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Stratigraphy and age of colluvial deposits indicating Late Holocene soil erosion in northeastern Germany

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ABSTRACT

In the focus of this study are the sedimentary characteristics, chronology, magnitude, and causes of past soil erosion dynamics of an agriculturally intensively used glacial lowland landscape. From the mesoscale Quillow river catchment, sedimentary sections bearing colluvial sediments from different landforms were analysed to explore their geoarchive potential and to establish a local chronology of Late Holocene soil erosion. Sections from footslopes contain a rather simple stratigraphy with one topping colluvial horizon of up to 1 m thickness burying a palaeosol. In contrast glacial kettle holes preserve more complex sequences partly having several colluvial layers with intercalating palaeosols. The most complex stratigraphy is associated with a kettle hole being the ultimate sediment trap for a dendritic gully system, forming a 4 m thick sequence of alternating peat and colluvial layers. Thirty OSL ages and 13 radiocarbon ages are used to reconstruct phases of soil erosion. Potentially human-induced soil erosion, which is corroborated by local archaeological and palynological data, can be traced back to the last c. 4000 years. The oldest colluvial deposits date back to the Late Bronze Age. Most datings, however, cluster within the last 600 years with a peak in the last 200 years, ascribing the main phase of local soil erosion to the recent past. Thus, although numerous archaeological finds are detected in the catchment since the Neolithic, considerable agricultural soil erosion does not occur before the last millennium. A compilation of OSL chronologies based on colluvial sediments from other regions in Central Europe shows a more complex erosion history there with a pronounced two- or three-phased distribution of ages primarily dating into the last c. 4000–5000 years. This study underlines that in northeastern Central Europe human impact on landscapes was effective apparently at a later stage as compared to some adjacent regions.

1. Introduction

Present-day landscapes are the result of various natural and anthropogenic processes. Many European landscapes have been intentionally modified by humans (e.g. by deforestation and agricultural activities) surely since the Neolithic and probably already since the Late Palaeolithic/Mesolithic period (e.g. Gramsch, 2000; Ryan and Blackford, 2010; Tolksdorf et al., 2013). The conversion of naturally vegetated areas into agricultural land, the intensification of soil management and land-use changes generally led to significantly increased soil erosion rates (Dotterweich, 2008; Vanwalleghem et al., 2017). In Central Europe, the onset of Neolithic economy introduced by the linear pottery culture people around 6 to 7 kiloyears (ka) BP (Bogucki, 1996; Gronenborn et al., 2014; Svizzero, 2015) potentially marks a drastic change in various landscape characteristics and processes, such as land cover, mesoclimate and solid matter fluxes. Beside human impact, changes in soil erosion rates are also linked to past climate changes and extreme meteorological events (e.g. the 1342 CE event in Central Europe; Dotterweich, 2013; Herget et al., 2015).

Research on prehistoric and historic soil erosion in central and western Europe have focused mainly on specific geomorphological settings and sub-thematic issues, namely on gully systems (e.g. Dotterweich et al., 2003; Schmitt et al., 2006; Dreibrodt et al., 2010a), on the input of sediments into valleys, rivers and lakes (e.g. Lang et al.,

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2003a; Dreibrodt and Bork, 2005; Hoffmann et al., 2013), and on the formation and distribution of colluvial sediments (e.g. Lang, 2003; Dreibrodt et al., 2010b; Fuchs et al., 2010). Further motivation to study human-induced soil erosion in the region came from geoarchaeological issues (e.g. Tinapp et al., 2008; Dreibrodt et al., 2013; Lubos et al., 2013).

Recent pedological research in the study area generally focusses on the nexus of water balance, soil erosion and matter fluxes in a strongly agriculturally used landscape (Wilken et al., 2017; Herbrich et al., 2017), implying, among others, the question how present-day soil erosion patterns are to be interpreted in a long-term, i.e. centennial to millennial perspective. Therefore, this study aims to analyse the sedimentological-pedological characteristics, chronology, magnitude, and causes of past soil erosion dynamics within a river catchment which is part of the global change TERENO observatories of the Helmholtz Association (Zacharias et al., 2011; Bogena et al., 2012; Pütz et al., 2016; www.tereno.net). Particularly, a sufficient number of geochronological datings is expected to allow insights into the history of colluvial sedimentation on a larger scale and to investigate if the colluvial dynamics are influenced by the landform on which they were deposited.

As a hypothesis, we assume a long lasting erosion pattern since this geomorphologically diverse area represents an old cultural landscape with a high number of prehistoric and historic archaeological sites (Figure 1).

2. Study area

The catchment of the Quillow river covers an area of 168 km^2 and is located in the hummocky glacial landscape of the Weichselian glacial belt ('young morainic area') of northeastern Germany. The end moraine of the *Gerswalder Staffel* runs from the northwest to the southeast in the western part of the Quillow river catchment (Supplement 1). The elevation varies between 18 m a.s.l. in the east to 120 m a.s.l. in the west of the study area (Fig. 1). The surficial sediments were mainly deposited during the Pomeranian phase (W2) of the Weichselian glaciation around 20 ka ago according to recalculated cosmogenic ages from erratics (Hardt and Böse, 2018) and luminescence age data from glaciofluvial deposits (Lüthgens et al., 2011). The area was completely deglaciated around 15 to 14 ka (Lüthgens et al., 2011). The hilltops and slopes consist mainly of sand-covered till and intercalated layers of glaciofluvial sand, whereas the valleys are filled by fine-grained fluvial sand and peat and gyttja (Suppl. 1). Locally, dendritic gully systems have incised in steep slopes (elevation between 67 and 115 m a.s.l.) with gully lengths of up to 120 m and depths of up to 8 m (Suppl. 2E). The soil pattern of the agricultural land is a result of prolonged erosion and deposition processes. Only 10–15% of the area consists of soils unaffected by soil erosion (Luvisols, Stagnosols, Arenosols). Convex hilltops and steep slopes are dominated by extremely eroded A-C profiles (Calcaric Regosols, soil classification according to IUSS Working Group WRB, 2015). Luvisols showing different degrees of erosion cover the up- and midslopes. From the footslopes to the depressions a sequence of Gleyic-Colluvic Regosols, Mollic Gleysols and (buried) Terric Histosols has developed (Deumlich et al., 2010; Janetzko and Schmidt, 2014). In the eastern part of the catchment degraded Phaeozems and Chernozems occur. Their formation and preservation is interpreted to result from the specific natural and land use conditions of the Uckermark region, i.e. high carbonate contents in the parent material, high clay content and subcontinental climate with relatively low annual

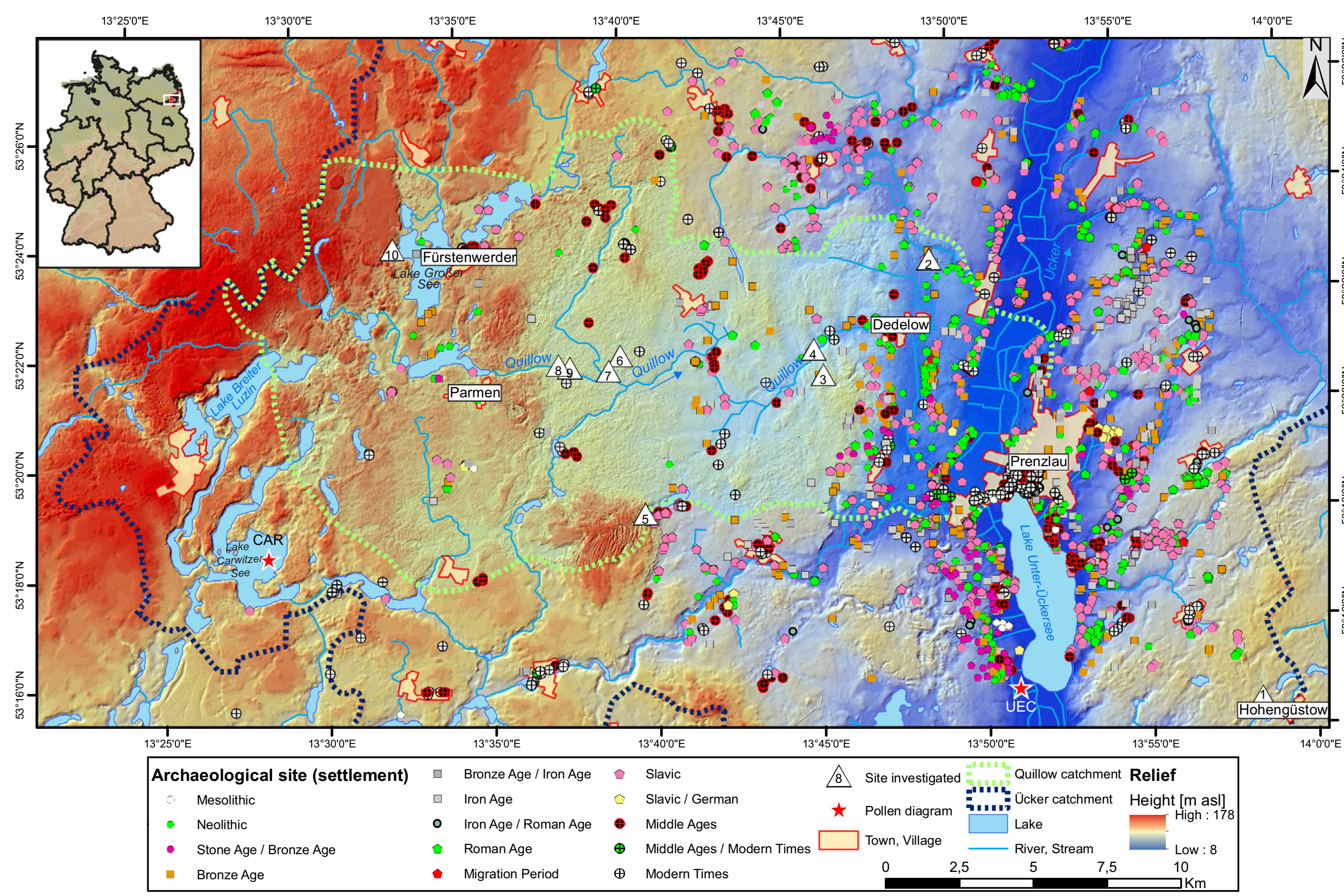

Fig. 1. Map of the Quillow river catchment, distribution of archaeological sites and investigated profiles. Investigated sites (with soil profile ID): 1: Lake Tiefer See (TSU09, TSU17); 2: Steinfurth (STF2, STF3); 3: Falkenhagen (FKHG1); 4: Falkenhagen (FKHG2); 5: Naugarten (NAU11, NAU13, NM-6); 6: Christianenhof (CHRIST647); 7: Christianenhof (CHRIST1); 8: Raakow (RAAK1); 9: Raakow (RAAK2); 10: Grauenhagen (GRHG1).