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Solifluction deposits, reworked loess, colluvia and archaeological features at the Early Neolithic site of Düren-Arnoldsweiler, Lower Rhine area, Germany – a micromorphological approach.

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1. Introduction

Archaeological excavations at Düren-Arnoldsweiler (2009-2011) exposed remnants of a Linear Pottery settlement including more than 30 post-built houses, a burial ground with about 220 burials, a well and an earthwork. The geological situation at the site is complicated. The archaeological features cut into a sequence of solifluction deposits and reworked loess, both containing gravel from the Upper terrace of the River Rhine. Several well developed paleosol horizons are intercalated in the Pleistocene deposits. These in turn are covered by layers of Holocene colluvia (hillwash), which bury most of the archaeological features and the erosional remnants of the Holocene soil represented by Bt and Btg horizons. Postdepositional pedogenesis has altered the Pleistocene and Holocene sediments and the sedimentary fills of archaeological features. Finally, recent tectonics along the Rurrand fault affected sediments and soils.

The aim of our investigations is to elucidate the depositional and pedogenic processes in order to set up a chronological framework of sediment accumulation and soil formation at Düren-Arnoldsweiler and to improve our understanding on site formation processes. For this purpose we conducted pedological field description along trenches and pits supplemented by micromorphological analyses of representative thin sections prepared for a) Pleistocene solifluction deposits, loess and intercalated paleosols, b) Holocene colluvia and 3) sedimentary fills of archaeological features.

2. Geographical setting, field descriptions and methods

The settlement is situated at 50°51’5” N and 6°30’16” E near the city of Düren in a gently sloping landscape structured by loess-covered Middle to Upper Pleistocene terraces of the River Rhine and its tributaries. Located in the rain shadow of the Eifel Mountains, the area receives annual precipitation rates of about 550 to 750 mm and has an annual temperature of 9 to 10 °C. The excavation proceeded along a gently inclined (~0.5°) southwest facing slope over a horizontal distance of about 400 m following the track of a new highway. The earthwork was documented in middle to upslope position, whereas evidence of post-built houses and the burial ground were found on the footslope. The valley is recently drained by the Ellebach, a creek with episodic runoff. In the broad valley bottom, hydromorphic soils, mainly Gleys, occur, whereas the soil map shows Cambisols and Luvisols on the footslope and backslope (Geologisches Landesamt 1976).

Two trenches, up to 350 m long and about 1 to 1.5 m deep, several deep pits and extensive planes were prepared to study the sequence of Pleistocene and Holocene sediments. Field descriptions and horizon nomenclature follow the guidelines of FAO (2006). The palaesol horizons were studied in three pits. They form a pedocomplex developed in reworked loess, which is divided into a well developed orange brown Bt with subangular blocky structure, unconformably covered by a light grey eluviated horizon with platy to angular blocky structure, denominated E, and a dark grey Ah horizon with subangular blocky structure. Interestingly, the Ah horizon contains thick brown coatings of illuvial clay. Locally, the Ah horizon is found close to modern land surface at 1 m depth.

The Ah horizon is covered by brown layers of solifluctional slope deposits with pockets of medium or fine grained fluvial gravel and/or reworked loess. The solifluction layers and reworked loess are partly laminated and, near the erosional boundary towards the Ah horizon, they are enriched in well-rounded Fe-Mn-hydroxide concretions of coarse sand to fine gravel size. Approaching the land surface, the Pleistocene layers grade into darker coloured soil horizons with weak structure and mottling, denominated as Bw. Due to macroscopical similarity they could be interpreted as colluvial deposits, which would imply that at least parts of the Early Neolithic earthwork were dug after a first phase of colluviation. Locally, well developed Bt- or Btg-horizons are preserved. Both, the Bw and Bt horizons probably represent erosional remnants of the Early to Mid Holocene soil. They are covered by at least three different colluvial deposits with characteristic macroscopic features known from other parts of the loess-covered Lower Rhine area (Fischer 2010). At the footslope, the Btg horizon is overlain by a dark coloured horizon with subangular to angular blocky structure, local charcoal impurities and illuvial clay coatings. This horizon was denominated as Bhtg or fBht-Sd by Gerlach et al. (in press), who studied the location before. Luminescence age estimates by the same authors suggest that the Bhtg is a colluvial sediment accumulated during the Younger Neolithic. The finding is corroborated by the fact that the Bhtg material is found only on the footslope near the post-build houses and burial ground and that it

occurs either directly resting on a Btg horizon or as fill of a pit. The Bhtg is covered by a light colored E horizon with hydromorphic mottling and albeluvic tonguing at the lower boundary. The E horizon itself is covered by a brown CB horizon and the modern Ap. As corroborated by luminescence age estimates, the E and CB horizons are pedogenically altered colluvia (see fAh and M horizons of Gerlach et al. "in press"). On the backslope, two colluvial deposits were found overlying the modern Bw horizons. A lower brown one, with a weakly developed subangular blocky structure denominated as CB2, and a light brown CB1, which both lack macroscopically visible clay coats.

The sedimentary fill of earthworks and ditches consists of loess-like sediments with dark brown to black colour, hydromorphic staining and massive structure. The fill of the earthwork locally shows lamination and alternation of layers slightly or heavily enriched in charcoal and humus.

About 40 undisturbed sediment blocks were extracted from the investigated profiles. The blocks were impregnated with artificial resin, cut and polished by Th. Beckmann (Schwülper-Lagesbüttel, Germany) to produce thin sections, 8 cm high, 6 cm wide and about 25 µm thick. The thin sections were analysed at different magnifications using plain polarized light (PPL) and crossed polarizers (XPL). Micromorphological description follows Stoops (2003).

3. Micromorphologcal results and discussion

All Pleistocene layers show several signs of frost activity and ice lensing including platy, lenticular and/or granular microstructures, banded fabric, silt cappings (Fig. 1A), vertically oriented elongated grains, as well as elongated horizontal voids and vesicles (Van Vliet Lanoë 2010).

Limpid illuvial clay coatings (Fig. 1B) are concentrated in the large interpedal pores of horizons Ah and E, where they locally cover laminated silt and clay coatings. The latter probably formed by meltwater during seasonal melting of permafrost soil, while the first were deposited after deformation of aggregates ceased. The pedocomplex consists of characteristic paleosol horizons of Last Interglacial to Early Last Glacial or even older pedocomplexes described in loess deposits of the Lower Rhine area (Ikinger and Schirmer 2002, Schirmer 2010). The Ah horizon can, most probably, be correlated with one of the so-called "Humuszonen" which are forest steppe soils formed during interstadials of the early glacial (Zöller and Semmel 2000). Clay illuviation has not been reported for later interstadial paleosols and, given the proximity of the pedocomplex to the modern land surface, it appears likely, that the limpid illuvial clay coatings resulted from clay eluviation during the Holocene. The pedocomplex is thus polygenetic. The "Humuszone" is an important stratigraphic marker for the site. It locally interferes with the dark colored sedimentary fill of archaeological features but can be distinguished from the latter by its darker colour, the thick illuvial clay coatings, and lack of charcoal.

Microscopic investigation reveals that the modern Bw horizons contain few to abundant thin limpid clay coatings in small channels and vughs. From a pedogenetical perspective, these horizons are Bt horizons. They have moderately developed subangular blocky structures, chitonic coarse/fine related distribution and granostriated b-fabrics. Since they lack microscopic evidence of reworking such as disrupted clay coatings, lamination, rounded soil aggregates or iron-manganese nodules (see Mücher et al. 2010), it is highly unlikely that they are colluvial sediments. Large pores locally contain dusty coatings of silt and clay which are superimposed on limpid illuvial clay coatings. The dusty coatings have formed during a later phase of illuviation, probably after the topsoil horizons had been reworked by sheet flow and replaced by colluvial deposits.

The colluvial deposits have quite different micromorphological characteristics. The upper colluvium on the backslope (CB1, Fig. 1C) has a high porosity, consisting of irregularly shaped large pores, vughs and channels. The b-fabric is undifferentiated, pedofeatures are rare. They include very few thin and dusty clay coatings as well as few iron-manganese hydroxide nodules with sharp boundaries. Iron-manganese hydroxide depletion zones are not present. The lower colluvium (CB2) is more densely packed, has a massive microstructure (Fig. 1D) and undifferentiated to stipple-speckled b-fabric. Few thin clay coatings are present and, locally, microlamination of clay and silt is apparent. This lamination may be related to separation of silt and clay by raindrop impact or sheet wash. Most clay coatings in CB2 have formed in-situ but some, being partly disrupted, suggest relocation from a former Bt horizon. At the footslope, the uppermost colluvium (CB horizon) is loosely packed and displays several parts with horizontal lamination. Iron-manganese nodules are separated from the groundmass suggesting reworking. The middle colluvium (E horizon) shows rounded aggregates and a strong hydromorphic overprint. Clay coatings, partly disrupted, are found in intrapedal pores of rounded soil aggregates suggesting that soil fragments from a former Bt horizon were incorporated during the deposition of the colluvium. This also holds for the Bhtg horizon (Fig. 1E), whose clay coatings are often disrupted. However, plenty of intact clay coatings are present, too, which indicate a post-depositional phase of clay migration. Fe-Mn-depleted zones within the Bhtg contain illuvial clay of light yellowish color, i.e. bleached after deposition of the sediment. Few dusty coatings are found throughout indicating the migration of clay and silt during cultivation of the site. Also, the thin section contains small fragments of charcoal as is the case in most other sections from colluvial deposits at Düren-Arnoldweiler, too. Overall, micromorphological evidence corroborates the colluvial nature of the Bhtg and overlying horizons.

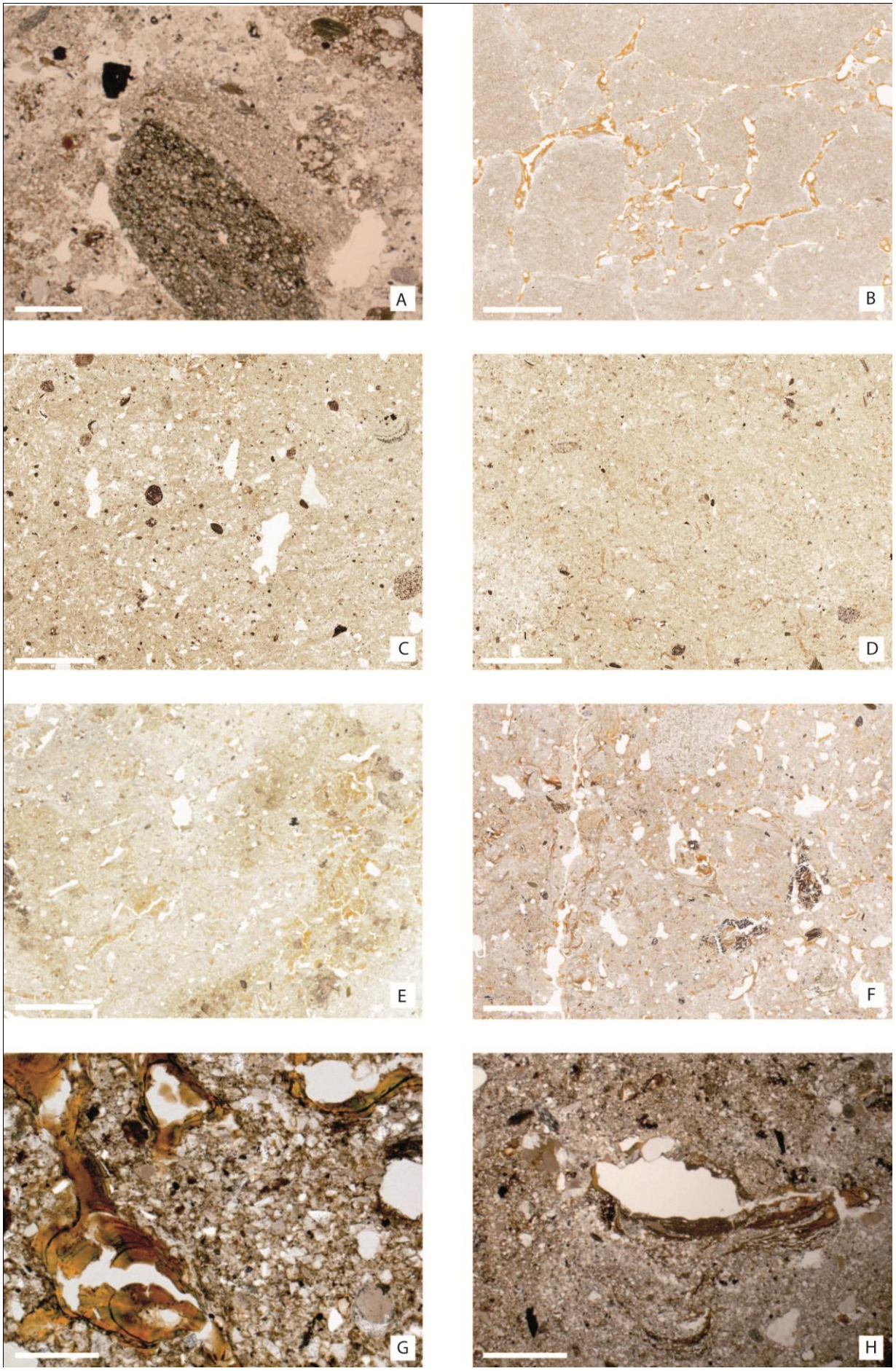

Figure 1. Micrographs (A, G, H) and flatbed scans (B to F) of thin sections from the Neolithic site at Düren-Arnoldsweiler. The scale bar equals 5 mm (B to F), 200 µm (A, G) or 50 µm (F). Ordinary transmitted light (flatbed scans) and plain polarized light (micrographs) have been used. Further explanations in the text.

The sedimentary fills of archaeological features show various microstructures including spongy, vughy, subangular blocky and massive in close neighborhood. The degree of compaction is mostly low and the pore space highly irregular. Many thin and comparatively dark clay coatings are present (Fig. 1F), too small and patchily distributed to be noticed in the field. The darkest coatings are found in close proximity with charcoal rich layers. An older generation of limpid clay coats is mostly disrupted and incorporated into the groundmass indicating that part of the fill derived from Bt horizons. Well laminated coatings are often intercalated by thin layers of opaque substances, probably consisting of organic matter (Fig. 1G). Dusty clay coatings are also frequent (Fig. 1H). Fine pieces of charcoal are found throughout.

4. Conclusions

The case study of Düren-Arnoldsweiler underlines the often complex history of sediment deposition and soil formation in the Lower Rhine area. The micromorphological approach provides information on the sequence of depositional and soil forming processes and offers important criteria for distinguishing paleosols, Holocene colluvia and sedimentary fill of archaeological features.

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