DECIPHERING VARIOUS PHASES OF SEDIMENTATION AND SOIL FORMATION BY MULTIPLE GEOCHEMICAL PROXIES AND MODELING APPROACHES

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Introduction

Terrestrial archives cover all continental surfaces and thus contain paleoenvironmental records as well as contamination histories. The source identification of organic matter (OM) in any kind of terrestrial archive such as soils, paleosols and sediments is a crucial and sensitive issue. Various geochemical methods have been proven to provide valuable information for source apportionment. However, most studies try to focus either on natural environmental developments or anthropogenic influences. The combination of both approaches is still scarce, but provides holistic insights into historical development and thus improved understanding of the respective archive. Therefore, we applied an interdisciplinary geochemical approach to a sandy archive to elucidate different sources of OM.

We excavated a profile in the Netherlands (Fig. 1) that developed on Pleistocene cover sands including a forest Entic Podzol, which was converted to agricultural use 900 years ago. The anthropogenic plaggen use led to a build-up of ca. 1 m of additional sandy material with high contents of nutrients and OM in the Plaggic Anthrosol. 200 years ago, inblown sand from a nearby sand dune led to abandonment and establishment of a mixed forest dominated by oak, which is still present today. During excavation we collected several replicate samples per depth increment (10-15 cm) until a depth of 2.4 m. Further, we determined sediment and soil features in the field like soil horizons, counted root abundances and noticed charcoal fragments as well as hints to anthropogenic use like ploughing furrows and pick marks. In the laboratory, numerous methods were applied to determine the inorganic chemical and physical properties such as grain size analysis, XRF-analysis, whereas our major focus was the organic geochemical investigation, covering TC, TN, $\delta^{13}C$, radiocarbon dating and analysis of GDGTs, lignin and cutin vs. suberin monomers and lipid fractions including e.g. alkanes, aromatic hydrocarbons, fatty acids, alcohols, aldehydes, sterols, stanols. Finally, plant-derived OM sources have been modelled by the VERHIB (Jansen et al. 2010) approach.

Results and Discussion

During field excavation the unexpectedly high root abundances in the anthropogenic plaggen soil exceeded by far the abundances observed in the topsoil, thus questioning the geochemical integrity of the different units in the profile. High nutrient and OM contents within the buried Podzol and the lower part of the plaggen soil promoted preferential root growth in deeper parts of the profile, thus contributing considerable amounts of root-derived OM and promoting degradation of old OM. The input of root-derived OM could be traced by suberin analysis even in distances of several cm around living and dead roots in the profile. Thus, the recent vegetation complicates paleoenvironmental reconstructions in deeper parts of the profile than the surface soil horizons. Further, it significantly lowers the radiocarbon ages compared to OSL ages. Despite the complication of admixture of organic OM from different

ages and sources, the VERHIB modelling approach enabled deciphering the recent root-contribution and reconstruction of paleovegetation. Hence, the old Podzol was produced under pine vegetation, where various crops have been planted during the agricultural phase. While the piled up material was originating from heathlands and used in the stable as bottom cover for the animals, agricultural crops contributed considerable amounts of OM to the plaggen layer. However, as crops changed during the centuries, different lipid patterns, together with pollen patterns from literature, enabled differentiation of preferentially used crops. The OM in the recent Podzol on top of the sequence is exclusively derived from the oak dominated forest. GDGTs enabled temperature reconstruction in the recent soil and the deeper parts of the old Podzol until the bottom of the profile, whereas high root abundances disturbed the signal especially in the plaggen soil and upper part of the old Podzol.
In the old Podzol no indications of anthropogenic perturbations were determined, apart from pick marks at its top, which are remains of the forest conversion to agricultural soil and initial ploughing methods. Charcoal fragments throughout the plaggen soil derive from house firing, where ash and charcoal were admixed to the stable filling and then transferred to the field. Also PAH composition documents the contribution of burning remains throughout the plaggen phase, even in depth intervals, without charcoal remains. Sterols and stanols provide insights into pig and cattle as dominant animals in the stables, whose respective contributions changed throughout the centuries. At the top of the plaggen soil straight ploughing furrows indicate the use of more modern ploughing techniques applied at the beginning of the 19th century. In the covering sediment and recent Podzol absence of indicative biomarkers apart from PAHs in the topsoil indicate the low anthropogenic impact since abandonment.

Conclusions
The combination of various lipid tools and feeding lipid data into the VERHIB model enabled proper assessment of the vegetation history at the investigated site. Further, the historical development of anthropogenic influences could be traced by various proxies. The chosen approach provided insights into environmental and anthropogenic historical developments. By such a holistic approach, even complex terrestrial archives can be interpreted much better than by using only some selected proxies.

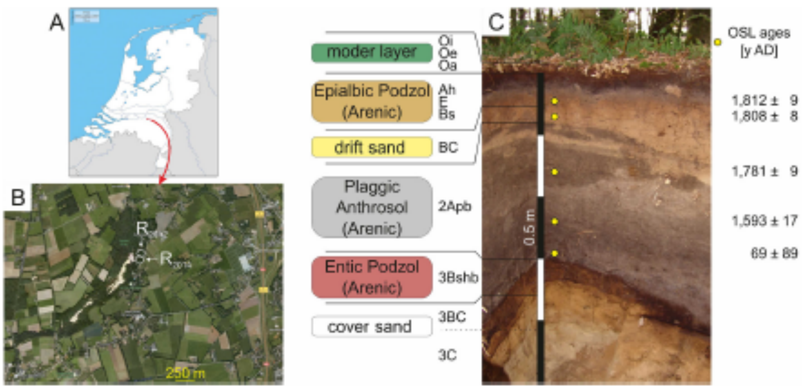

***Figure 1** The investigated site in the Netherlands (taken from Gocke et al. 2016)*

Reference
Gocke, M.I., Kessler, F., van Mourik, J.M., Jansen, B., Wiesenberg, G.L.B., 2016. SOIL 2, 537-549.
Jansen, B., van Loon, E.E., Hooghiemstra, H., Verstraten , J.M., 2010. Palaeogeography, Palaeoclimatology, Palaeoecology 285, 119-130.