profile examples below, the emphasis will be put on describing the multilayer substrate composition and the temporal classification. There is no scope for presenting soil analysis data or for discussing soil systematics.

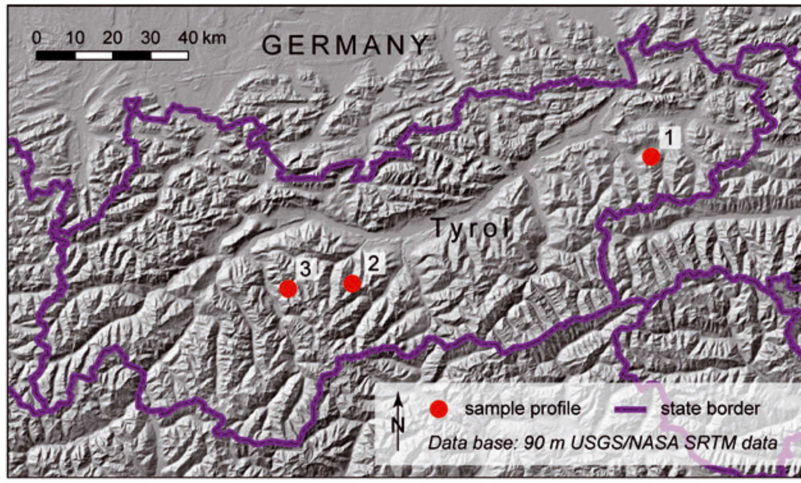

Fig. 2: Location of the sample profiles in valleys of the Eastern Alps (1 = Brixenbachtal, 2 = Fotschertal, 3 = Horlachtal).

Slope dynamics during the late-glacial period (Profile 1)

Figure 3 shows soil profile 1 on a west-facing slope in Brixenbachtal. A petrographic boundary between shale (below) and dolomite (above) runs horizontally through the rock across this slope (Fig. 4). In a series of soil profiles we were able to identify dolomite debris as soil-forming parent material far down the slope (Geitner et al., at press a). The presented profile stems from the upper part of the debris tongue. The clearly distinct skeleton content indicates a three-tier composition of the substrate (Fig. 3).

The massive transport of material as witnessed by the soil profiles across more than 1 000 m on a slope with a mean inclination of 25° must have happened mainly in the late-glacial period. As can be seen in Figure 4, the slope is essentially stable today except for the occasional fall of individual rocks. Here, the soils and the substrates near the surface turn out to archive long gone morphodynamics that occurred between the presence of ice in the Pleistocene and the stabilizing of the slopes in the Holocene period.

Fig. 3: Soil profile 1 from dolomite debris in Brixenbach valley (1 000 m): the multiple layers of the parent material are clearly identifiable from the varying skeleton content. Photograph by C. Geitner 2008.

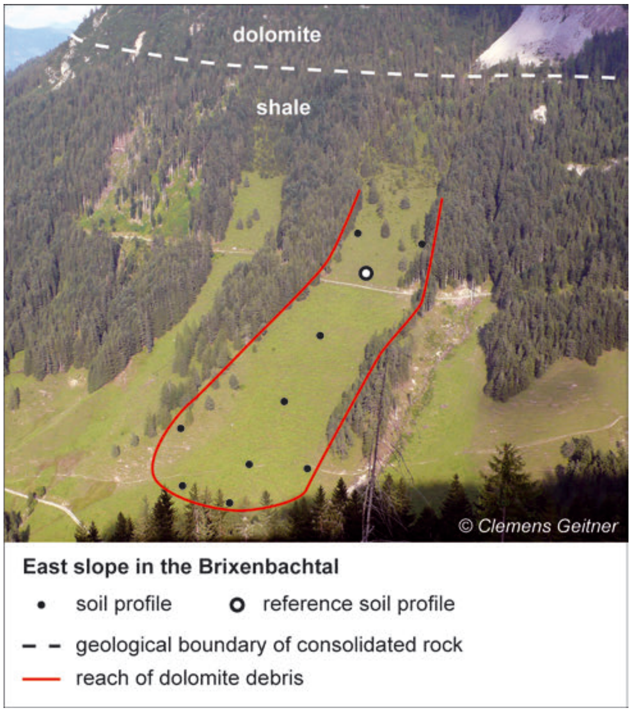

Fig. 4: West-facing slope of the Brixenbachtal with horizontal boundary of consolidated rock (dolomite/shale) and vertical reach of dolomite debris (Geitner et al., at press a). Photograph by C. Geitner 2008.

Fig. 5: Soil profile 2 from silicate sediments in Fotschertal (Ullafelsen, 1 869 m.): here too, the multi-layered characteristic of the original substrate can be traced by the varying skeleton content. Photograph by D. Schäfer 2003.

Aeolian dynamics at the end of the late-glacial period (Profile 2)

Figure 5 shows profile 2 of the almost flat top of the Ullafelsen in the Fotschertal valley. There is a striking light horizon in the middle of the profile. At its upper limit, charcoal can regularly be found. Its distribution pattern suggests that this layer was once on the surface of the terrain. Extensive archaeological findings and ^{14}C datings of charcoal prove that the light horizon served as living floor about 9 500 years ago (Geitner et al., at press b).

This suggests that the humic horizon in the lower part of the profile must belong to an older, i.e. late-glacial, soil formation. There are numerous indications that the two cover beds above it are of aeolian origin. The striking light layer probably stems from the Younger Dryas, the last cool phase of the late-glacial period. The uppermost layer, with clearly discernable features of soil formation, was likely laid down in the Holocene but with a much lower sedimentation rate. It was only through ^{14}C dating that the complex origins of the profiles at the Ullafelsen and their relation to landscape history could be unravelled. Figure 6 provides an overview of the sedimentological-soil-forming sequence in the last 15 000 years (Geitner et al., at press b).

Anthropogenic fluvial sedimentation in historical time (Profile 3)

Profile 3 from Horlachtal, a tributary valley of the Ötztal, shows two clearly distinguishable sections (Fig. 7). The lower one is a fossil, strongly humic and skeleton-rich soil. At its upper limit, there are distinct concentrations of charcoal, which ^{14}C dating has identified as medieval. The original slope debris is covered by a thick, very even, layer of fine unconsolidated material with insignificant indications of soil formation. These are sediments from meadow irrigation over many centuries. Such an intensive use of meadows with artificial irrigation is documented for the Ötztal for the Middle Ages (Geitner 1999) and as early as the Bronze Age (Oeggl

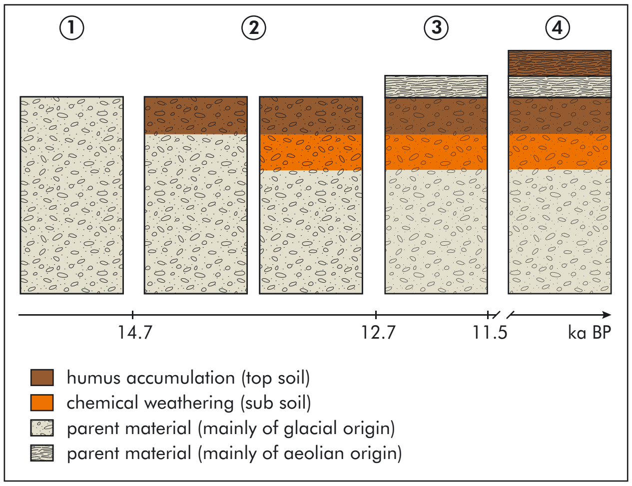

Fig. 6: Hypothetical sequence of four phases of varying dominance of sedimentological and soil-forming processes at the Ullafelsen (time scale after Ivy-Ochs et al. 2009) (Geitner et al., at press b).

et al. 1997). The discernible current soil formation in the uppermost part of the profile suggests that irrigation was abandoned several decades ago.

Today, examples of such land-use measures in the Ötztal are only found in a handful of places (Fig. 8). The introduction of fine mineral particles over a long period has, however, improved the ecological conditions, especially the water regime, of these sites in the longer term, so that agriculture continues to benefit from it.

Conclusion

The profiles presented here confirm both well-known and lesser known findings which can be summarized as follows:

- the unconsolidated material which has formed most of the soils in the Alps, is often composed of several layers.
- the layers can vary greatly in thickness; occasionally, particularly by aeolian introduction, they measure just a few centimetres.
- age and length of formation also vary greatly, as shown for the presented profiles in Figure 8 in a schematic overview.

Fig. 7: Soil profile from Horlachtal (Grastalfeld, 1720 m): the multiple layers of the parent material can be clearly distinguished by the different colours (Geitner 1999: 189) (photograph by C. Geitner 1997).

- analysis and interpretation of the sequence of layers can provide clues to natural as well as anthropogenous processes.
- as a rule, soil formation took place during phases between sedimentation.

These examples make it clear that soil archives must always be looked at in their spatial embeddedness in the total landscape system and its temporal variations in the

Fig. 8: One of the last examples of traditional meadow irrigation in the upper Ötztal near Obergurgl: where water is channelled into the meadow, the accumulation of suspended matter produces distinct ridges in the terrain. Photograph by D. Lammerer 1997.

late-glacial and Holocene periods as well as historical land use. Analysis and interpretation of these archives relies on complementing soil-scientific methods with expertise from other disciplines, such as geomorphology, geoecology and archaeology. In addition, datings by the ^{14}C method, dendrochronology or via archaeological artefacts are essential. Such a coordinated approach should make the soils of the Alps yield more information on local and regional aspects of landscape history yet.

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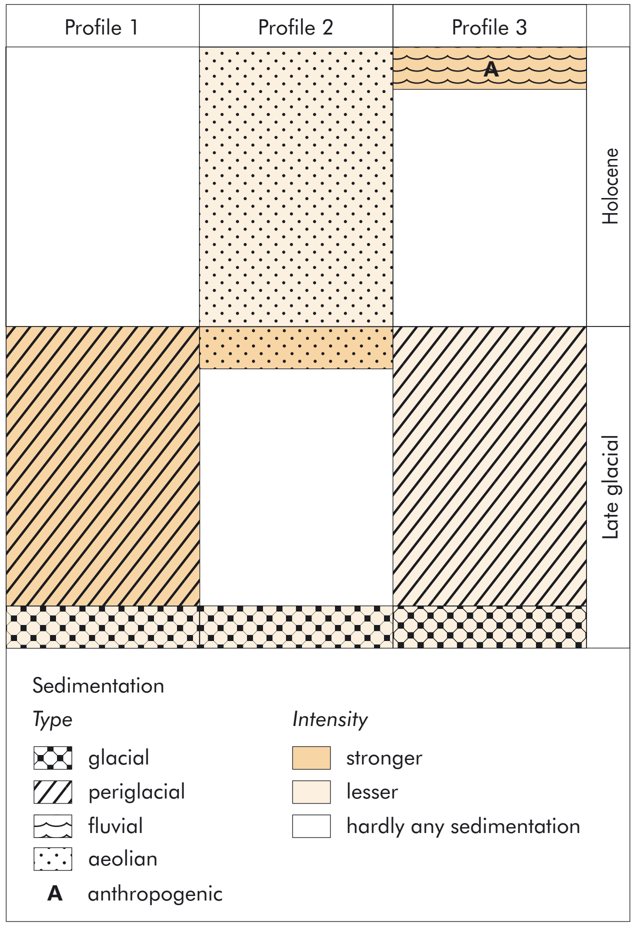

Fig. 9: Generalized sketch of the temporal sequence of sedimentation processes for the three examples presented here. The position of the profiles means that glacial sediments from the early late-glacial period form the basis of the unconsolidated material, even if they might be quite shallow due to the position of this site in the terrain. This glacial unit is only visible at the Ullafelsen, in the other profiles it has been absorbed into periglacial slope dynamics.

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