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Assessment of a locally-sourced loess system in Europe: The Swiss Jura Mountains

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Loess of Northern, Central, and Eastern Europe cover large areas and can be of considerable thickness. However, this already well-described loess belt did not reach the Swiss Jura Mountains. Nevertheless, local deflation, transportation, and deposition processes were efficient during the Late Glacial Period. Alpine moraines and outwash deposits on the Swiss foreland worked as deflation sources under the action of winds. Aeolian particles were deposited on the easternmost ridge and summits of the Jura Mountains, forming a thin loessic cover (<50 cm), which was generally eroded and/or incorporated in periglacial sediments. Jura "loess" is enriched in Alpine silicate minerals and constitutes a clear allochthonous input in the context of Jura Mountains, where Mesozoic limestones, and their weathering products, compose the quasi-entirety of autochthonous material. The Jura loess, already recognised for more than 40 years, still needs to be characterised more accurately. Five study sites were chosen along an 85 km long transect on the easternmost ridge of the Jura Mountains. A soil pit was dug and analysed at each site, in order to identify loess layers. Grain-size distribution curves of loess permitted to discriminate four particle subpopulations, which are related to various aeolian episodes/sources and post-depositional weathering processes, respectively. The mineralogical composition is dominated by Alpine components. However, high amounts of kaolinite in the clay fraction of loess layers point to a more local origin, thus indicating the contribution of Jura moraines as potential deflation sources. Finally, the geochemical composition of loess reflects the preponderant influence of Alpine minerals.

1. Introduction

Loess in Northern, Central, and Eastern Europe covers vast areas and constitutes important records of the Quaternary period (Fig. 1; Jamagne, 1973; Lang et al., 2003; Markovic et al., 2006; Preusser and Fiebig, 2009; Zöller et al., 1988 among many others). The Jura Mountains defining the northwestern Franco-Swiss border are not part of this large European loess belt (Frechen et al., 2003; Haase et al., 2007). Nevertheless, thin (<50 cm) and irregularly distributed loess covers the southeastern end of the Jura Mountain range. These deposits, as well as the mixed sediments in which loess is incorporated, form the uppermost layer of superficial deposits commonly observed in the Jura Mountains and constitute the parent material for Holocene soil development (Lorz et al., 2011; Völkel et al., 2001, 2011). Moreover, these aeolian sediments are neither linked to the Po plain loess (Northern Italy), which originated from the reworking of sediments from the Adriatic Sea during Glacial Periods (Cremaschi, 1990). In addition, present-day aeolian inputs, mainly composed of Sahara dust, could only represent a partial and minor contribution to the total amount in loess in the Jura Mountains (Stuut et al., 2009). Jura loess is most likely locally sourced, according to the concept developed by Luehmann et al. (2013) in the Upper Peninsula of Michigan, and the result of nearby aeolian processes, which include deflation, transportation, and deposition of particles on the Jura ridge.

The source area of the Jura loess has been previously described as being composed of Alpine moraines and outwash deposits from the Swiss foreland (Pochon, 1973, 1978), known to be formed by a mix of carbonate and silicate minerals (Portmann, 1954) transported by the Rhône glacier during the Last Glacial Period (from about 114,000–11,000 BP; Ivy-Ochs et al., 2008). Deflation of mineral particles probably started after the glacier melted, during the

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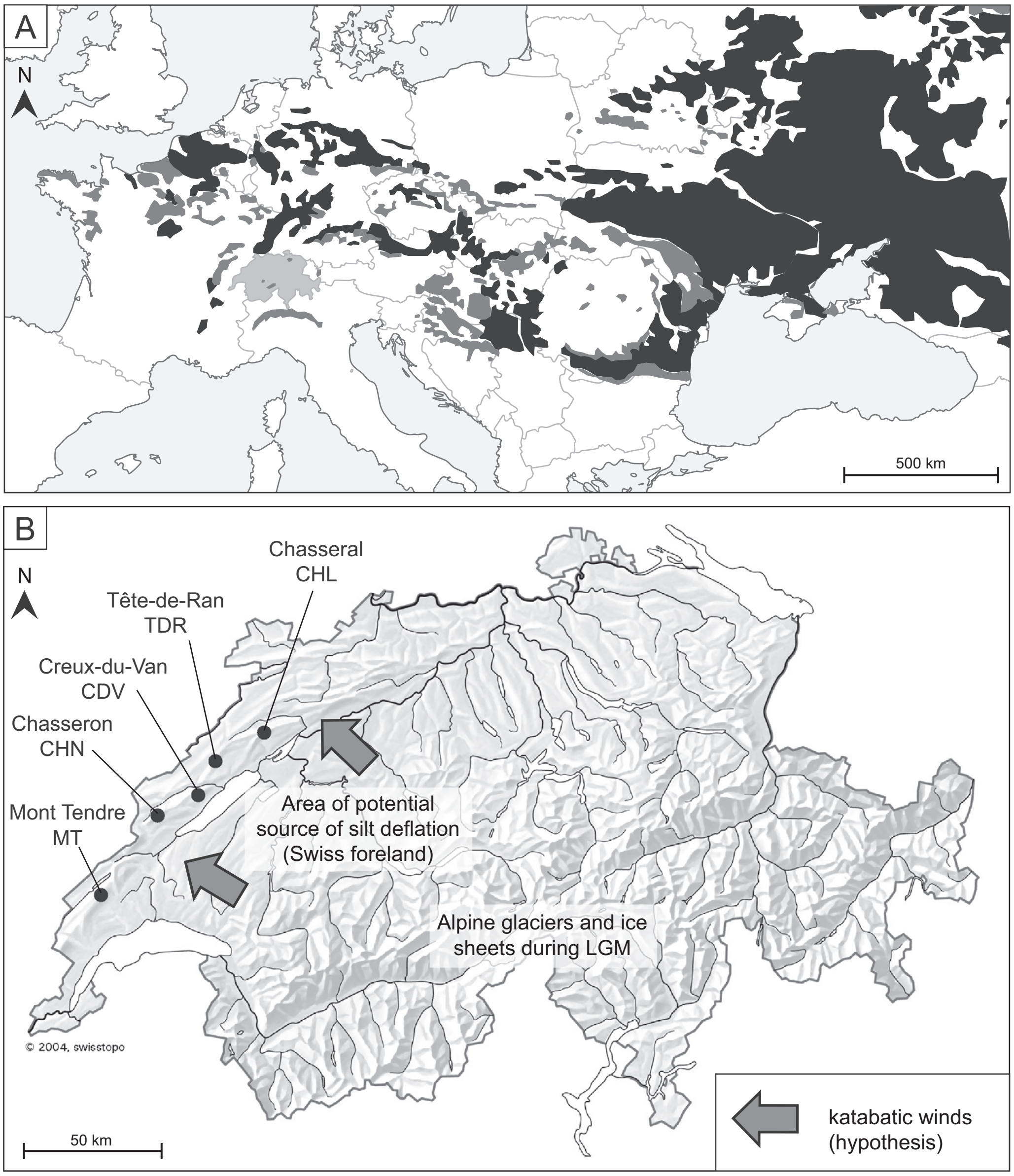

Fig. 1. (A) Location of loess in Europe (redrawn after Haase et al., 2007; Muhs, 2013, and Muhs et al., 2014). Thick loess, thin loess, and sandy loess are indicated in black; "loess derivates" in dark grey. Switzerland is located on the map. (B) Map of Switzerland showing the location of the five study sites and corresponding soil profiles along the first ridge of the Jura Mountains. Potential areas of loess deflation are indicated on the Swiss foreland. The most probable direction of katabatic winds during the LGM is also shown.

Oldest Dryas (from 18,000 to 14,500 BP; Ivy-Ochs et al., 2004). Therefore, it can easily be hypothesised that fine material from the ground moraines was winnowed out by katabatic winds coming from the Alps and descending through the Swiss foreland. The presence of sparse Arctic tundra-like vegetation (Hadorn et al., 2002; Magny et al., 2003) allowed efficient particle deflation (Muhs, 2013). Mineral grains were deposited on the Jura's easternmost ridge to form an approximately 45 cm-thick layer (Aubert et al., 1979), which covered the bare limestone bedrock and the sediments present on summit areas. Loess was preferentially preserved in small depressions and as cladding on the mountain top, as well as in karst features, such as rock cracks (lapiaz) and dolines (Pochon, 1978). However, most of the loess was eroded and redistributed along hill slopes through solifluction and gravity, and integrated in cover-bed deposits (Kleber, 1992; Kleber and Terhorst, 2013; Martignier and Verrecchia, 2013; Martignier et al., 2013). It is hypothesised that loess contained carbonate when they were deposited, according to the composition of their potential source material, but have most likely been decarbonated during early stages of post-glacial pedogenesis, from about 17,000 BP (Magny et al., 2003; Van Vliet-Lanoë, 2005).

The input of Alpine silicate minerals into the calcareous environment of the Jura Mountains has a direct impact on the composition of superficial deposits and therefore, on soil evolution. However, recent studies suggest that there were multiple aeolian episodes, resulting in a mix of distinct subpopulations of grain-sizes, including coarse sand particles (Martignier et al., 2013). Consequently, more proximal deflation sources must also be considered, such as local carbonate moraines situated at the southeastern Jura foot slope (Martignier and Verrecchia, 2013). In the studied context of the Jura Mountains, loess contains loamy particles brought by wind action in a former periglacial environment. This Jura loess must include *in situ* genuine loessic sediments, as well as some slightly reworked loess (corresponding to