Chronosequence of postglacial soil paleocatenas in the dune area of the Toruń Basin (Northern Poland)

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Abstract
The paper presents structure and interpretation of combined chronosequence of soil paleocatenas, formed in the postglacial period in the inland dune area of the Toruń Basin (Northern Poland, Central Europe). Based on radiocarbon, palynological and archaeological datings, four generations of paleosols were distinguished, of Alleröd, Preboreal, Eo-Mesoholocene and Neoholocene ages. Time spans of pedogenesis divide periods of aeolian activity: Late Glacial climatogenic period with three phases: pre-Alleröd, Younger Dryas and late Preboreal and anthropogenic period with episodes correlated with archaeological cultures and second-level climate oscillations, during Neoholocene. Paleosols of particular generations form similar catena patterns on dune slopes, composed of Podzols, Gleyic Podzols, Humic Gleysols and Histosols, providing diversity of geoecosystems depending on landscape position. Additionally, during Holocene two different sandy analogues of Cambisols developed: so called Finow soils (Schlaak 1993), as the effect of climate cooling at the break of Younger Dryas and Preboreal and Brunic Arenosols, as the effect of leave forest succession during Eo-mezoholocene and Neoholocene. Despite typological similarity, soils of different ages distinctly differ in stage of development, which relates to both time and conditions of pedogenesis.

Key Words
Paleocatena, Chronosequence, Paleosols, Aeolian sands, Late Glacial, Holocene

Introduction

The general scheme of stratigraphy of postglacial paleosols and aeolian sands in dune areas of Central Europe are now well recognized and described in literature (Manikowska 1991, Schirmer 1999). As an effect of aeolian sand mobility, paleosols in dunes can be preserved very easily. However, mostly only fragments of buried soil mantle, represented by single soil types are found. Studies of buried toposequences of different soils, changing depending on topographical position, can support more complex paleogeographical interpretations. Natural paleocatenas (Valentine, Dalrymple 1975) met in the field are rare objects in aeolian sands (Wilson 1987, Kaiser et al. 2006). In some cases combined toposequences can be structured using the same age paleosols from different places of well recognized landscape position.
This paper presents a combined chronosequence of soil paleocatenas developed in the dune area during Late Glacial and Holocene and its paleogeographical interpretation.

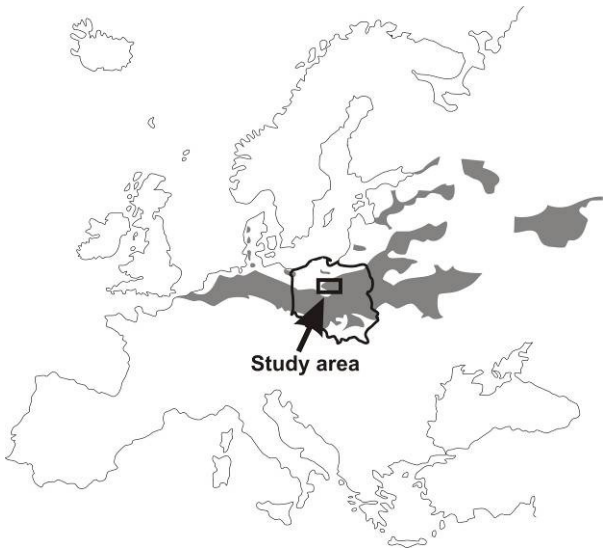

Figure 1. Location of the study area, in the European sand belt (Zeeberg 1998)

Study area, the Toruń Basin is situated in the Northern Poland, Central Europe (Figure 1). From geomorphological point of view it consists of a system of sandy, strongly windblown glaciofluvial terraces

of the Toruń-Eberswalde ice-marginal stream, formed during the deglaciation after the Pomeranian phase of the last glaciation (Vistulian; ca 16 ka BP). One of the biggest inland dune fields of Europe formed there in the Late Glacial period, mostly under impact of W winds.

Methods

Numerous buried soils were documented in dunes and aeolian covers of the Toruń Basin. Three main study sites (Katarzynka, Lasek Bielański, Rudak), representing vertical sequences of different-age buried soils and five additional sites with single paleosols were chosen for further studies. Two sites (Katarzynka and Lasek Bielański) contain natural paleocatenas. The remaining study objects complement individual paleocatenas and the whole view of their combined chronosequence.

Paleosols were dated using ^{14}C radiocarbon method (13 samples of charcoals or humic material, in the Gliwice Radiocarbon Laboratory, Poland), palynological analyses (3 shallow profiles, performed by dr B. Noryśkiewicz, Institute of Geography NCU, Toruń) and on the basis of archaeological findings (2 sites, known from documentation and field studies). Soil morphology, main properties (texture, organic carbon and nitrogen contents, pH, oxalate extractable Fe_o and Al_o, total Fe_t and dithionite extractable Fe_d contents) and soil typology were determined according to standard procedures. Pedogenic characteristics of particular paleosols were reported in previous work (Jankowski 2002).

Results

In the light of radiocarbon datings, palynological and archaeological findings, paleosols of the Toruń Basin can be grouped in four generations: of Alleröd (buried ca 11100 BP), Preboreal (buried ca 9500 BP), Eo-Mesoholocene (existing on land surface during late Preboreal-Subboreal time span) and Neoholocene (developing during Subbboreal and/or Subatlantic) ages (Figure 2). Such pedostratigraphy documents also four phases of intensive aeolian activity, lasting: before Alleröd, during Younger Dryas, in late Preboreal and through the whole Subboreal and Subatlantic periods. According to results from other parts of Central Europe (Schirmer 1999) three first dune-forming phases, dividing short periods of pedogenesis, were connected to periglacial conditions during Late Glacial and the beginning of Holocene. During Neoholocene, few cycles of older soils covered with dune sands, as well as new soil formation occurred. Numerous archaeological data and also findings of cereals grains and other synanthropic plants in pollen diagrams, show anthropogenic origin of aeolian activity during last 4800 years. Sand blowing started together with the appearance of the first neolithic people who learned how to cultivate sandy soils. Records of aeolian processes, simultaneous in distant places, refer to intensification of human activity during Neolith (Funnel Beaker Culture - 4800-4500 BP), Bronze Age (Iwno Culture, 3800-3400 BP, Lusatian Culture, 3000-2900 BP) and Iron Age (Lusatian Culture, 2200-1900 BP, Middle Ages, 1300-1000 BP).

It is worth noticing, that periods of intensive human activity, as the main factor of aeolian process initiation, imposed on drier second-level climate phases during Neoholocene, could promote wind activity. Probably only during dry periods Gleysols, the most fertile among poor sandy soils, were not too wet for primitive agricultural use. On the other hand, cultivation induced wind blowing and thus burial of deforested soils.

All four generations of paleosols built similar catena patterns on buried land surfaces, for the first time formed during Alleröd on dunes and on slopes of glaciofluvial terraces. In that pattern, automorphic Podzols occupy the highest position, changing downslope into Gleyic Podzols and further into Humic Gleysols. In the most wet places Histosols developed. Such diversity of soil cover seems to prove the diversity of the whole landscape already at the beginning of post-glacial forest succession. Thus Alleröd forests, traditionally called “pine-birch” should be called rather “pine and birch”, with most pine participation in dry positions (Podzols, Gleyic Podzols) and birch in wetlands (Humic Gleysols and shallow Histosols). Alleröd shallow Histosols, often formed on surface of dead-ice blocks, after ice melting sank and now lie in inverse position – under lake sediments (gytiia; Figure 2).

In Preboreal paleocatena additionally so called “Finow soils” (Schlaak 1993), similar to Cambisols of cold climates occur in places with an autogenic regime. This probably marks environmental conditions change at the break of last cooling of the Late Glacial (Youngest Dryas) and Holocene.

In two younger generations of the Holocene age (Eo-mezoholocene and Neoholocene) the Podzol-Gleyic Podzol-Humic Gleysol-Histosol catena pattern was limited to slopes of poor dunes only. In relatively more

fertile places (glaciofluvial terraces, shallow aeolian covers on erosional moraine surfaces), sandy analogues of Cambisols (Brunic Arenosols) developed, which is interpreted as an influence of leaf forests succession.

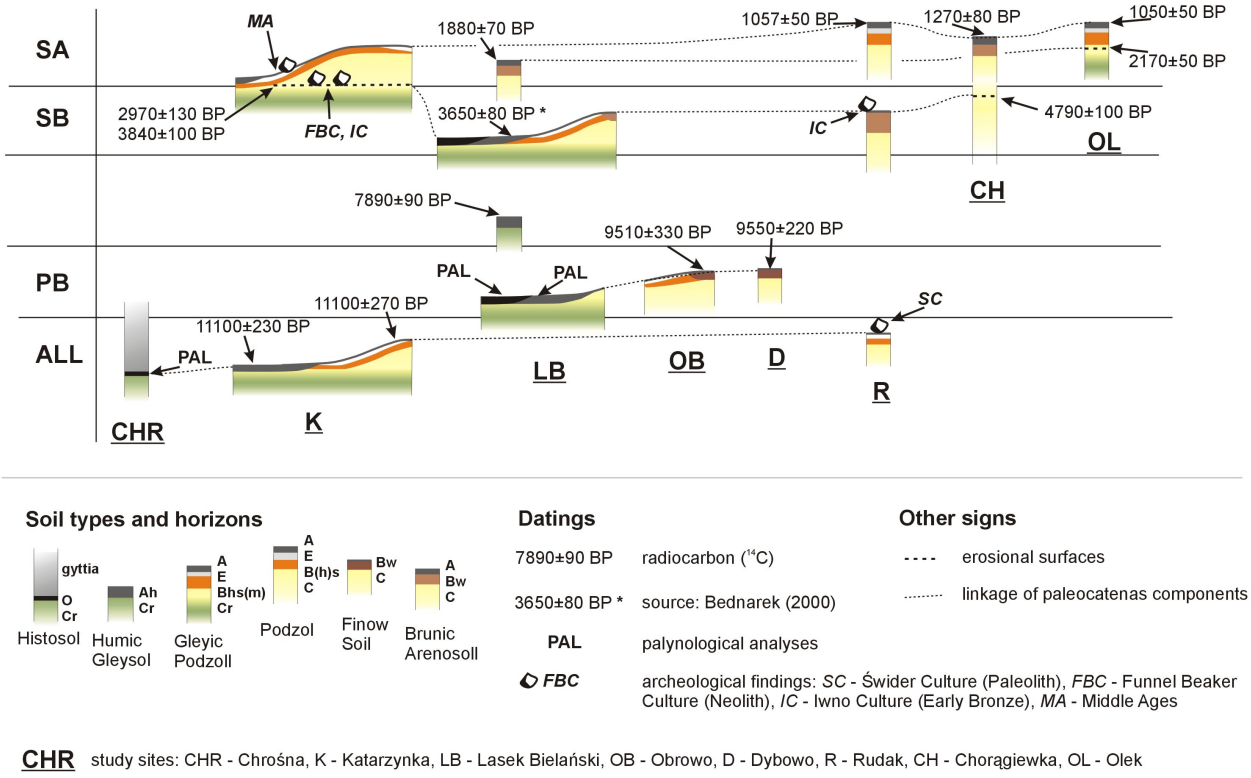

Figure 2. Combined chronosequence of soil paleocatenas in the dune area of the Toruń Basin in the light of ^{14}C, palynological and archaeological datings

Table 1. Fe_d/Fe_t ratio as an evidence of developmental stage of soils in different age paleocatenas.

Soil generation	Podzols	Gleyic Podzols	Brunic Arenosols	Humic Gleysols
Neoholocene (SA)	**CH** E: 0.30 Bhs: 0.49	**K, Ol** E: 0.54-0.60 Bhs: 0.65-0.70	**LB** Bw: 0.28	-
Neoholocene (SB-SA)	**R** E: 0.54 Bs: 0.54	**LB** E: 0.32 Bhm: 0.39 BmA: 0.46	**LB, W*** Bw: 0.28-0.51	**LB*** Ah: 0.59
Eo-Mesoholocene (PB-SB)	-	**LB** BmA: 0.46 E: 0.38 Bhs: 0.17	**R** Bw: 0.51	**LB*** Ah: 0.31
Preboreal (PB)	**OB** (E): 0.29 (Bs): 0.27	**OB** (EA): 0.19 (Bs)Cr: 0.28	-	-
Alleröd (All)	**K** E: 0.20-0.37 Bs: 0.20-0.23	-	-	**K** Ah: 0.07

* - source: Bednarek (2000); **Ch** - symbols of study sites (see fig. 1); E, Bhs, Bhm, Bw, Cr, Ah – soil horizons symbols acc. To FAO (2006)

Despite of typological similarity, various age dune paleosols clearly differ in stage of development, depending on conditions and length of pedogenesis. This can be demonstrated by both, morphological and chemical properties (Table 1). Soils formed during Alleröd and in the first part of Preboreal period have shallow profiles, less distinct genetic horizons and low Fe_d/Fe_t ratios (0.1-0.4). Soil-forming processes have found the strongest expression in soils representing Eo-Mesoholocene and Neoholocene paleocatenas (Fe_d/Fe_t ratios: 0.3-0.7) .

Conclusions

Studies of toposequences and numerous single paleosols, carried out in the dune area of the Toruń Basin, allowed us to construct combined chronosequence of paleocatenas of four generations of soils, developed during: Alleröd, Preboreal, Eo-Mesoholocene and Neoholocene. Catenary variability of soil types reflects diversity of vegetation and the whole landscapes, during particular periods of pedogenesis. Time spans of soil development were separated by phases of aeolian activity, including wind erosion and burial of the former soil mantle. Although at the break of Late Glacial and Holocene, climate conditions were responsible for dune forming processes, human impact became the main driving force of aeolian activity initiation during Neoholocene.

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