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Identifying and dating buried micropodzols in Subatlantic polycyclic drift sands

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ABSTRACT

Polycyclic soil sequences provide valuable archives of alternating unstable periods (sand drifting) and stable periods (soil formation) in NW-European coversand landscapes during the Subatlantic. Here we study six polycyclic soil sequences at the Weerterbergen (The Netherlands) to investigate how to read and interpret this geological archive. At each of the sites a micropodzol forms a clear stratigraphic marker between drift sand beds. We show that soil micromorphology is a practical method to distinguish geogenetic humic layers (containing redeposited organic material) from true pedogenic micropodzols. Optically stimulated luminescence dating of drift sand deposits above and below the micropodzols provides robust ages for periods of aeolian activity, and confines the timing and maximum duration of soil formation. We show that a pedogenic micropodzol was formed in many places in the study area around 1900 AD, and that the duration of this period of landscape stability differed between sites from decades to centuries. Radiocarbon dates, when carried out on soil organic matter, grossly overestimate the burial time of the micropodzols because the organic material in the micropodzols is a mix of geogenic particles and pedogenic carbon.

1. Introduction

Since Medieval times, polycyclic drift sands have developed in many NW-European areas where the surface geology is dominated by Late-glacial aeolian, medium fine, chemically-poor coversand deposits (Koster, 2010). On sheltered sites, valuable soil archives arose in the form of polycyclic soils, consisting of inorganic sands intercalated with organic layers. These provide unique palaeo-ecological records of alternating unstable (sand drifting) and stable (soil formation) phases in landscape evolution. The micropodzols embedded in polycyclic sequences may provide stratigraphic markers between various drift sand beds or phases.

The analysis of soil archives as records of the past plays a key role in the reconstruction of the genesis of Holocene drift sand landscapes in NW-Europe. For correct interpretation of these archives, robust age control is essential, and two dating methods are potentially applicable. Radiocarbon dating can be used to determine the age of fossilized soil organic carbon, but it is unlikely to correctly estimate the age of buried soils (e.g. Wang et al., 1996). This was confirmed in a previous study of palaeo podzols in the study area of Weerterbergen (van Mourik et al., 2010). A suitable alternative is provided by optically stimulated luminescence (OSL) dating, which is ideally suited for aeolian deposits, and has been shown to yield reliable results even on decadal time-scales (Ballarini et al., 2003; Madsen and Murray, 2009). OSL dating determines the last exposure to light of sand-grains, and can be used to determine the time of deposition and burial of drift sands above and below the micropodzol of interest.

Our study concerns a detailed multi-disciplinary investigation of micropodzols in drift sand sequences in the Weerterbergen area, SE Netherlands. In this study, we investigate the origin of the micropodzols using soil micromorphology, we test the applicability of both radiocarbon (^{14}C) and optically stimulated luminescence (OSL) dating, and we established a robust chronology for the polycyclic soils of the study area. The main research questions addressed in this paper are: 1) How can buried initial podzols in polycyclic drift

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sands be differentiated from sedimentary layers enriched with organic carbon due to redeposition of organic particles? 2) What methods are suitable to determine the age of the soil horizons, and to infer the duration of soil development? The insights gained are used to discuss whether buried micropodzols in polycyclic sequences can be used as a chronological marker for a period with landscape stability on a regional scale.

2. Background

2.1. Research area

In the Early Preboreal, aeolian activity in The Netherlands was suppressed by the Holocene vegetation development, starting with a pioneer steppe-like vegetation, succeeded by temperate deciduous forest (van Mourik et al., 2012). Natural forest fires and storms may have induced local sand drifting. From Subboreal times, human influence gradually increased, with scattered wood cutting, forest grazing and shifting cultivation resulting in forest degradation and partial degradation of heath. Sand drifting in this period was still local and small scale. During the 11th, 12th and 13th centuries, commercial clear-cutting of the remaining forests resulted in the first large scale extension of the drift sand landscape; the introduction of the use of deep litter accumulations for livestock ("potstal") and the resulting exploitation of heath sods ("doffing") in the 18th century caused the second large scale extension of sand drifting (Vera, 2011). Holocene sand drifting transferred parts of the coversand landscape, consisting of coversand ridges, planes and valleys, into drift sand landscapes, consisting of deflation plains and complexes of inland dunes. Polycyclic drift sand deposits occur on sheltered locations in the inland dune complexes.

The research area Weerterbergen (SE-Netherlands) is located a few kilometres SW of the city of Weert (Fig. 1), and is part of an intensively studied drift sand landscape (van Mourik, 1988; van Mourik et al., 1988, 2010, 2012). Here we briefly summarizes results of previous investigations. The area directly around the city of Weert was used for agriculture, and plaggic antrosols developed due to fertilization of the poor sandy soils by plaggic agriculture (Bokhorst et al., 2005). The area to the west of the arable fields was used for cattle (and sheep) grazing (van Mourik, 1988; van Mourik et al., 2010). This area today has restored heath, pine forests (planted since 1850 AD) and an extensive area with active sand drifting. During the 20th century, sand drifting continued in this area as a consequence of degradation of the heath cover related to toxic pollution from a Zn smelter and use of the area as military exercise ground (van Mourik and Hermans, 2011).

2.2. Development of micropodzols

Micropodzols (Green et al., 1993; Sevink and de Waal, 2010) are initial podzols that develop in chemical poor substrates such as drift sand deposits. Based on field characteristics alone, buried micropodzols are easily recognized, but a distinction between real pedogenic micropodzols and more sedimentary (sediment-dominated) micropodzols must be based on soil micromorphological observations. In pedogenic micropodzols, the sequestration of soil organic carbon is mainly the result of *in situ* decomposition of litter in the ektorganic layer (mormoder) or endorganic layer (rhizomull) over at least some decades. In sedimentary micropodzols, in contrast, the accumulation of organic matter is mainly due to redeposition of wind-transported soil organic matter originating from eroded humic soil horizons in the direct vicinity.

The controlling processes for micropodzol formation are organic carbon accumulation and sesqui (Al, Fe) mobilization (Dijkstra and van Mourik, 1996; Koster, 2010; Sevink and de Waal, 2010). Organic carbon accumulation results in the formation of humus forms (Green et al., 1993). Stabilizing drift sand will be colonized by plants in a specific succession (Riksen et al., 2006; Sevink and de Waal, 2010). Algae are the first colonizers, followed by lichens (e.g. *Cladonia*) and *Polytrichum*. The litter of these organisms will be decomposed by fungi and micro-arthropods and the humus form is restricted to a thin (<1 cm) mormoder. After some years, the micro-environment becomes less extreme in temperature and moisture

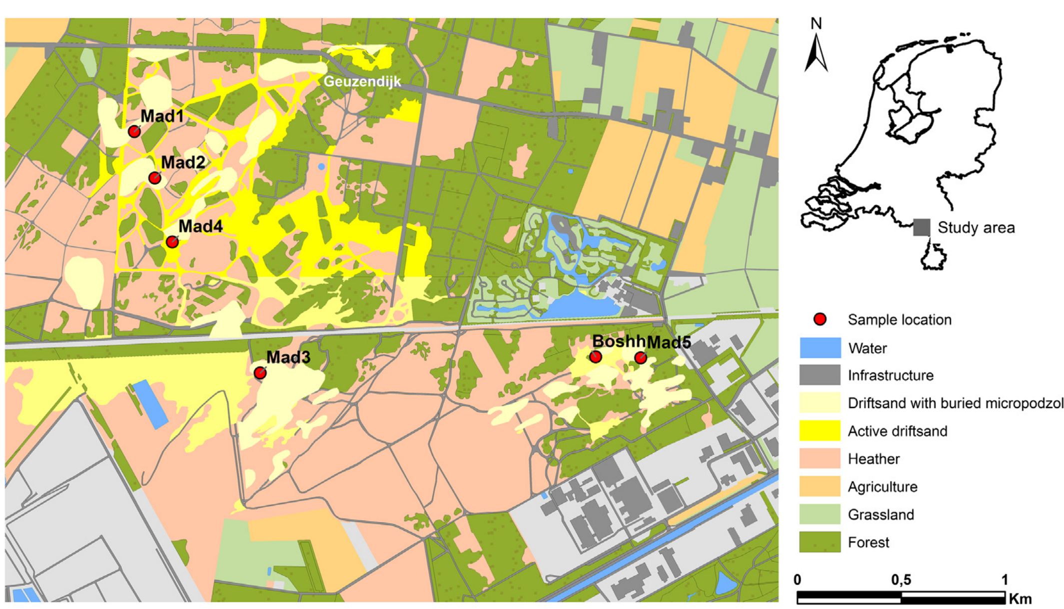

Fig. 1. The study area at Weerterbergen, SE-Netherlands, with sample sites indicated.