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A Lateglacial palaeosol cover in the Altdarss area, southern Baltic Sea coast (northeast Germany): investigations on pedology, geochronology and botany

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In memory of Wolfram Lemke (1955 - 2005)

Abstract

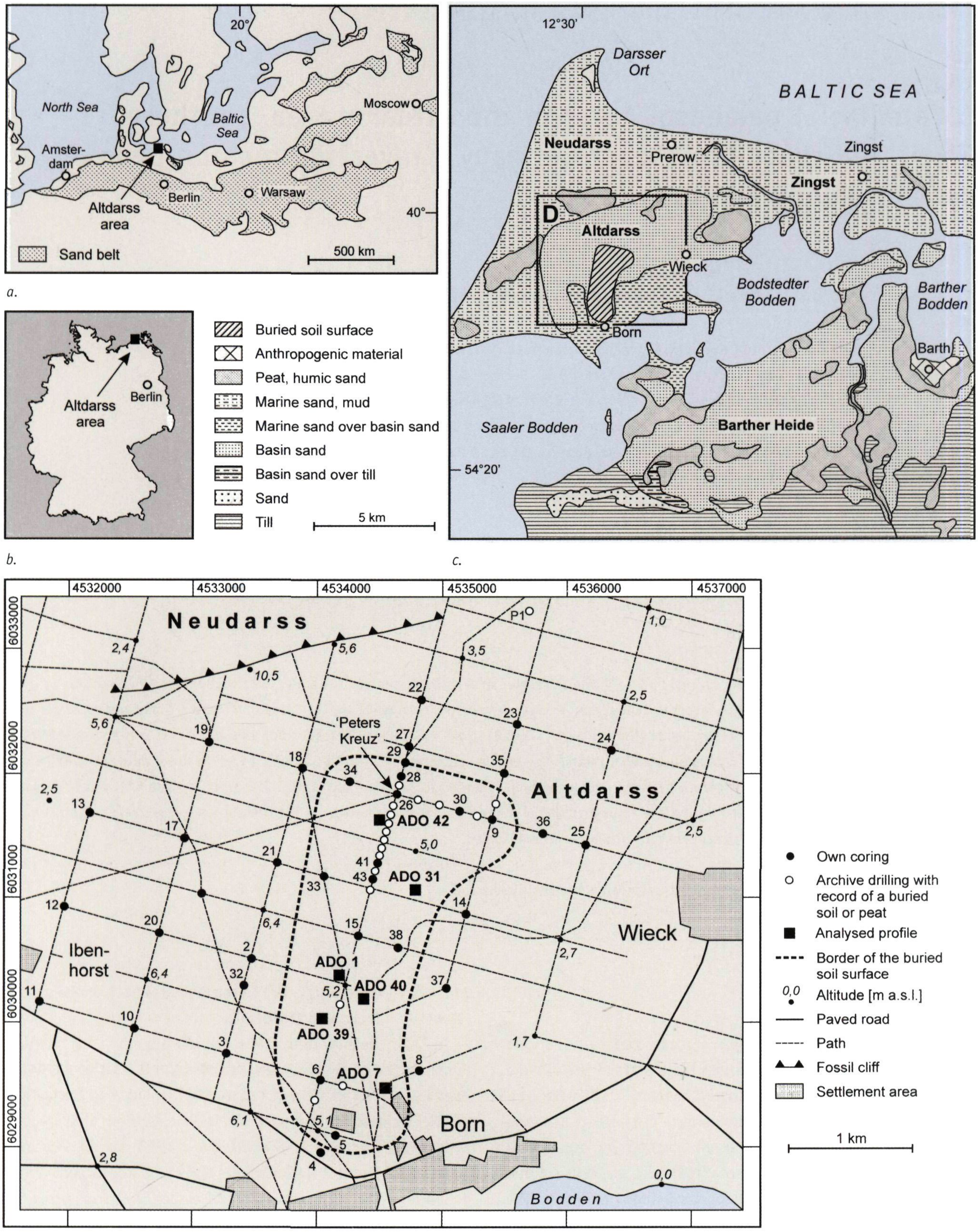
A new site with Lateglacial palaeosols covered by 0.8 - 2.4 m thick aeolian sands is presented. The buried soils were subjected to multidisciplinary analyses (pedology, micromorphology, geochronology, dendrology, palynology, macrofossils). The buried soil cover comprises a catena from relatively dry ('Nano'-Podzol, Arenosol) via moist (Histic Gleysol, Gleysol) to wet conditions (Histosol). Dry soils are similar to the so-called Usselo soil, as described from sites in NW Europe and central Poland. The buried soil surface covers ca. 3.4 km^2. Pollen analyses date this surface into the late Allerød. Due to a possible contamination by younger carbon, radiocarbon dates are too young. OSL dates indicate that the covering by aeolian sands most probably occurred during the Younger Dryas. Botanical analyses enables the reconstruction of a vegetation pattern typical for the late Allerød. Large wooden remains of pine and birch were recorded.

Keywords: buried palaeosol, Late Quaternary, palaeoenvironment, Usselo soil

Introduction

The so-called 'European sand belt' spreads over ca. 2,500 km from NW to NE Europe and comprises large parts of the old and young morainic areas of Germany (Zeeberg, 1998; Fig. 1). Beside former ice-marginal streamways, outwash-plains and ice-dammed lakes, also large areas covered by dunes and coversands are an important feature of this zone. Stratigraphically, the aeolian deposits belong mainly to the Weichselian Lateglacial and the Holocene. The analysis of buried soils / palaeosols in this area is known as a reliable method for dividing aeolian deposits and deriving stages of landscape evolution (pedostratigraphy). Generally, buried soils in this area can be divided into soils strongly influenced by groundwater such as Gleysols and Histosols (peat layers), and soils of more or less dry terrestrial sites such as Arenosols, ('Nano'-) Podzols, and Cambisols.

In the Netherlands, western Germany, and western Denmark the so-called Usselo soil (Dücker & Maarleveld, 1957; Hijszeler, 1957) is a characteristic and widespread buried soil of the Weichselian Lateglacial. It is classified as a weakly podzolized Arenosol (ISSS-ISRIC-FAO, 1998) or as a weakly podzolized Regosol (AG Boden, 1994). Radiocarbon dates, pollen analyses, and archaeological evidence characterises the Usselo soil as a mainly Allerød soil formation (e.g. Kolstrup & Jørgensen, 1982; Stapert & Veenstra, 1988; Hoek, 1997; Kasse, 1999; Vandenberghe et al., 2004; Kaiser & Clausen, 2005). A similar buried soil of identical age has been found in central and northwestern Poland (Manikowska, 1991; Jankowski, 2002).



a.

b.

c.

d.

Fig. 1. *Location, geology, and topography of the study area; a. European sand belt (after Zeeberg 1998, modified); b. Location in Germany; c. Geology of the Altdarss area and surroundings (after Geologischer Dienst Schwerin 1957, modified); d. Topography, corings, and profiles analysed of the study area (topography after Topographical Map 1 : 25 000).*

From central Europe the stratigraphically identical but pedologically different Finow soil was described. It is found in and around northeastern Germany's Federal State of Brandenburg. The Finow soil has features of a weakly developed Cambisol (Bussemer et al, 1998; Schlaak, 1998; Schirmer, 1999). Radiocarbon and luminescence dates as well as archaeological evidence support the assumption, that a stable soil surface still existed during the *early* part of the Younger Dryas (Hilgers et al., 2001; Bogen et al., 2003; Hilgers, 2006). Furthermore, possible single occurrences of Lateglacial Cambisols were reported from Belgium (Kasse, 1999) and Poland (Borowka et al., 1999; Jankowski, 2002). However, there is no sufficient explanation (climate?, geological / edaphic conditions?) for the apparent 'provinces' of the Usselo and Finow soil.

Little attention has been given so far to the lithostratigraphy and pedostratigraphy of aeolian deposits along the northern border of the European sand-belt comprising the coastal areas and the hinterland of the southern Baltic Sea. First dated records of Lateglacial buried terrestrial soils became available not before the 1980s. These studies revealed i) the existence of the Usselo and the Finow soil in the estuary region of the Oder River and ii) a widespread aeolian sedimentation during the Younger Dryas (Borowka et al., 1986, 1999; Bogen et al., 2003). However, the lateral characteristics of the Lateglacial soil cover remained vague and chronological control was inadequate including the wide lack of accompanying palaeoecological data. Up to now, only a few studies in the European sand belt tried to differentiate the palaeosol cover spatially and, furthermore, tried to explain the site development based on a multidisciplinary approach (van Geel et al., 1989; Kowalkowski et al., 1999; Friedrich et al., 2001).

The buried soil cover in the Altdarss area was discovered during geomorphological fieldwork in 1999 (Kaiser, 2001). Similar to the occurrences in the Oder River area, it is situated in a Late Pleniglacial glaciolacustrine basin, which also passed through Lateglacial terrestrial and aeolian stages (Fig. 1). Extraordinary circumstances such as the large extension of an undisturbed buried land surface (ca. 3.4 km^2), the number of buried soil types, and the preservation of plant remains including wood made a detailed investigation of the site worthwhile. First of all, the investigations focussed on a comprehensive description of the palaeosols. Special attention was given on the manifold dating of the stratigraphy including optically stimulated luminescence dating (OSL). A final synthesis aimed at a palaeoenvironmental synthesis resulting primarily in a transect of Lateglacial soils and vegetation.

Unfortunately, the investigation presented here is possibly the 'final' documentation of the research object. In the near future, a fallen groundwater level caused by permanent drinking water conveyance since the 1960s will result in a far reaching destruction of the organic components in the buried soils.

Settings

In the Late Pleniglacial, the Altdarss area was part of a large glaciolacustrine basin (>700 km^2) comprising also the adjacent areas of the Rostocker Heide and the Barther Heide as well as the later coastal lagoons, the so-called 'Bodden' in German (Fig. 1). To the south, the edge of the basin consisted of *unburied* dead ice. Flat till plains appeared after melting around 14,000 uncal BP (Görsdorf & Kaiser, 2001). To the north, the melting of *buried* dead ice formed extended (sub-) basins, the later water-filled 'Bodden'.

Within the Altdarss area more than 60 deep-reaching drillings, carried out since the 1960s for hydrogeological purposes, are available for stratigraphical conclusions. These drillings indicate the following basin sequence: The base in a depth of ca. 20 m consists of sandy-loamy till. It is covered by 3 - 4 m of glaciolacustrine silt. Above follow ca. 15 m of glaciolacustrine sands, sometimes containing drop stones in the size of gravel. On top occurs a storey of buried soils including peats and gyttjas, which is overlain by 1 - 3 m of aeolian sand (Fig. 2). Marine and brackish sediments of the Mid- and Late Holocene rise of the Baltic Sea surround the former 'Altdarss-Island'.

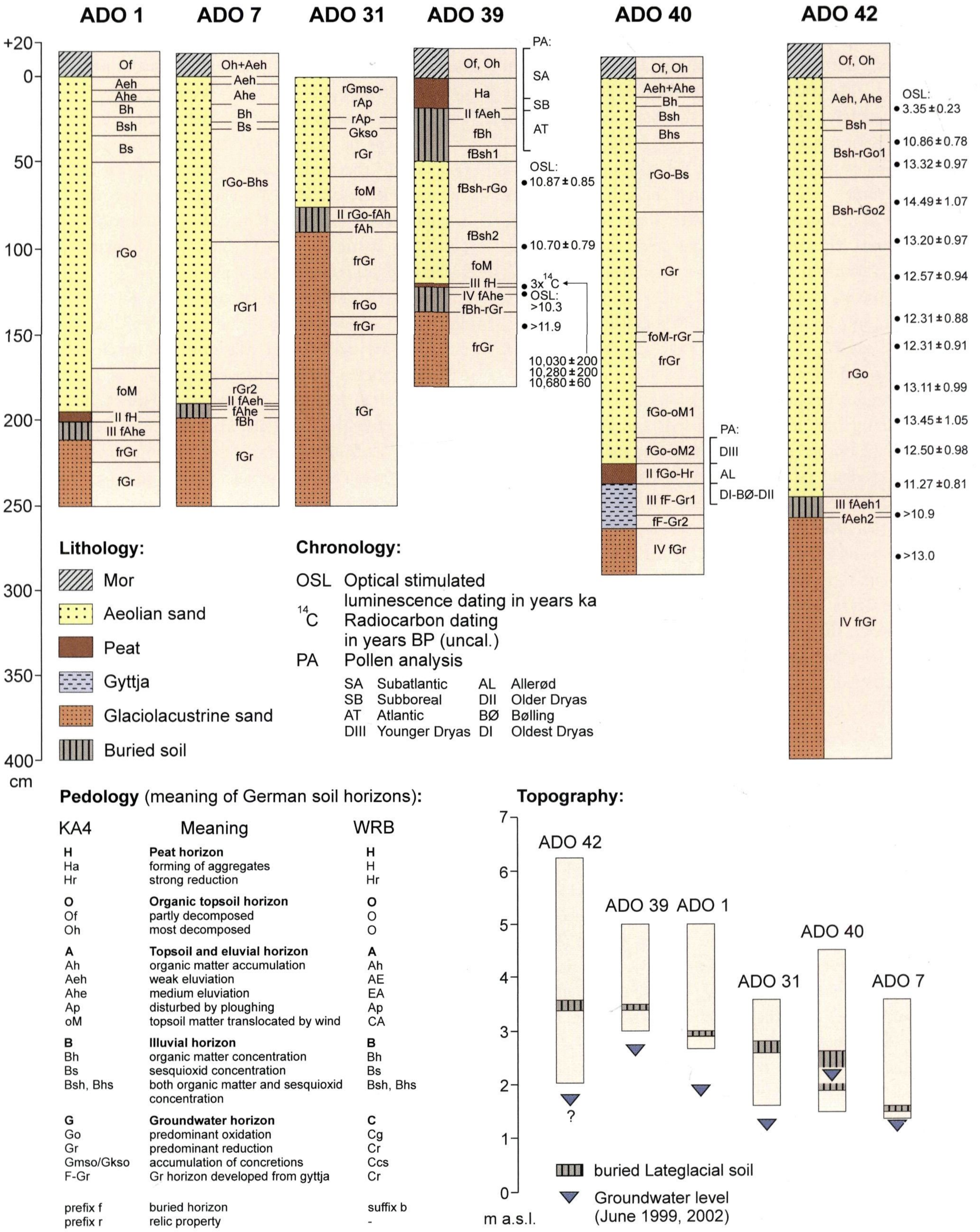
The relief of the Altdarss area is flat to gently undulating with a highest altitude of 10.5 m a.s.l. Aeolian land forms close to the investigated profiles consist of low longitudinal dunes (1 - 2 m high, partly several 100 m long), flat sand sheets, and small deflation hollows.

Soils of the surface are, if relatively dry, classified mainly as well developed (Relic) Gleyic Podzols and Podzols, which have thick covers of raw humus / mor (usually 10 - 20 cm, but partly up to 50 cm thick; Billwitz, 1997). Relatively wet soils are classified as anthropogenically drained Histosols and Gleysols. Improved draining started in the early 20th century and was, accompanied by drinking water conveyance, further intensified since the 1960s. This strongly influenced the surface soils and the preservation of the buried soils.

Dry sites are covered by pine forests or used for arable farming. Wet sites are covered by alder forests or used for meadows and pastures. The Holocene vegetation history of the area is well known from palynological investigations performed by Fukarek (1961) and Kaffke & Kaiser (2002; profile ADP). Prior to the onset of strong human impact on this landscape in the 13th - 14th century, the widespread sandy and podzolized sites were dominated by beech.

Methods

After an initial survey in 1999 - 2000 with first soil and pollen analyses as well as OSL dating (Kaiser, 2001), the extensive investigation of the Altdarss site took place in 2001-03 comprising grid based coring, digging, and sampling of selected trenches with subsequent pedological, micromorphological, geochronological, and botanical analyses.



Pedology (meaning of German soil horizons):

KA4	Meaning	WRB
H	**Peat horizon**	**H**
Ha	forming of aggregates	H
Hr	strong reduction	Hr
O	**Organic topsoil horizon**	**O**
Of	partly decomposed	O
Oh	most decomposed	O
A	**Topsoil and eluvial horizon**	**A**
Ah	organic matter accumulation	Ah
Aeh	weak eluviation	AE
Ahe	medium eluviation	EA
Ap	disturbed by ploughing	Ap
oM	topsoil matter translocated by wind	CA
B	**Illuvial horizon**	**B**
Bh	organic matter concentration	Bh
Bs	sesquioxid concentration	Bs
Bsh, Bhs	both organic matter and sesquioxid concentration	Bsh, Bhs
G	**Groundwater horizon**	**C**
Go	predominant oxidation	Cg
Gr	predominant reduction	Cr
Gmso/Gkso	accumulation of concretions	Ccs
F-Gr	Gr horizon developed from gyttja	Cr
prefix f	buried horizon	suffix b
prefix r	relic property	-

Fig. 2. Profiles investigated of the Altdarss area.

Pedology

In a 400 by 800 m grid, 38 cores were taken using a percussion corer (diameter 5 cm). Additionally, several archive drillings were evaluated. Detailed results have been documented in Czakó Pap (2003). Six trenches up to a size of 4 × 4 m were excavated in order to provide horizontal sections ('plans') as well as profiles and samples. Different standards were applied to classify soil horizons and soil types (AG Boden, 1994: 'KA4'; ISSS-ISRIC-FAO, 1998: 'WRB'; Tabs 1, 2). The German KA4-standard (partly modified) was used to name horizons since it is more precisely. Soil types, however, are classified according to the WRB-standard. Pedological analyses were carried out on 71 samples. After humus destruction and dispersion with sodium pyrophosphate, a pipette and sieving test was used to determine the grain-size distribution. In profile ADO 42 grain-size distribution was determined by laser diffractometry. Samples were treated by burning for two hours 550 °C to estimate the organic content (loss-on-ignition = LOI). Iron-components (Fe_d, Fe_o, Fe_p) were extracted following Schlichting et al. (1995). Soil pH was determined potentiometrically in 0.01 M $CaCl_2$. According to AG Boden (1994), depth is measured from the upper limit of the mineralic soil.

Table 1. Pedological parameters of profiles ADO 1, ADO 7, and ADO 31 (analysis: K. Kaiser & S. Czakó Pap).

Profile ADO 1 (altitude: 5.0 m a.s.l.; German coordinates: RW 4534350, HW 6030450; groundwater level 06/2002: c. 330 cm)

Depth	**Horizon**	**Horizon**	**Substrate**	**Colour**	**Grain size distribution** (%)				**LOI**	**pH**	**Iron**		
(cm)	(KA4)	(WRB)		(Munsell)	**Clay** (<0.002 mm)	**Silt** (<0.063 mm)	**Fine sand** (<0.2 mm)	**Med. sand** (<0.63 mm)	(%)	($CaCl_2$)	Fe_d (mg/ 100 g)	Fe_o (mg/ 100 g)	Fe_p (mg/ 100 g)
+15	Of	O	Mor	2.5YR2.5/3	-	-	-	-	85.3	3.0	-	-	-
0-8	Aeh	AE	Aeolian	10YR2/1	0.0	10.1	84.9	5.0	12.0	3.0	0.4	19.9	35.6
15	Ahe	EA	sand	10YR5/2	0.0	5.4	90.9	3.7	2.4	3.3	0.3	4.7	5.7
24	Bh	Bh		10YR2/1	1.9	5.9	85.2	7.0	11.7	3.0	0.7	53.7	51.5
35	Bsh	Bsh		2.5YR2.5/3	0.8	-	89.6	5.7	3.5	3.8	0.9	9.2	11.7
50	Bs	Bs		5YR5/8	1.3	3.6	90.3	4.8	2.9	3.8	0.9	9.6	12.2
170	rGo	Cg		10YR6/8	0.0	2.8	88.9	8.3	0.6	4.3	0.2	1.6	1.7
195	foM	CAb		2.5Y6/4	0.5	3.8	90.6	5.1	1.0	4.2	0.3	5.3	7.7
201	II fH	2Hb	Peat	2.5YR2.5/3	3.5	49.1	44.7	2.7	60.5	3.8	90.0	240.0	102.0
211	III fAhe	3EAb	Glacio-	10YR5/3	1.7	18.4	79.6	0.3	2.7	3.9	0.9	6.4	6.5
225	frGr	Crb	lacustrine	2.5Y7/3	0.3	4.5	89.6	5.6	0.4	4.2	0.6	4.8	3.5
250+	fGr	Crb	sand	5Y6/3	-	-	-	-	-	-	-	-	-

Surface soil: KA4: Relikt-Gley-Podsol (KA4); WRB: (Relic-) Gleyic Podzol

Buried soil: KA4: schwach podsolierter Moorgley; WRB: weakly podzolized Histic Gleysol

Profile ADO 7 (altitude: 3.6 m a.s.l.; German coordinates: RW 4534750, HW 6029575, groundwater level 06/2002: c. 250 cm)

Depth	**Horizon**	**Horizon**	**Substrate**	**Colour**	**Grain size distribution** (%)				**LOI**	**pH**	**Iron**		
(cm)	(KA4)	(WRB)		(Munsell)	**Clay** (<0.002 mm)	**Silt** (<0.063 mm)	**Fine sand** (<0.2 mm)	**Med. sand** (<0.63 mm)	(%)	($CaCl_2$)	Fe_d (mg/ 100 g)	Fe_o (mg/ 100 g)	Fe_p (mg/ 100 g)
0-14	Oh+Aeh	O/AE	Mor	10YR2/1	-	-	-	-	77.9	3.1	-	-	-
18	Aeh	AE	Aeolian	7.5YR3/1	0.0	5.3	87.7	7.0	6.2	2.9	0.4	8.0	15.0
32	Ahe	EA	sand	7.5YR6/3	0.0	4.1	88.6	7.3	0.9	3.4	0.2	0.8	3.0
40	Bh	Bh		5YR2.5/2	2.7	5.0	82.1	10.2	6.5	3.4	3.5	332.0	189.0
44	Bs	Bs		7.5YR5/8	0.0	4.5	86.0	9.5	2.6	4.0	2.4	267.0	29.6
110	rGo-Bhs	BhsCg		10YR6/6	0.0	2.6	88.6	8.8	0.6	4.3	0.8	35.9	18.1
190	rGr1	Cr		2.5YR6/3	0.0	2.4	89.4	8.2	0.3	4.4	1.2	5.6	4.6
205	rGr2	Cr		5Y7/3	2.5	5.7	82.1	9.7	0.6	4.0	1.0	7.2	4.1
206	II fAeh	2AEb	Glacio-	10YR2/2	5.2	15.1	77.6	2.1	11.4	3.9	1.3	5.7	2.6
208	fAhe	EAb	lacustrine	10YR7/3	0.0	21.4	78.2	0.4	1.8	4.0	0.8	1.7	0.4
213	fBh	Bhb	sand	10YR4/4	0.1	17.6	78.8	3.5	1.1	4.1	1.0	1.5	1.5
250+	fGr	Crb		2.5Y5/3	0.0	4.8	86.9	8.3	0.4	4.3	1.1	1.8	0.8

Surface soil: KA4: Relikt-Gley-Podsol; WRB: (Relic-) Gleyic Podzol

Buried soil: KA4: ('Nano'-) Podsol; WRB: ('Nano'-) Podzol

Profile ADO 31 (altitude: 3.6 m a.s.l., German coordinates: RW 4534825, HW 6031125; groundwater level 06/2002: c. 250 cm)

Depth	**Horizon**	**Horizon**	**Substrate**	**Colour**	**Grain size distribution** (%)				**LOI**	**pH**	**Iron**		
(cm)	(KA4)	(WRB)		(Munsell)	**Clay** (<0.002 mm)	**Silt** (<0.063 mm)	**Fine sand** (<0.2 mm)	**Med. sand** (<0.63 mm)	(%)	($CaCl_2$)	**Fe$_d$** (mg/ 100 g)	**Fe$_o$** (mg/ 100 g)	**Fe$_p$** (mg/ 100 g)
0-24	rGmso-rAp	ApCcs	Aeolian	10YR3/3	-	-	-	-	-	5.4	-	-	-
30	rAp-rGkso	CcsAp	sand	5YR5/8	-	-	-	-	-	5.6	-	-	-
58	rGr	Cr		2.5Y7/2	0.0	3.0	95.9	1.1	0.2	5.7	-	-	-
76	foM	CAb		10YR5/3	0.8	4.7	93.2	1.3	2.7	5.4	-	-	-
84	II rGo-fAh	2AhbCg	Glacio-	10YR2/2	1.3	23.4	75.1	0.2	6.0	5.3	-	-	-
90	fAh	Ahb	lacustrine	2.5Y5/2	1.7	25.6	70.9	1.8	1.8	5.4	-	-	-
126	frGr	Crb	sand	10YR7/2	0.0	3.5	90.4	6.1	0.2	5.5	-	-	-
140	frGo	Cgb		2.5Y6/6	0.0	4.2	92.7	3.1	0.2	5.6	-	-	-
150	frGr	Crb		10YR7/2	0.0	5.5	93.2	1.3	0.3	6.8	-	-	-
250+	fGr	Crb		2.5Y6/3	-	-	-	-	-	-	-	-	-

Surface soil: KA4: Relikt-Brauneisengley; WRB: (Relic) Ferric Gleysol

Buried soil: KA4: Gley; WRB: Gleysol

Micromorphology

Nine undisturbed samples were collected with modified Kubiëna tins (4.5 × 2.5 × 2.5 cm) from profile ADO 42 (221 - 270 cm). The blocks were air dried, impregnated with Palatal P80-21 and sliced into 4.0 × 2.4 cm thin sections. Thin sections were described at 25 - 400× magnification under a petrological microscope mainly using the terminology of Stoops (2003).

Radiocarbon dating

Three radiocarbon samples were taken from the fH horizon in ADO 39. Hv-24639 is dated conventionally using coniferous wood (probably pine). Poz-2212 and Poz-3207 are AMS dated using birch fruits (probably *Betula pubescens*) and remains of the moss *Polytrichum* spec., respectively. Both macro remain (AMS) samples were treated chemically before selection (10% KOH). The radiocarbon ages discussed in the text are mostly uncalibrated (^{14}C-years before present = BP). Any comparison with OSL ages, however, have to be based on the calibrated radiocarbon ages (cal BP-values). The calibration of the own data is based on the radiocarbon calibration program CALIB Rev 5.0.1 (Stuiver & Reimer, 2005).

Luminescence dating

Detailed principles and different protocols used for OSL dating have been summarised by Aitken (1998). All luminescence measurements were carried out on the purified quartz fraction in the grain size range of 0.1 - 0.2 mm following the single-aliquot regenerative-dose protocol ('SAR'; Murray & Wintle, 2000). To calculate the annual dose derived from the decay of lithogenic radionuclides in the sediment, the concentration of uranium, thorium, and potassium was determined by neutron activation analysis (NAA, analysed by Becquerel Laboratories, Sydney, Australia). In addition, for some samples radionuclide contents have been determined by gamma-spectrometry.

Dendrology

Twenty samples of woods from the profiles ADO 1, ADO 31, and ADO 39 were determinated by H. Süß (Potsdam) using a reference collection and literature (Schweingruber, 1990).

Palynology

Single samples were taken from the buried soils at ADO 1, ADO 7, ADO 31, and ADO 39. Furthermore, two longer sections from profiles ADO 39 and ADO 40 were sampled comprising 60 and 40 cm in length, respectively. Sample preparation after Faegri & Iversen (1989) included treatment with HCl, 20% KOH, sieving (120 µm) and acetolysis (7 min). Additionally, samples rich in silicates were treated with HF. Samples were mounted in silicone oil. Counting was carried out with 400× magnification. Percentages are calculated based on upland pollen sum (excluding Cyperaceae), including pollen types attributed to trees and herbs from terrestrial sites.

Macrofossil analysis

Samples were taken from profiles ADO 1, ADO 7, ADO 31, and ADO 39 (volume: 250 ml). Treatment of samples included 10 minutes boiling with 10% KOH and sieving in 3 fractions (>1 mm, >0.5 mm, >0.2 mm). For analysis, a stereo microscope (5 - 50× magnification) and a microscope (100 - 400× magnification) was used. The abundance of non-countable macrofossil types was estimated in categories. Percentages are recalculated to the sample volume after processing.

Table 2. Pedological parameters of profiles ADO 39, ADO 40, and ADO 42 (analysis: K. Kaiser & S. Czakó Pap).

Profile ADO 39 (former profile AD 1; altitude: 5.0 m a.s.l.; German coordinates: RW 4534200, HW 6030100; groundwater level 06/2002: c. 250 cm)

Depth (cm)	Horizon (KA4)	Horizon (WRB)	Substrate	Colour (Munsell)	Grain size distribution (%)				LOI (%)	pH ($CaCl_2$)	Iron		
					Clay (<0.002 mm)	Silt (<0.063 mm)	Fine sand (<0.2 mm)	Med. sand (<0.63 mm)			Fe_d (mg/ 100 g)	Fe_o (mg/ 100 g)	Fe_p (mg/ 100 g)
+17	Of, Oh	O	Mor	5YR2.5/2	-	-	-	-	94.0	2.7	-	-	-
0-18	Ha	H	Peat	10YR2/1	-	-	-	-	86.4	2.8	-	-	-
24	II fAeh	2AEb	Aeolian sand	7.5YR2.5/3	0.0	7.9	91.0	1.1	7.9	2.9	<0.2	10.5	12.1
40	fBh	Bhb		5YR2.5/2	1.3	7.2	90.3	1.2	13.0	3.0	<0.2	5.4	5.4
49	fBsh1	Bshb		5YR3/4	0.2	6.4	91.3	2.1	4.7	3.3	<0.2	2.9	3.3
84	fBsh-rGo	BshbCg		10YR6/8	0.4	2.7	91.3	5.6	1.1	4.0	0.3	2.0	2.6
99	fBsh2	Bshb		2.5Y6/4	1.6	3.6	90.0	4.8	1.8	4.0	0.4	1.7	2.7
120	foM	CAb		2.5Y6/4	0.5	3.6	93.3	2.0	1.3	4.2	0.6	<0.2	1.9
122	III fH	3Hb	Peat	7.5YR2.5/3	3.8	61.2	30.9	4.1	58.6	3.9	28.2	66.9	27.6
126	IV fAhe	4EAb	Glacio-lacustrine sand	10YR5/4, 6/2	0.8	14.6	84.2	0.4	2.0	4.2	0.3	<0.2	1.2
136	fBh-rGr	BhbCr		2.5Y5/4	0.0	5.3	90.7	4.0	0.6	4.3	0.8	0.5	1.5
180+	frGr	Crb		5Y5/3	-	-	-	-	-	-	-	-	-

Surface soil: KA4: Relikt-Moor-Podsol; WRB: (Relic-) Histic Podzol

Buried soil: KA4: schwach podsolierter Moorgley; WRB: weakly podzolized Histic Gleysol

Profile ADO 40 (former profile AD 2; altitude: 4.5 m a.s.l.; German coordinates: RW 4534575, HW 6030350; groundwater level 06/2002: c. 250 cm)

Depth (cm)	Horizon (KA4)	Horizon (WRB)	Substrate	Colour (Munsell)	Grain size distribution (%)				LOI (%)	pH ($CaCl_2$)	Iron		
					Clay (<0.002 mm)	Silt (<0.063 mm)	Fine sand (<0.2 mm)	Med. sand (<0.63 mm)			Fe_d (mg/ 100 g)	Fe_o (mg/ 100 g)	Fe_p (mg/ 100 g)
+12	Of, Oh	O	Mor	See verbal description in Kaiser (2001)	-	-	-	-	63.8	2.7	-	-	-
0-12	Aeh+Ahe	AE/EA	Aeolian sand		0.0	6.2	88.9	4.9	1.8	3.2	-	-	-
17	Bh	Bh			0.9	8.1	84.7	6.3	9.9	2.9	-	-	-
28	Bsh	Bsh			4.6	5.8	84.4	5.2	11.2	3.4	-	-	-
38	Bhs	Bhs			1.4	3.8	87.2	7.6	4.4	3.8	-	-	-
78	rGo-Bs	BsCg			0.0	3.3	91.9	4.8	1.2	4.2	-	-	-
148	rGr	Cr			0.0	2.0	91.8	6.2	0.4	4.5	-	-	-
154	foM-rGr	CAbCr			0.5	2.7	89.4	7.4	0.7	4.2	-	-	-
170	frGr	Crb			-	-	-	-	-	-	-	-	-
176	foM	CAb			0.6	3.8	91.1	4.5	0.9	4.1	-	-	-
200	frGr	Crb			-	-	-	-	-	-	-	-	-
210	fGo-oM1	CAbCg			0.0	3.5	89.1	7.4	0.7	4.1	-	-	-
225	fGo-oM2	CAbCg			0.6	4.3	89.9	5.2	1.4	3.8	-	-	-
237	II fGo-Hr	2HbGg	Peat		3.8	55.9	38.2	2.1	61.5	3.6	-	-	-
255	III fF-Gr1	3Crb	Gyttja		0.6	22.7	75.7	1.0	5.4	3.3	-	-	-
263	fF-Gr2	Crb			0.4	9.6	83.9	6.1	0.7	3.5	-	-	-
290+	IV fGr	4Crb	Glacio-lac. sand		0.0	6.0	89.2	4.8	0.3	3.6	-	-	-

Surface soil: KA4: Relikt-Gley-Podsol; WRB: (Relic-) Gleyic Podzol

Buried soil: Moorgley (KA4); Histosol (WRB)

Profile ADO 42 (former profile AD 4; altitude: 6.2 m a.s.l.; German coordinates: RW 4534625, HW 6031675; groundwater level 06/1999: >400 cm)

Depth	**Horizon**	**Horizon**	**Substrate**	**Colour**	**Grain size distribution** (%)				**LOI**	**pH**	**Iron**		
(cm)	(KA4)	(WRB)		(Munsell)	**Clay** (<0.002 mm)	**Silt** (<0.063 mm)	**Fine sand** (<0.2 mm)	**Med. sand** (<0.63 mm)	(%)	($CaCl_2$)	**Fe_d** (mg/ 100 g)	**Fe_o** (mg/ 100 g)	**Fe_p** (mg/ 100 g)
+20	Of, Oh	O	Mor	See verbal description in Kaiser (2001)	-	-	-	-	-	-	-	-	-
0 - 25	Aeh, Ahe	AE, EA	Aeolian sand		1.5	10.4	70.2	17.9	2.1	2.9	-	-	-
31	Bsh	Bsh			1.1	13.4	67.4	18.1	12.3	3.0	-	-	-
58	Bsh-rGo1	CgBsh			2.2	7.2	66.1	24.5	1.4	4.2	-	-	-
100	Bsh-rGo2	CgBsh			1.5	3.7	71.2	23.6	0.7	4.2	-	-	-
150	rGo	Cg			2.0	4.9	69.7	23.4	0.4	4.1	-	-	-
200	rGo	Cg			1.4	3.7	71.7	23.2	0.2	4.0	-	-	-
244	rGo	Cg			1.7	4.3	66.6	27.4	0.2	4.0	-	-	-
253	II fAeh1	2AEb	Aeolian sand		6.0	19.9	73.8	0.3	3.9	3.4	-	-	-
257	fAeh2	AEb			3.0	32.8	63.9	0.3	3.0	3.5	-	-	-
265	III frGr	3Crb	Glacio-lacustrine sand		3.1	19.1	65.7	12.1	0.6	3.8	-	-	-
300	frGr	Crb			1.4	5.5	69.9	23.2	0.2	4.0	-	-	-
350	frGr	Crb			1.3	4.7	71.0	23.0	0.2	4.0	-	-	-
400+	frGr	Crb			1.2	3.9	74.5	20.4	0.2	3.8	-	-	-

Surface soil: KA4: Relikt-Gley-Podsol; WRB: (Relic-) Gleyic Podzol

Buried soil: KA4: schwach podsoliger Regosol; WRB: weakly podzolized Dystric Arenosol

Results

Pedology

A reliable classification of the buried soils was only successful for those profiles that were accessible in trenches and analysed by several methods. Uncertainties remain in the majority of the cores, especially in those with peats and gyttjas. Furthermore, the assumption that the sands immediately *below* the buried soils are of glaciolacustrine origin is hypothetical. This opinion is based on the present state of the art of geological research in the Altdarss area: The relatively high content of silt (14.6 - 32.8%) in the upper part of these sands might have been caused by aeolian sedimentation as well. The recent relief consisting of longitudinal dunes, deflation hollows, and a gently undulating overall relief clearly indicates that the sands above the buried soil are of aeolian origin. They are dominated by fine sand particles ranging from 0.063 - 0.2 mm (general grain-size distribution: medium sand = 1.1 - 27.4%, fine sand = 66.1 - 95.9%, silt = 2.0 - 13.4%, clay = 0.0 - 4.6%). Geomorphological evidence from the adjacent Barther Heide area (same pedostratigraphy, sand sheets with high-angle cross lamination of 24 - 36° to SE) points to an aeolian facies of the upper sands as well (Kaiser, 2001).

ADO 39

The buried soil is covered by only ca. 100 cm of aeolian sand (Figs 2, 3, 4a, 4b, Table 2). Since the present groundwater level was recorded in a depth of ca. 250 cm, the peat horizon in between the mor layer and the aeolian sands indicates a substantial lowering of the groundwater level. In the lower part of the aeolian sand several conspicuous illuviation bands occur; they consist of humic matter. A thin organic horizon ('foM', LOI: 1.0%) was found immediately above the buried soil. It is interpreted as material from the buried soil below, which was translocated by wind. Since such horizon formed by aeolian relocation had not yet been suitably named, a new designation was created for it: 'oM/foM' (prefix *o* from aeolian, *M* from *migrare*). The buried soil itself is 6 cm thick and divided into an upper organic horizon (fH) and a lower minerogenic horizon (mostly fAhe, partly fAeh). Both the profile and the plan show a wavy shape of the buried soil surface. While the thickness is constant, the surface is undulating strongly, with highest amplitude of 43 cm. The undulations may reflect a periglacial movement of the ground or are a result of the pressure of the overlying sands. Large remains of birch and coniferous wood (probably pine) occur in the fH horizon. The dominating component of this horizon is silt (61.2%), LOI is high (58.6%). The high amount of iron can be explained by the 'trap-effect' of organic matter. The iron originates most probably from the podzolized sands above. The dominance of *Sphagnum*-moss and the low amount of fine litter of wood indicate that this horizon predominately consists of peat. Following a standard for construction grounds (DIN V 4019-100, 1996), the original thickness was 2.1 cm (pers. comm. K. Krienke, Stralsund). Similar results with only a little increase in thickness of the peat were obtained for the other profiles (ADO 1: 6.0 cm → 6.5 cm, ADO 40: 12.0 cm → 16.4 cm). The underlying fAhe horizon is dominated by sand (84.6%) and has a relatively low organic content (LOI: 2.0%). A following fBh-rGr horizon is only weakly developed.

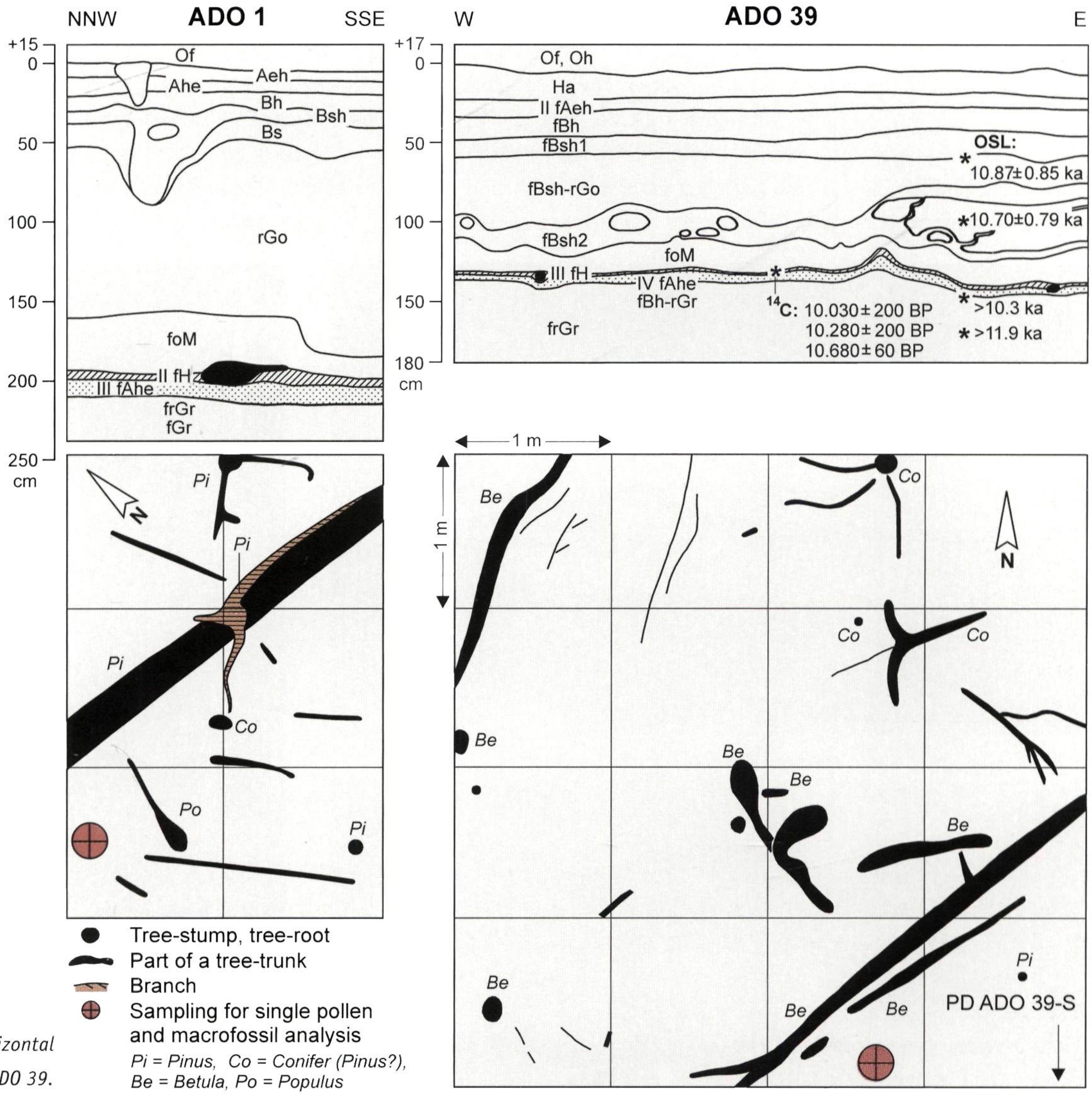


Fig. 3. Profiles and horizontal sections of ADO 1 and ADO 39.

ADO 1

This profile is very similar to ADO 39 (Figs 2, 3, 4c, 4d, Table 1). The buried soil occurs in a depth of 195 - 211 cm. It comprises an upper fH horizon (LOI: 60.5%, silt: 49.1%) and a lower fAhe horizon (LOI: 2.7%, silt: 18.4%). The fH horizon is rich in Fe due to infiltration of humic acids with percolating soil water from the surface. Large remains of pine wood were found in the fH horizon.

ADO 40

The buried soil is situated in a low relief position (ca. 2.2 m a.s.l.) and it is classified as a Histosol. It occurs in a depth of 225 - 237 cm (LOI: 61.5%, silt: 55.9%; Figs 2, 4e, Table 2). A sandy gyttja was found below the buried soil (LOI: 0.7 - 5.4%) indicating the former existence of a pond. In contrast to the other profiles, profile ADO 40 contains *several* foM horizons. Consequently, the aeolian covering took place locally in several short episodes.

ADO 42

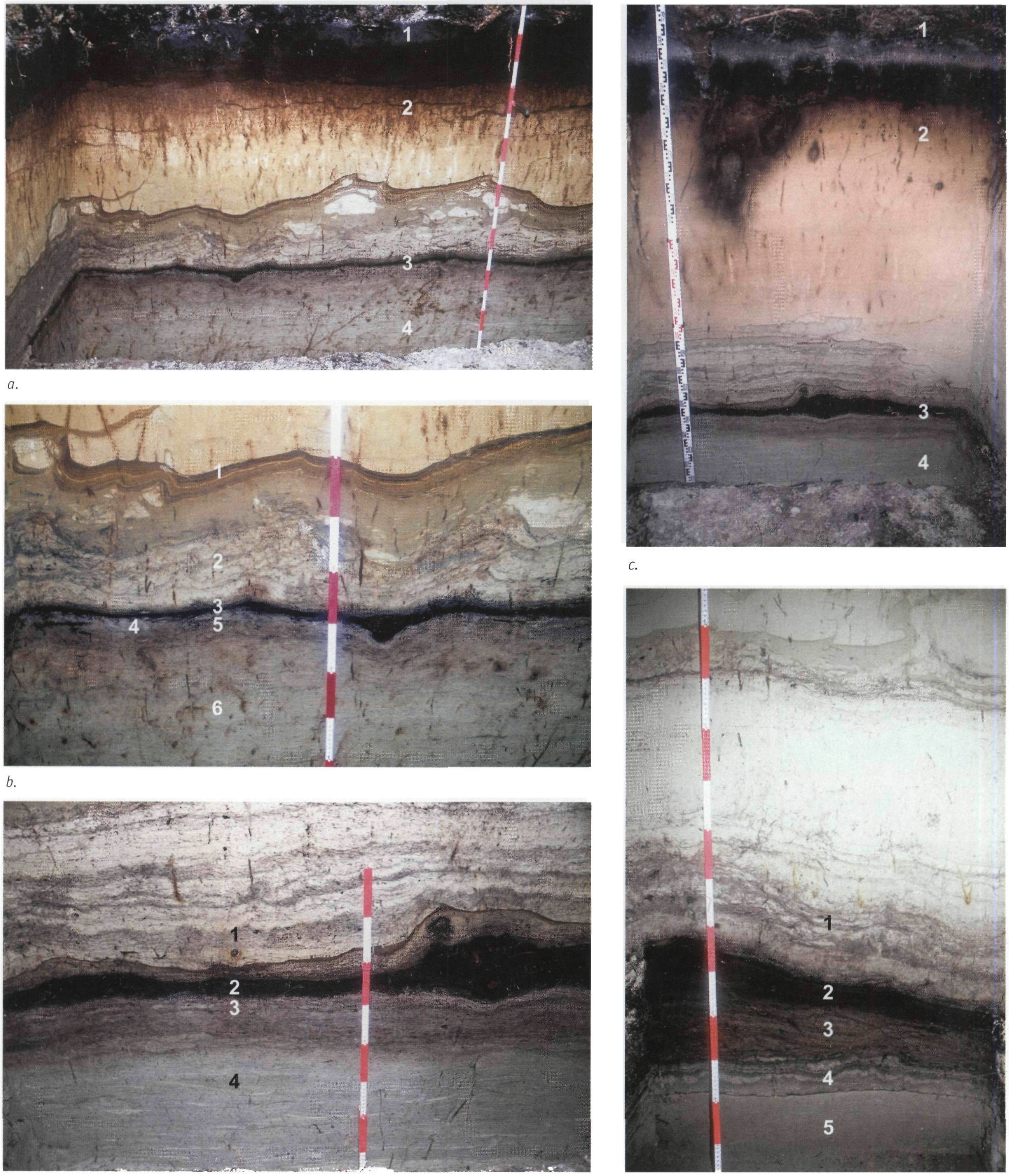
Two fAeh horizons in a depth of 244 - 257 cm form the buried soil (LOI: 3.0 - 3.9%, silt: 19.9 - 32.8%; Figs 2, 4f, 4g, Table 2). Both horizons show a distinct horizontal layering indicating soil formation during input of drifting sands. Furthermore, it points to a low intensity of syngenetic bioturbation. The soil is classified as weakly podzolized Dystric Arenosol.

ADO 31

This profile is situated in a long and shallow depression. Two (rGo-)fAh horizons are covered by an only 79 cm thick cover of aeolian sand (LOI: 1.8 - 6.0%, silt: 23.4 - 25.6%; Figs 2, 4h, Table 1). Because of the low content of organic matter and the situation in the relief it is classified as a Gleysol. Remains of alder in the buried soil originate from the surface of the modern soil.

ADO 7

The buried soil is formed by an 8 cm thick fAeh-fAhe-fBh sequence (LOI: 1.1 - 11.4%, silt: 15.1 - 21.4%; Figs 2, 4i, Table 1). It is classified as a weakly developed ('Nano'-) Podzol. Macrofossil analysis points to a high degree of decomposition of the organic matter due to dry site conditions; pollen analysis supports this assumption (see further). However, the buried soil is situated in the lowest position of all profiles investigated (ca. 1.6 m a.s.l.). This could be explained by a change in altitude after soil formation. Taking the position of the profile close to a large depression into account (Fig. 1), the melting of buried dead ice might have been responsible for that phenomenon.



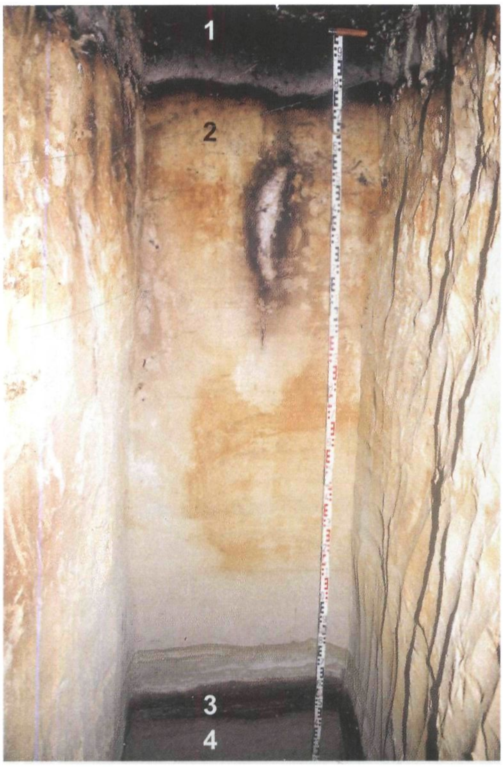
a.

b.

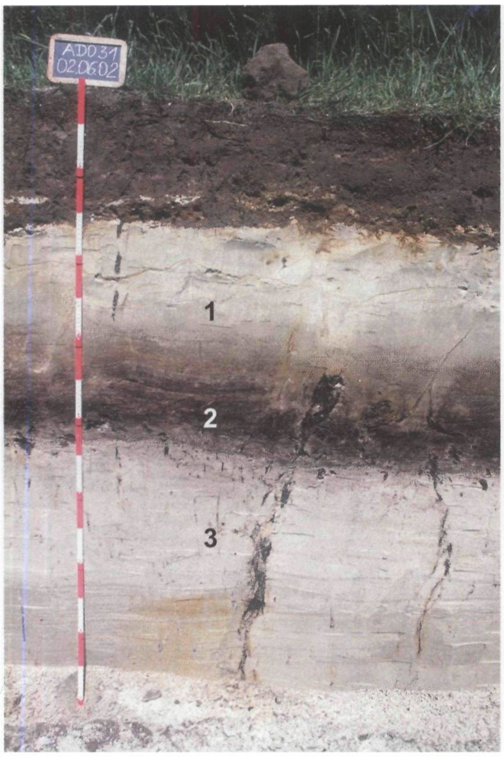
c.

d.

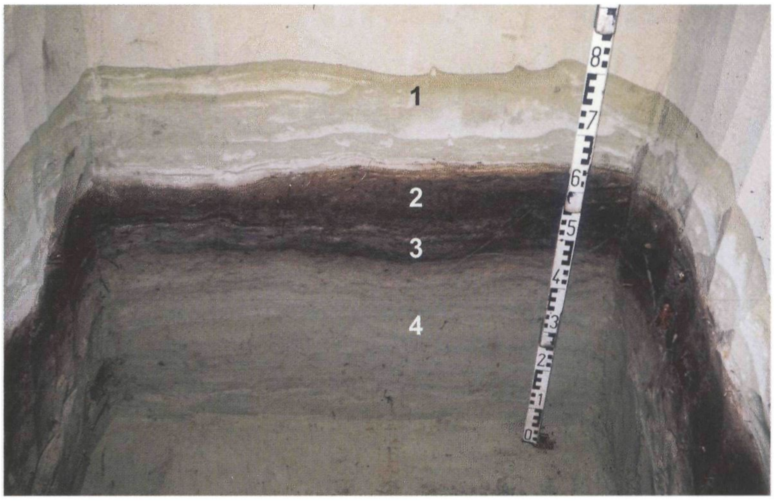
e.



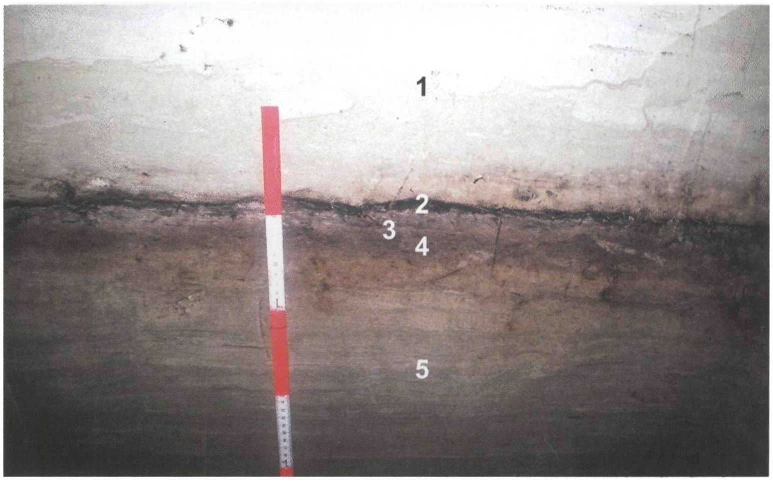
f.



h.



g.



i.

Fig. 4. Photos of the profiles investigated (photos: K. Kaiser); a. All-up view of profile ADO 39: 1 – peat, 2 – aeolian sand with (Relic-) Gleyic Podzol (gleyic properties masked), 3 – buried Lateglacial soil (weakly podzolized Histic Gleysol), 4 glaciolacustrine sand; b. Close-up view of the buried Lateglacial soil in Profile ADO 39: 1 – fBsh2 horizon (aeolian sand), 2 – foM horizon (aeolian sand), 3 – fH horizon (peat), 4 – fAhe horizon (glaciolacustrine sand), 5 – fBh-rGr horizon (glaciolacustrine sand), 6 – frGr horizon (glaciolacustrine sand); c. All-up view of profile ADO 1: 1 – mor cover, 2 – aeolian sand with (Relic-) Gleyic Podzol, 3 – buried Lateglacial soil (weakly podzolized Histic Gleysol), 4 – glaciolacustrine sand; d. Close-up view of the buried Lateglacial soil in Profile ADO 1: 1 – foM horizon (aeolian sand), 2 – fH horizon (peat), 3 – fAhe horizon (glaciolacustrine sand), 4 frGr horizon (glaciolacustrine sand); e. Close-up view of the buried Lateglacial soil in Profile ADO 40 (Histosol): 1 – fGo-oM horizon (aeolian sand), 2 – fGo-Hr horizon (peat), 3 – fF-Gr1 (gyttja), 4 – fF-Gr2 (gyttja), 5 – fGr (glaciolacustrine sand); f. All-up view of profile ADO 42: 1 – mor cover, 2 – aeolian sand with (Relic-) Gleyic Podzol, 3 – buried Lateglacial soil (weakly podzolized Dystric Arenosol), 4 – glaciolacustrine sand; g. Close-up view of the buried Lateglacial soil in Profile ADO 42: 1 – rGo horizon (aeolian sand), 2 – fAeh1 horizon (aeolian sand), 3 – fAeh2 horizon (aeolian sand), 4 – frGr horizon (glaciolacustrine sand); h. All-up view of profile ADO 31: 1 – aeolian sand with (Relic-) Ferric Gleysol, 2 – buried Lateglacial soil with rGo-fAh and fAh horizon (Gleysol), 3 – glaciolacustrine sand; i. Close-up view of the buried Lateglacial soil in Profile ADO 7 ('Nano'-Podzol): 1 – rGr horizon (aeolian sand), 2 – fAeh horizon (glaciolacustrine sand?), 3 – fAhe horizon (glaciolacustrine sand?), 4 – fBh horizon (glaciolacustrine sand?), 5 – fGr horizon (glaciolacustrine sand).

Micromorphology

The option of a micromorphological characterisation of a buried soil was given only for the weakly podzolized Dystric Arenosol (ADO 42), which is situated in the highest position of the palaeotransect.

rGo horizon (200 - 244 cm, lower 15 cm)

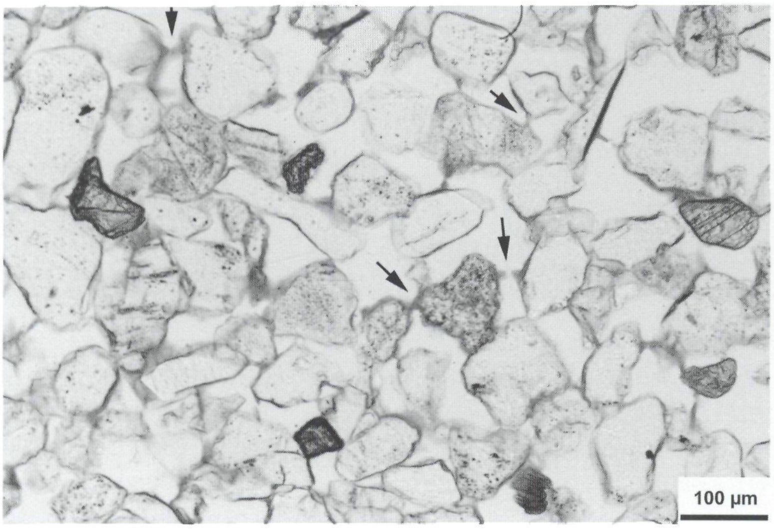
Mineral grains are subangular to rounded, only some angular. Grain size varies from 50 - 300 µm. Numerous grains are surrounded by a hem of oriented clay or linked by concave yellow-brown clay bridges (Fig. 5a). Organic matter is absent above 10 cm from the upper boundary of the fAeh1 horizon. A small amount of organic matter was detected in 2 - 5 cm above the fAeh1 horizon. Longitudinal plant residues are layered horizontally. The degree of decomposition of the organic matter is low. The sharp boundary to the fAeh1 horizon lies within 0.5 cm.

fAeh horizons (244 - 257 cm)

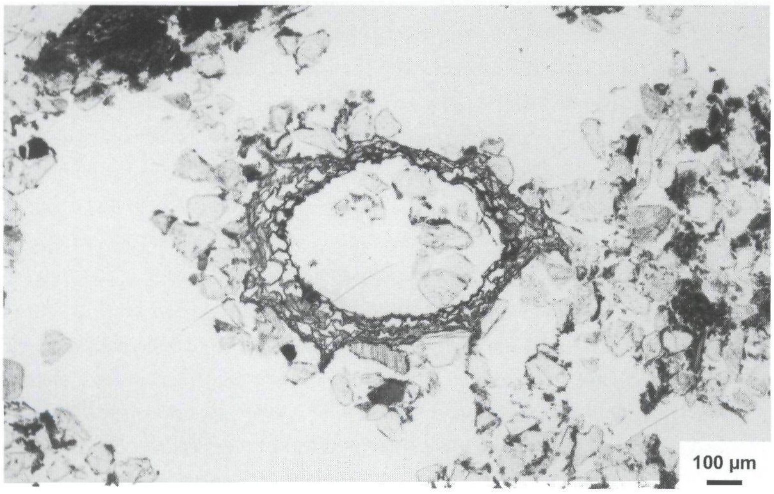
Mineral grains are subangular to rounded, only some angular. Grain size varies between 60 - 200 µm in the upper 5 cm and between 60 - 150 µm in the lower 15 cm. Translocation features are hardly detectable. Few minerals are surrounded by a hem of oriented clay (<10 µm). Longitudinal plant residues are layered horizontally (Fig 5b). Rounded peds of reddish brown organic matter (diameter ca. 100 µm) occur particularly in the lower 5 cm. These peds show a high degree of decomposition, whereas roots and remains of roots are weakly deformed (Fig. 5c). Nearly no fine mineral components are present. Biotites are weakly bleached.

frGr horizon (257 - 265 cm)

Layers of coarser fractions (100 - 200 µm, partially up to 250 µm) alternate with layers of finer fractions (50 - 100 µm). The thickness of each layer is 5 mm. The grains are angular or subrounded, some rounded. Nearly no fine material is present.



a.



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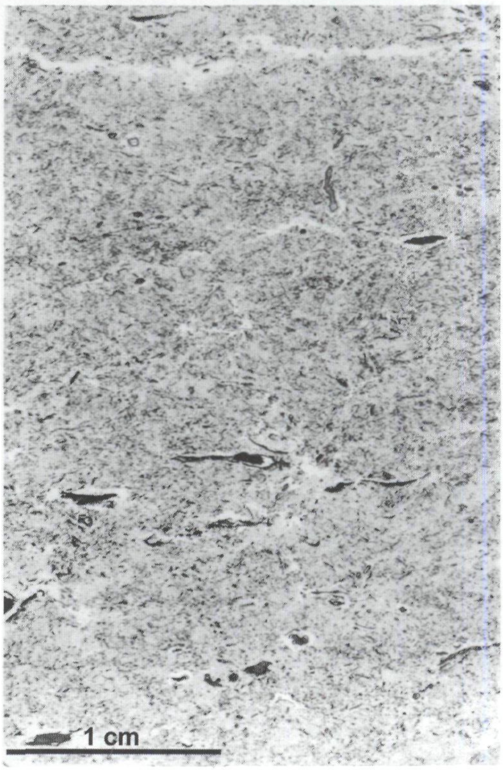

b.

Fig. 5. Photomicrographs of profile ADO 42 (photos: P. Kühn); a. Photomicrograph of the Go horizon at 238 cm, plane polarized light. Black arrows point at concave yellow-brown clay bridges (gefuric b-fabric); b. Thin section of the fAeh1 horizon at 248 cm. Almost horizontal layering of longitudinal organic residues; c. Photomicrograph of the fAeh1 horizon at 250 cm, plane polarized light. Perpendicular section of a root in the centre of the photo. The root hardly shows deformation or decomposition effects.

Interpretation

Distinct clay illuviation features can not be formed under near groundwater conditions. Therefore, oriented clay-hems around minerals and concave clay bridges in the rGo horizon are formed after the groundwater table has dropped. The sharp boundary between the fAeh1 and rGo horizon is marked by a high amount of coarse grains in the rGo horizon. We assume that prior to the main aeolian activity moderate aeolian input led to a layered sand accumulation in the upper part of the fAeh horizons. The characteristic horizontal layering of longitudinal plant tissues alternating with banded sand layers can be interpreted as synsedimentary soil formation of the fAeh horizons. Otherwise the layering should have been homogenised by bioturbation. In the fAeh horizons, the main processes of soil formation were enrichment of organic matter and to a minor degree its humification. Weak bleaching features of Biotite imply a weak silicate weathering. With increasing aeolian activity the amount of sand and coarser grains increases. Therefore, a rapid change of the palaeoenvironmental site conditions can be inferred from the sharp boundary of the fAeh1 to the overlying rGo horizon. The boundary between the fAeh2 and the underlying frGr horizon is sharp as well. The lamination of the frGr horizon indicates low bioturbation due to groundwater influence.

Geochronology

Radiocarbon dating

All samples were taken from the fH horizon in ADO 39 (Table 3, Figs 2, 3). Hv-24639 yielded an age on wood of 10,680 ± 60 BP (= 12,810 - 12,700 cal BP). Poz-3207 and Poz-2212 gave ages on macro remains of 10,030 ± 200 BP (11,960 - 11,250 cal BP) and 10,280 ± 200 BP (= 12,400 - 11,700 cal BP), respectively. The high standard deviation of the latter is caused by a relatively small amount of organic carbon (each with 0.1 mg C_{org}). Nevertheless, both dates are considered to be reliable (pers. comm. T. Goslar, Poznan). Taking the standard deviations into account, the data comprise a time interval from the early Younger Dryas to the early Preboreal (10,740 - 9,830 BP; Björck et al., 1998).

Table 3. Radiocarbon datings from the buried Lateglacial soil of profile ADO 39 (C = conventional ^{14}C date, A = AMS ^{14}C date). The samples were extracted 120 cm below the limit of the minerogenic soil. The calibrated ages were calculated using the software Calib Rev4.4.2 (Stuiver & Reimer, 2005).

Lab. No.	^{14}C age (years BP)	Age calibrated (years BP)	Material dated	δ^{13}C (o/oo)
Hv-24639 (C)	10,680 ± 60	12,810 - 12,700	coniferous wood (probably from *Pinus*)	-25.9
Poz-2212 (A)	10,030 ± 200	11,960 - 11,250	birch fruits (probably from *Betula pubescens*)	-58.2
Poz-3207 (A)	10,280 ± 200	12,400 - 11,700	remains of the moss *Polytrichum* spec.	-32.9

Luminescence dating

Twelve samples were taken from the aeolian sand of profile ADO 42 (Fig. 2, Table 4). Sample ADO 42-1 from only 18 cm below the surface was dated to 3.35 ± 0.23 ka. This young age could be a result of post sedimentary mixing with surface material due to bioturbation. Ages of the underlying aeolian sand scatter considerably and do not increase consistently towards the bottom (samples ADO 42-2 to ADO 42-12). Concerning the age errors the sedimentation took place between the Late Pleniglacial and the Early Holocene. To check, whether the scatter in age could be a result of insufficient bleaching of the luminescence signals during short distance transport further experiments have been carried out. A 'dose recovery' test carried out for sample ADO 42-5, which had been completely bleached before irradiation in the laboratory and OSL measurement, thus simulating ideal conditions at deposition. The test showed, that the relative standard deviations of the equivalent dose distributions (Table 4) for most samples are well within the range of 6% as measured for the test sample. Furthermore, the detailed investigation of the palaeodose distribution of the sample with the highest equivalent dose value (ADO 42-4) gave no evidence for a significant population of grains which had not been completely bleached during transport and deposition, and therefore would cause an overestimation of the palaeodose and hence the age (Hilgers, 2006). Insufficient bleaching is thus probably not the reason for the high scatter in OSL ages, more likely the problem is caused by dose rate determination. To check the reliability of the NAA results, gamma spectrometry measurements have been carried out for several samples of ADO 42 and ADO 39 (Table 4). In ADO 42-4, ADO 39-1, and ADO 39-3, dose rates and hence ages differ significantly. In ADO 42-12, the difference is lower and thus the mean of both dose rate values was finally used for age calculation.

Because of these difficulties, OSL dates should be interpreted carefully. The aeolian sand was probably deposited within a very short period. The weighted mean of all OSL ages of the samples ADO 42-2 to ADO 42-12 is 12.36 ± 0.84 ka. This date coincides well with the Younger Dryas period (11,500 - 12,650 cal BP, Björck et al, 1998; 11,590 - 12,680 cal BP, Litt et al., 2001).

Considering only samples ADO 42-12 and ADO 42-2 from the base and the top of the aeolian sand, there is evidence to suggest that the palaeosol was buried during the Younger Dryas-Preboreal transition. OSL ages of 11.0 ± 0.9 ka and 10.9 ± 0.8 ka

Table 4. Parameters and results of the dose rate calculation and palaeodose estimation, and the resulting OSL-ages (analysis: A. Hilgers).

Lab. code	**Sample**	**H_2O[1]** (%)	**Depth** (cm)	**Uranium** (ppm)	**Thorium** (ppm)	**Potassium** (%)	**Dose rate** (Gy/ka)	**Equivalent dose** (Gy)	rel. s.d.[2]	**OSL-age** (ka)
C-L0680	AD039-1	4.7 ± 0.1	62	0.50 ± 0.06	1.79 ± 0.09	1.12 ± 0.06	1.46 ± 0.09	15.8 ± 0.8	7	10.87 ± 0.85
C-L0681	AD039-2	7.3 ± 0.1	100	0.74 ± 0.06	3.00 ± 0.15	1.21 ± 0.06	1.64 ± 0.09	17.5 ± 0.9	5	10.70 ± 0.79
C-L0682	AD039-3	12.8 ± 3.7	124	1.63 ± 0.08	4.61 ± 0.23	1.40 ± 0.07	2.03 ± 0.11	21.0 ± 1.1	12	>10.3
C-L0683	AD039-4	6.2 ± 0.1	147	0.88 ± 0.05	2.65 ± 0.13	1.28 ± 0.06	1.70 ± 0.09	20.3 ± 1.0	7	>11.9
C-L0666	AD042-1	5.2 ± 1.3	18	0.63 ± 0.05	1.88 ± 0.09	0.56 ± 0.03	1.02 ± 0.05	3.41 ± 0.17	11	3.35 ± 0.23
C-L0667	AD042-2	4.8 ± 1.3	38	0.64 ± 0.05	2.63 ± 0.13	0.97 ± 0.05	1.43 ± 0.07	15.5 ± 0.8	10	10.86 ± 0.78
C-L0668	AD042-3	2.8 ± 0.3	50	0.45 ± 0.05	2.18 ± 0.11	0.98 ± 0.05	1.36 ± 0.07	18.1 ± 0.9	11	13.32 ± 0.97
C-L0669	AD042-4	3.7 ± 0.2	72	0.50 ± 0.06	2.54 ± 0.13	0.95 ± 0.05	1.35 ± 0.07	19.5 ± 1.0	7	14.49 ± 1.07
C-L0670	AD042-5	3.8 ± 0.1	95	0.53 ± 0.06	1.98 ± 0.10	1.00 ± 0.05	1.36 ± 0.07	17.9 ± 0.9	6	13.20 ± 0.97
C-L0671	AD042-6	3.9 ± 0.1	116	0.56 ± 0.06	2.25 ± 0.11	0.95 ± 0.05	1.34 ± 0.07	16.8 ± 0.8	6	12.57 ± 0.94
C-L0672	AD042-7	4.9 ± 0.1	140	0.79 ± 0.06	2.72 ± 0.14	1.02 ± 0.05	1.48 ± 0.07	18.2 ± 0.9	6	12.31 ± 0.88
C-L0673	AD042-8	3.8 ± 0.2	157	0.46 ± 0.05	1.67 ± 0.08	1.01 ± 0.05	1.32 ± 0.07	16.2 ± 0.8	6	12.31 ± 0.91
C-L0674	AD042-9	4.3 ± 0.2	181	0.40 ± 0.04	1.68 ± 0.08	0.95 ± 0.05	1.24 ± 0.07	16.3 ± 0.8	6	13.11 ± 0.99
C-L0675	AD042-10	3.5 ± 0.2	200	0.38 ± 0.06	1.71 ± 0.09	0.92 ± 0.05	1.21 ± 0.07	16.3 ± 0.8	6	13.45 ± 1.05
C-L0676	AD042-11	3.4 ± 0.2	218	0.37 ± 0.06	1.29 ± 0.06	0.94 ± 0.05	1.20 ± 0.07	14.9 ± 0.7	6	12.50 ± 0.98
C-L0677	AD042-12	4.1 ± 0.2	238	0.64 ± 0.05	2.79 ± 0.14	1.05 ± 0.05	1.46 ± 0.07	16.4 ± 0.8	6	11.27 ± 0.81
C-L0678	AD042-13	11.9 ± 1.4	255	1.63 ± 0.08	5.87 ± 0.29	1.06 ± 0.05	1.79 ± 0.09	19.5 ± 1.0	5	>10.9
C-L0679	AD042-14	1.9 ± 0.3	280	0.64 ± 0.05	1.98 ± 0.10	0.98 ± 0.05	1.32 ± 0.07	17.2 ± 0.9	6	>13.0

1 Actual water content at the time of sampling in October 2000.

2 Relative standard deviation in % of the weighted mean.

are similar to the OSL dates 10.9 ± 0.9 and 10.7 ± 0.8 ka obtained for the aeolian sand of profile ADO 39 (samples ADO 39-1, ADO 39-2; Figs 2, 3). This similarity could indicate an aeolian phase of widespread extent. But taking the OSL age for sample ADO 39-1 of 12.6 ± 0.8 ka into account, which is based on the gamma spectrometry results for dose rate calculation, a covering of the palaeosol during the Younger Dryas seems similarly possible.

The interpretation of the OSL ages from the glaciolacustrine sands below the buried soils (samples ADO 42-13, ADO 42-14, ADO 39-3, ADO 39-4) is difficult as well, predominantly caused by difficulties in dose rate estimation. Because there are two problems here, which cannot be solved satisfactory, the ages should be regarded as minimum ages. One problem are considerable changes in the water content of the sediment. The water content in the pore volume has to be considered for dose rate calculation, because radiation attenuation is enhanced with rising moisture content in the sediment. The four samples discussed here originate from frGr horizons (Figs 2, 3, Table 4). Higher water contents then the actual measured have to be assumed, especially for the time span after the Holocene transgression of the Baltic Sea (Lampe, 2005) and before drainage improvements and groundwater conveying caused a drop of the groundwater level in the last century. Therefore, dose rate values and OSL dates (Table 4) have been calculated assuming a water content of up to 30% for at least 6,000 years. Further difficulties are radioactive disequilibria in the uranium decay series. The occurrence of an uranium disequilibrium, caused by the geochemical mobility of uranium and its daughter isotopes, is a well-known problem in waterlogged sediments. In contrast, it is rather unlikely in aeolian deposits (Krbetschek et al., 1994). Disequilibria in the U decay chain occurring in connection with the sedimentation in lacustrine basins often result in uranium excess (Krbetschek et al., 1994). As only the concentration of the parent nuclide of the ^{238}U decay chain is determined by NAA, which was predominantly applied in this study to measure the radionuclide concentration in the sediments, the presence of a disequilibrium could not be investigated. An uranium excess would cause an overestimation of the U content by NAA thus result in too young ages. Therefore, as long as the glaciolacustrine sediments are not checked for radioactive disequilibria in detail, the OSL ages are just minimum age estimates. First analyses using gamma-spectrometry to verify the NAA results illustrate the difficulties in radionuclide determination (Table 4). Based on the knowledge of the regional landscape history, the glaciolacustrine sands were deposited presumably considerable time before the onset of the Younger Dryas (glaciolacustrine sedimentation: ca. 14,000 - 13,000 BP = >15,200 cal BP; Kaiser, 2001).

Recapitulating, the OSL dating at both sites is problematically. Especially the determination of the dose rate suffers from various unpredictability. Thus, the OSL data just produce a rough framework but cannot resolve the chronostratigraphy with satisfying accuracy.

Botany

Dendrology

In total 24 samples of large wooden remains originating from ADO 1, ADO 31, and ADO 39 were analysed (det. by H. Süß, Potsdam). Four samples could not be identified. The samples from ADO 1 and ADO 39 have been collected from the plans. They were part of the fH horizons bordering immediately to the aeolian sands. The wood was rotten and infiltrated by fungal hyphae. The trunks were ovally deformed by the pressure of covering sands.

In ADO 39, roots, trunks, stumps, and branches of different tree species were identified (8× *Betula*, 3× conifer – probably *Pinus*, 1× *Pinus*; Fig. 3). An incompletely excavated trunk of *Betula* was 290 cm long and 12 cm thick.

In ADO 1, besides smaller objects (4× *Pinus*, 1× conifer – probably *Pinus*, 1× *Populus*; Fig. 3), an incompletely excavated trunk of Pinus (240 cm long, 22 × 14 cm thick) was discovered.

At ADO 31 two vertical roots of *Alnus* were found in the buried soil. Based on the low depth of the buried soil and the postglacial re-immigration history of *Alnus* in this area (Kaffke & Kaiser, 2002), the roots certainly originate from a Holocene stand of *Alnus* at this site (secondary position).

Pollen analysis

Pollen samples from the surface of the buried soil were taken at four sites (ADO 1, ADO 7, ADO 31, ADO 39; Table 5). The samples thus represent the vegetation towards the end of the formation of the soil. In ADO 39 additionally one sample (ADO 39-3) was taken from the central part of the only 2 cm thick fH horizon. Pollen sums are low (n = 86 - 181) because of the very low pollen concentration. Pollen is well preserved in ADO 31-5, ADO 39-2, and ADO 39-3, markedly corroded in ADO 1-9, and strongly corroded in ADO 7-3.

Pinus pollen dominates all samples except for ADO 7-3. *Betula* pollen occurs in accordingly low percentages. No other tree

Table 5. Results of pollen analysis (analysis: M. Theuerkauf).

Pollen types	**ADO 39-2**	**ADO 39-3**	**ADO 1-9**	**ADO 7-3**	**ADO 31-5**
	120 - 120.5 cm	121 - 121.5 cm	195 - 196 cm	205 - 206 cm	76 - 77 cm
			(%)		
AP					
Pinus total	85.0	84.9	74.0	45.7	89.7
Betula total	14.0	10.5	25.2	53.7	9.3
NAP-upland					
Artemisia	0.9	0.0	0.8	0.0	0.0
Chenopodiaceae	0.0	2.3	0.0	0.0	0.0
Ranunculus acris type	0.0	0.0	0.0	0.0	1.0
Rumex acetosella type	0.0	1.2	0.0	0.0	0.0
Anthemis type	0.0	1.2	0.0	0.0	0.0
Circaea	0.0	0.0	0.0	0.6	0.0
Sum AP	99.1	95.3	99.2	99.4	99.0
Sum NAP-upland	0.9	4.7	0.8	0.6	1.1
Pollensum [n]	107	86	123	181	97
NAP divers, Types					
Poaceae	1.9	0.0	1.6	0.6	3.1
cf. Poaceae	0.0	1.2	0.0	0.0	0.0
Cyperaceae	4.7	0.0	12.2	0.6	15.5
Caryophyllaceae undiff.	4.7	0.0	0.0	0.6	0.0
Salix	0.0	1.2	0.8	0.6	0.0
Polypodiales monolet incomplet	98.1	183.7	0.8	131.9	0.0
Sphagnum	0.9	0.0	2.4	0.6	1.0
Microdalyellia spec. (Type 353)	0.0	0.0	0.0	0.0	1.0
Filinia spec.	0.0	1.2	0.0	0.0	0.0
Spirogyra spec. (Type 315)	3.7	1.2	1.6	0.0	4.1
Coniferious wood	15.9	280.2	0.0	0.0	0.0
Gelasinospora spores (Type 1)	8.4	12.8	1.6	0.6	0.0
Indet.	0.9	0.0	8.1	16.6	0.0
Exotic spores	143.9	157.0	179.7	62.6	107.2

pollen was found. Pollen from upland herbs (NAP-upland) are rare (<1%), except for ADO 39-3. Sample sites were thus probably densely forested, mostly by *Pinus sylvestris*. *Betula* (probably tree birches *Betula pubescens/pendula*) played only a minor role. More open forests might be assumed at an earlier stage because of higher percentages of NAP-upland pollen (Chenopodiaceae, *Rumex acetosella* type, and *Anthemis* type) in ADO 39-3. However, the absence of other typical indicators of open forests (e.g. *Artemisia*, *Juniperus*) does not support this assumption.

On the other hand, macrofossil analysis (see further) indicates that the buried soils developed partly under open forest vegetation. Pollen samples from relatively open sites reflect vegetation composition on a larger scale with a diameter of 100 - 1000 m (e.g. Jacobson & Bradshaw, 1981). As also indicated in ADO 40 (see below), *Pinus* probably dominated in such a larger area. In pollen samples ADO 31-5, ADO 39-2, and ADO 39-3 *Pinus* dominates while only macrofossils of tree-birches were found. The vegetation might thus be interpreted as small stands of scattered tree birches in a forest dominated by *Pinus*. The dominance of *Pinus* and low NAP-upland percentages points to pollen spectra dating into the late Allerød or the Allerød-Younger Dryas transition as known from other Lateglacial sequences in the region (e.g. de Klerk, 2002).

Cyperaceae pollen was found in high percentages in ADO 1-9, ADO 31-5, and ADO 39-2, but hardly occurs in ADO 7-3 and ADO 39-3. Poaceae pollen is similarly distributed, but less abundant. Polypodiales monolet incomplet spores have very high percentages in ADO 7-3, ADO 39-2, and ADO 39-3 (98.1 - 183.7%), but hardly occur in ADO 1-9 and ADO 31-5 (0.8% and 0.0%). At ADO 1 and ADO 31 vegetation was probably rich in grasses and sedges, at ADO 7 and ADO 39 rich in ferns. At a later stage grasses and sedges became more important at ADO 39. *Sphagnum* spores were most abundant in ADO 1-9 (2.4%). Only single spores occurred in ADO 39-2, ADO 7-3, and ADO 31-5. No *Sphagnum* spores were found in ADO 39-3. Here however, the occurrence of *Sphagnum* is shown by macrofossil analysis (see below). In all samples except for ADO 7-3 non-pollen palynomorphs that indicate open water were detected. Spores of *Spirogyra* spec. occurred in four samples, *Microdalyellia* spec. and *Filinia* spec. each in one sample (Table 5). ADO 7 was probably much drier than the other sites, explaining the bad preservation of pollen and macrofossils.

Additional palynological data are available from profiles ADO 40 and ADO 39: samples of pollen diagram ADO 40 were already extracted in 1999 by coring (Kaiser, 2001). Thus small deviations in depth and thickness of the buried sediments are to consider. Samples were taken from peat and gyttja in 223 - 263 cm below the surface (Fig. 6). The progression of tree pollen types resembles that of other Lateglacial sequences in the region (e.g. de Klerk, 2002). The diagram comprises Lateglacial vegetation zones from the Oldest Dryas to the Younger Dryas. The buried soil surface is represented by a peat dating into the late Allerød.

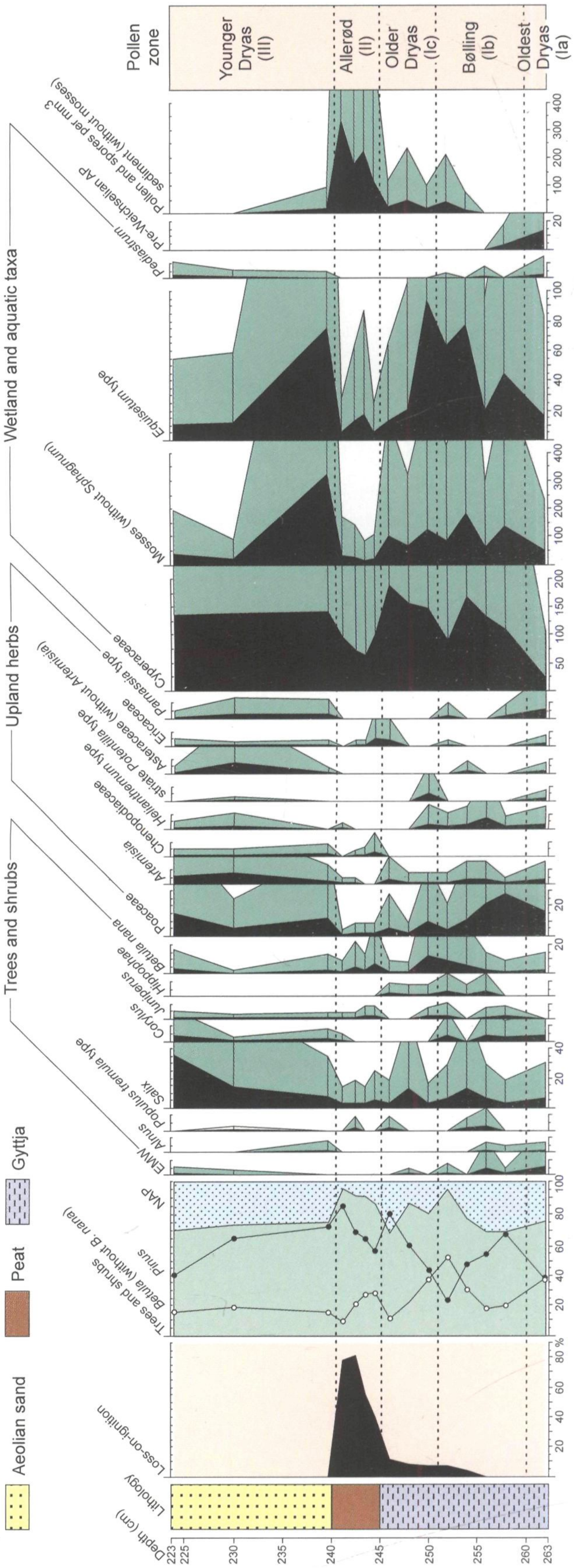

Fig. 6: Pollen diagram ADO 40 representing selected taxa based on the upland pollen sum with AP and shrubs (analysis: W. Janke). Exaggeration of microfossil curves 5x. (Pollen zones after Firbas, 1949).

Pollen diagram ADO 39-S was taken in the south of trench ADO 39 (Figs 3, 7). It represents a (Relic-) Gleyic Podzol near the present surface, covered by a peat layer and mor. Pollen analysis was carried out to (post) date the sandy aeolian substrate of the soil. Pollen analysis in soils faces major problems (e.g. Tipping et al., 1999). However, the diagram reflects typical features of the regional pollen stratigraphy, e.g. the first *Ulmus*-decline marking the end of the Atlantic period, and the beginning of continuous presence of *Fagus* and *Carpinus*. Despite a length of only 60 cm, the diagram comprises several Holocene pollen zones described from the much longer peat profile ADP of the Altdarss area (Kaffke & Kaiser, 2002) as well as from other profiles of the surroundings (e.g. Fukarek, 1961; Kaiser et al, 2000; Lampe & Janke, 2004). Pollen samples from the lower sandy part are attributed to the Atlantic. The topping peat and mor date into the Subboreal and Subatlantic, respectively.

Macrofossil analysis

Samples ADO 1 and ADO 39 were dominated by *Sphagnum* sect. *Acutifolia* leaves and branches, and undeterminable *Sphagnum* remains (Table 6). Most respective taxa indicate wet, nutrient poor, and acidic conditions (Frahm & Frey, 1992). Seeds of *Empetrum nigrum* were found in both samples, *Polytrichum strictum* only in ADO 1. *Empetrum nigrum* indicates acidic and nutrient poor conditions (Oberdorfer, 1994), *Polytrichum strictum* wet and acidic conditions with a vegetation rich in *Sphagnum* (Frahm & Frey, 1992).

At ADO 39 pieces of wood were identified as *Betula*. Fruits of *Betula* (mainly *Betula pubescens/pendula*) indicate the presence of *Betula* trees. Charred seeds of *Empetrum nigrum* indicate fire at ADO 1 and ADO 39.

Sample ADO 31 is dominated by woody macrofossils. *Betula* bud scales were recorded. *Betula* (trees or dwarf shrubs) was probably growing at the site during the genesis of the buried soil. Diaspores of *Carex lasiocarpa* and *Menyanthes trifoliata* indicate wet, occasionally flooded, and moderately nutrient rich conditions (Oberdorfer, 1994) with a higher pH value than it is indicated at ADO 39 and ADO 1. They also are light demanding plants (Ellenberg, 1992), allowing only scattered trees or dwarf shrubs. Diaspores of *Potamogeton* species indicate the presence of long time flooded areas, e.g. small ponds (Oberdorfer, 1994).

Sample ADO 7 is dominated by woody macrofossils partly from *Betula*. The high amount of undeterminable tissue indicates a high degree of decomposition. Reconstruction of the vegetation during the genesis of the buried soil is fragmented possible only. However, the high degree of decomposition indicates drier conditions at ADO 7 compared to the other sites.

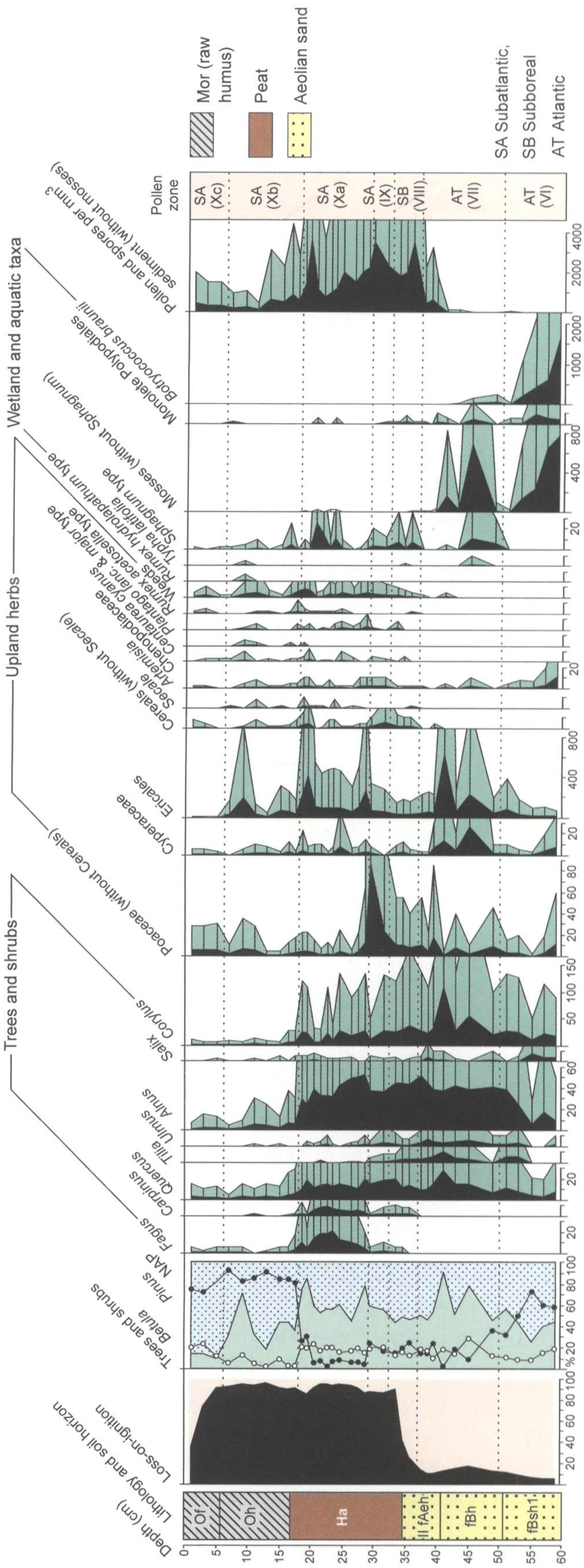

Fig. 7. Pollen diagram ADO 39-S representing selected taxa based on the upland pollen sum with AP and shrubs (analysis: W. Janke). Exaggeration of microfossil curves 5x. (Pollen zones after Firbas, 1949).

Palaeoenvironmental synthesis

First of all it has to be clarified whether the palaeosols belong to an isochronous surface. All 42 investigated profiles show an uniform succession of basal glaciolacustrine sand, intermediate palaeosol, and aeolian sand on top. The aeolian cover is memberless, except for thin oM horizons indicating soil erosion at the beginning of the aeolian phase. Furthermore, Holocene

Table 6. Results of macrofossil analysis; a. Counting of diaspores and bud scales; b. Share of tissue types in the sample volume (estimation grades: + = >>1%, 1a = >1%, 1b = 1 - 3%, 2 = 4 - 9%, 3 = 10 - 24%, 4 = 25 - 49%, 5 = 50 - 79, 6 = 80 - 100%; analysis: A. Barthelmes).

Macrofossils: Counting	**ADO 39**	**ADO 1**	**ADO 31**	**ADO 7**
	120 - 121 cm	195 - 196 cm	76 - 77 cm	205 - 206 cm
		(number)		
Betula cf. nana fruit	2	-	-	-
Betula pubescens/pendula fruit	31	-	-	-
Juncus spec. seed	1	-	-	-
Sphagnum fuscum leaf of stem	2	-	-	-
Empetrum nigrum seed	9	-	-	-
Empetrum nigrum part of a seed	11	3	-	-
Empetrum nigrum anther	-	1	-	-
Empetrum nigrum seed (burnt)	-	8	-	-
bud scale indet.	-	5	2	-
Salix spec. bud scale	-	2	2	-
Betula spec. bud scale	-	-	9	-
Carex lasiocarpa utriculus	-	-	11	-
Menyanthes trifoilata seed	-	-	11	-
Potamogeton spec. endocarp	-	-	2	-
Carex tricarpellate seed	-	-	4	-

a.

Macrofossils: Share of tissue types	**ADO 39**	**ADO 1**	**ADO 31**	**ADO 7**
	120 - 121 cm	195 - 196 cm	76 - 77 cm	205 - 206 cm
		(estimation grade)		
Polytrichum strictum	3	-	-	-
Sphagnum spec. leafs	3	-	-	-
Sphagnum spec. stem	1a	2	-	-
Sphagnum sect. *Acutifolia* leafs	4	4	-	-
Betula spec. wood	1b	1b	-	-
Burnt material	2	2	-	2
Betula spec. periderm	1b	2	1b	2
Wood	2	2	2	2
Wooden fibres	1b	2	-	2
Wooden radicels	1b	3	5	4
Radicels of herbaceous plants	2	2	2	2
Chitinous animal remains	1a	1a	1b	1b
Amorphously organic material	1b	1b	1a	3
Tissue indet.	2	3	3	3
Brown moss indet.	-	1b	2	-
Homalothecium nitens	-	1b	-	-
Epidermis of leafs of Cyperaceae	-	1a	-	-
Stems of mosses	-	1b	-	-
Pinus spec. periderm of roots	-	1a	-	-
Calliergonella cuspidata	-	-	1b	-
Periderm indet.	-	-	1a	-

b.

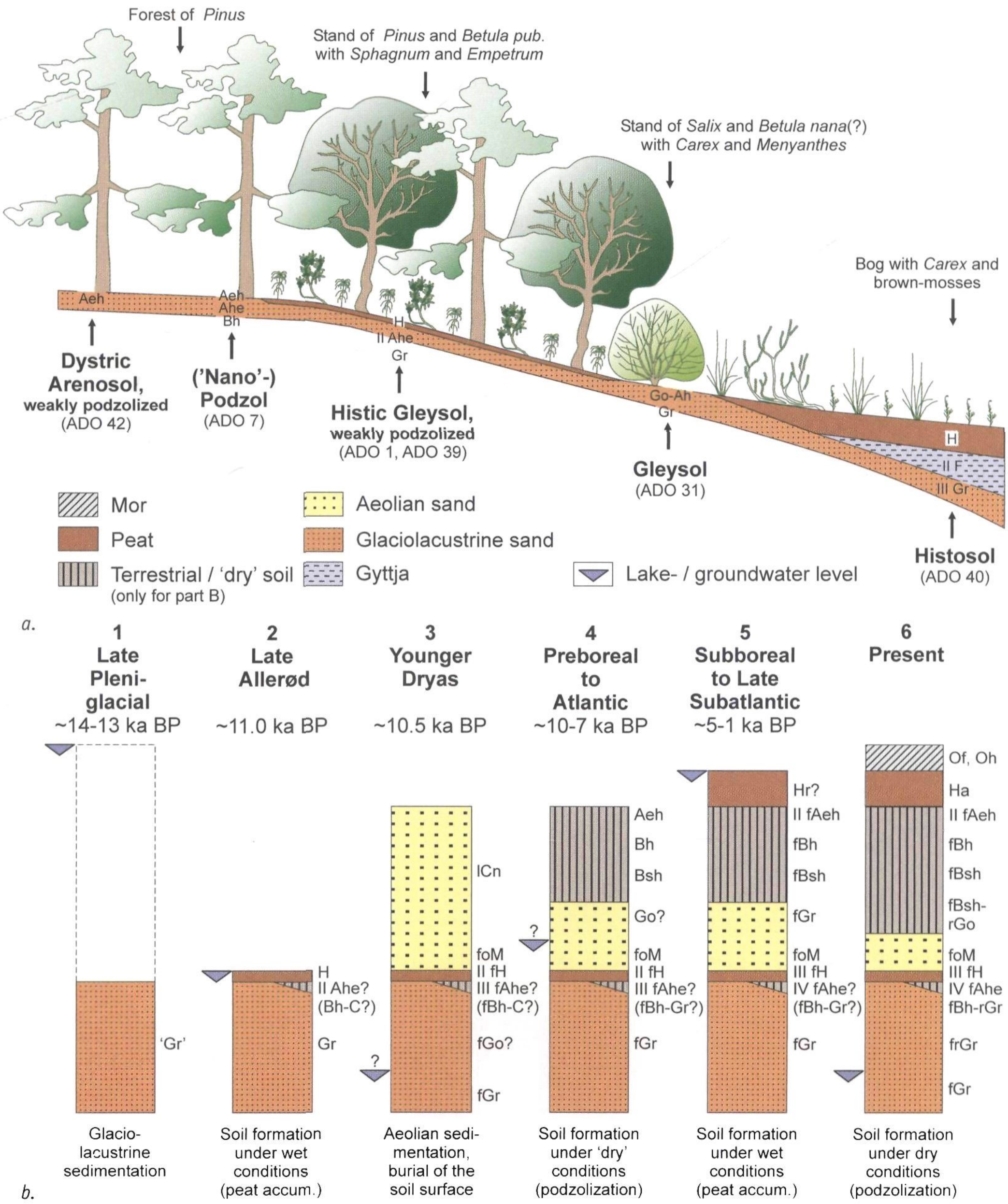

Fig. 8. Palaeoenvironmental synthesis; a. Reconstruction of late Allerød soils and vegetation; b. Genesis of profile ADO 39.

peats developed in some profiles that cover the aeolian sands. Direct or indirect dating of the buried soil was possible in all profiles, but the dates differ. Taking the standard deviations into account, the radiocarbon ages from profile ADO 39 comprise a time interval of early Younger Dryas to early Preboreal (10,740 - 9,830 BP; Björck et al., 1998). The upper part of the peat in profile ADO 40 was dated palynologically into the late Allerød. The high values of Pinus in profiles ADO 1, ADO 7, ADO 31, and ADO 39 also indicate a late Allerød age. The OSL ages of profiles ADO 39 and ADO 42 suggest that the palaeosols were covered by aeolian sands within the time interval Younger Dryas to Younger Dryas-Preboreal transition. The palynological results dated the buried soil surface into the late Allerød. This requires a rejuvenation of the radiocarbon dates, which possibly was caused by contamination with younger carbon (Wohlfarth et al., 1998; Turney et al., 2000). Based on the palynological dating, the rejuvenation could amount to 500 - 1000 years. To sum up, it seems given, that the palaeosols and the contact soil-aeolian sand, respectively, form an isochronous surface. The buried soil surface dates into the late Allerød, while the aeolian sands were deposited during the Younger Dryas. Thus, previous information given on a slight younger age of the palaeosol cover (Kaiser, 2004; Terberger et al., 2004) must be corrected.

The buried soils as well as the vegetation reconstructed can be arranged in a catena and a transect, respectively (Fig. 8a). It covers a range of 1.6 m in height except for ADO 7 (2.2 - 3.8 m a.s.l.; Fig. 2). ADO 42 is situated at the highest position. The fAhe horizons display soil formation under the weak influence of drifting sands. This buried Arenosol is the only soil profile which reflects unstable site conditions during soil formation. At site ADO 7, despite its lowermost position in the present-day transect, soil type ('Nano'-Podzol) and the high degree of decomposition of organic matter indicate that the soil was formed under relatively dry conditions. The profile was most probably displaced vertically after soil formation (possibly by dead-ice melting?).

Pedological and botanical results indicate the prevalence of moist, partly wet site conditions along the catena, except for ADO 7 and ADO 42. As shown by the dendrological results, sites ADO 1 and ADO 39 (Histic Gleysols) were forested by *Pinus* and *Betula*. Macrofossils of the ground vegetation, dominated by *Sphagnum* sect. *Acutifolia* and *Empetrum nigrum*, reflect wet, acidic, and nutrient poor conditions. The palynological results show, that the forests surrounding the sampling sites were dominated by *Pinus*. *Betula* played a role in the local vegetation on wet sites. Macrofossils of ADO 31 (Gleysol) indicate a wet, occasionally flooded site moderately rich in nutrients. This site was dominated by sedges and scattered stands of *Betula*. At ADO 40, the lowermost site, mire vegetation was reconstructed. It was dominated by brown-mosses and sedges, and probably surrounded by a belt of *Salix* and *Betula* (compare Bos et al., 2006).

A reconstruction of the soil formation and local landscape development through time is summarised with profile ADO 39 as an example (Fig. 8b). The initial stage was a large ice-dammed lake that was terminated during the Late Pleniglacial by a marked drop in the lake level. A high groundwater level during the Lateglacial resulted in the formation of peat. In the Younger Dryas, accompanied by a falling groundwater level, the peat surface was covered with aeolian sand. The podzolization of the aeolian sand occurred probably in the time interval from the Preboreal to the Atlantic. A significant rise in the groundwater level during the Subboreal and Subatlantic caused the formation of a peat layer. This groundwater rise was probably triggered by the Late Holocene transgression of the Baltic Sea (Lemke, 1998; Lampe, 2005). Recently, drainage improvements and water conveyance resulted in a falling groundwater level, drier site conditions with renewed podzolization, and the enforced formation of mor. Both regional landscape development and local site genesis of the Altdarss area is summarised in Fig. 9.

Discussion

The buried soil cover of the Altdarss area comprises a succession from relatively dry via moist to wet palaeosites. Profiles ADO 7 ('Nano'-Podzol) and ADO 42 (weakly podzolized Dystric Arenosol) are similar to the Usselo soil, as described from NW Europe and Poland (Manikowska, 1991; Hoek, 1997; Kasse, 1999; Kaiser & Clausen, 2005). Consequently, this record and the absence of a distinct silicate weathering (Bv/Bw horizon), attributed to the Finow soil, assign the Altdarss area to the 'province' of the Usselo soil. The overlying aeolian sands can be correlated with the 'Younger Coversand II' of NW Europe (Kasse, 1999; Schirmer, 1999; Koster, 2005).

In the last decade, several new locations with Lateglacial sandy palaeosols were found in NE Germany: close to the Altdarss site, Lateglacial buried palaeosols were also found in the Rostocker Heide and Barther Heide area, situated in the

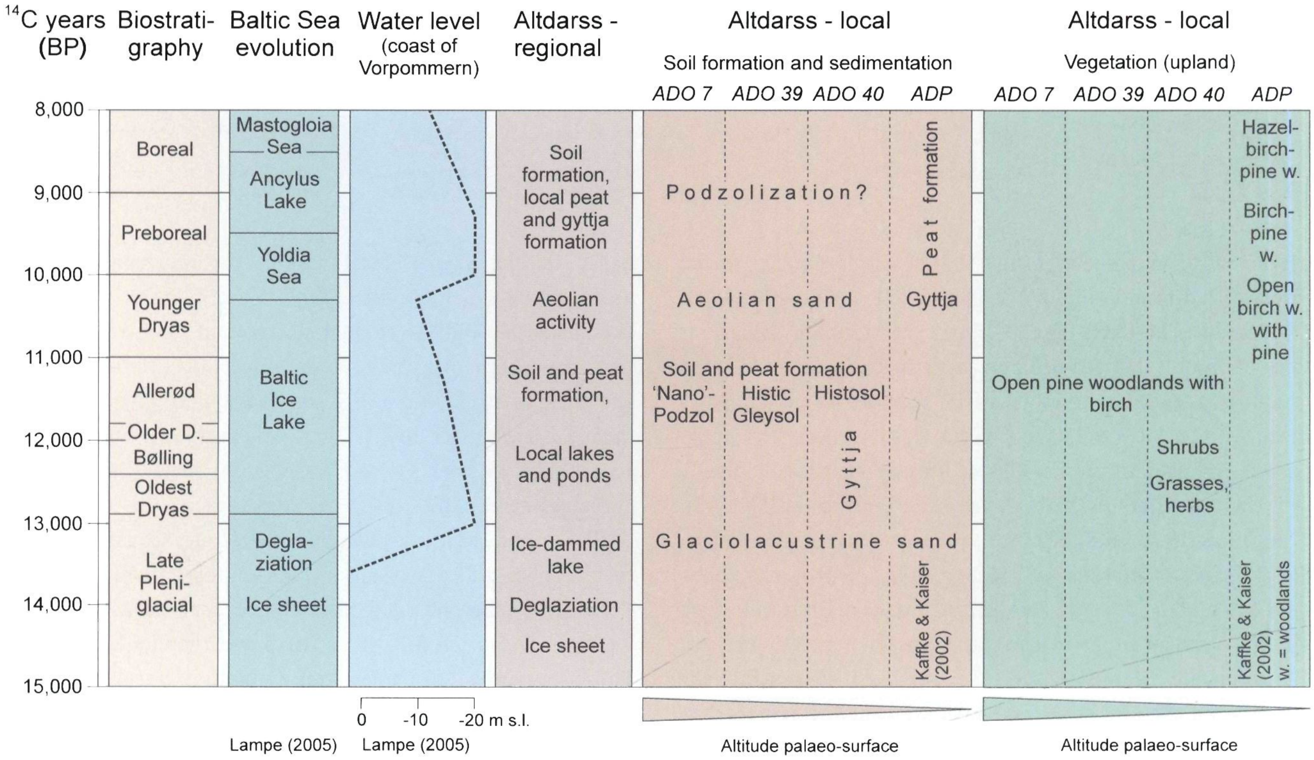

Fig. 9. Regional landscape development and local site genesis of the Altdarss area.

same glaciolacustrine basin. In the adjacent Barther Heide area (Fig. 1) three profiles consisting of basal glaciolacustrine silts and sands, intermediate gyttjas and covering aeolian sands were investigated (Kaiser, 2001). The gyttjas have been dated palynologically to the Bølling to *early* Younger Dryas period. Thus, both areas show the same geomorphic character during the termination of the Pleistocene.

Another well-known site is situated in the Rostocker Heide area. Since the late 19th century, stratigraphical investigations were repeatedly performed at the so-called 'Heidesandkliff', a cliff exposure of the Baltic Sea (studies summarised in Kaiser, 2001). A layer of lacustrine and telmatic sediments as well as a buried palaeosol (named as Usselo soil; Ludwig, 2002) covered by aeolian sands have been described. Parts of the buried soil cover were dated to the Allerød using pollen and macrofossils. In a peat layer, stumps and trunks of pine were found after extremely high tides of the Baltic Sea (Süß, 1968). A radiocarbon sample of pine was dated at 11,220 ± 250 BP and confirmed an Allerød age (Ludwig, 2002).

In the Ueckermünder Heide area, ca. 140 km further to the southeast, at the Late Palaeolithic Hintersee and Forst Mützelburg sites weakly developed Cambisols of the Finow soil type have been found (thickness of Bv horizons 7 - 14 cm; Bogen et al., 2003). The buried soils are developed from glaciolacustrine sands and covered by aeolian sands. According to the artefacts in the palaeosols (Ahrensburgian; usually assigned to the Younger Dryas) and OSL dating (weighted means of the aeolian sands: 12.12 ± 0.49 ka, n = 6, and 12.18 ± 0.57 ka, n = 3), a land surface has still existed during the *early* Younger Dryas (Allerød-Younger Dryas boundary acc. to Björck et al., 1998 = 12,650 cal BP; acc. to Litt et al., 2001 = 12,680 cal BP). Furthermore, a buried Bt horizon (Luvisol) with a thickness of about 15 cm was described in the vicinity of the Late Palaeolithic Forst Mützelburg site (Kühn, 2003). The OSL dating of the covering aeolian sand (9.59 ± 0.62 ka) suggests a Lateglacial age of the buried Bt horizon. Organic components, such as humus, charcoal or wood, are not preserved at these terrestrial sites and thus prevents a comparison with other radiocarbon dated studies.

A further complex of buried palaeosols has been recorded from Wolin Island, NW Poland (Borowka et al., 1986, 1999). Besides Histosols and Gleysols also soils of the Usselo type as well as the Finow type were reported. Pollen analysis and one radiocarbon age (11,590 ± 270 BP) date the buried soil cover into the Allerød.

This indicates that the border of present occurrences of the Usselo and Finow soil can be placed in between the Altdarss and the Ueckermünder Heide area. A dated occurrence of the Finow soil close to Krakow am See, Mecklenburg Lake District (10,938 ± 69 BP; Lorenz, 2006) suggests that the Altdarss site has a minimum distance of about 90 km to the area of Finow soil occurrences.

In NE Germany, the Finow soil (Bv horizons with thicknesses of 15 cm in maximum) is found within an area of ca. 250 × 150 km, with Krakow am See being the northernmost site. In depressions the Finow soil laterally corresponds to Gleysols at moist and peats or gyttjas at wet sites. Five radiocarbon ages between 11,800 ± 140 BP and 10,290 ± 385 BP date the Finow soil in the period Older Dryas to Younger Dryas-Preboreal transition (Bussemer et al., 1998; Schlaak, 1998; Schirmer, 1999; Lorenz, 2006).

Near Cottbus (Niederlausitz), Lateglacial soils were discovered during archaeological excavations. A pattern of buried soils consisting of ('Nano'-) Podzols, Gleysols, Histosols, and gyttjas have been reported from the lignite open-cast mine 'Cottbus-Nord' (Bittmann & Pasda, 1999; Pasda, 2002). The soils are buried by aeolian sands as well as by fluvial sands of the Spree River. Eight radiocarbon dates range from 11,000 ± 100 BP to 9,780 ± 75 BP. The majority of the ^{14}C-data cluster into the Younger Dryas. Trunks of pine up to a length of 9 m have been excavated at a wet site (Gleysol) dating between 10,310 ± 45 BP and 10,148 ± 84 BP. Pollen analysis indicates, that the trees were rooting into a soil horizon formed during the Allerød (Spurk et al., 1999). However, a precise pedological record including soil analysis was not performed here.

Furthermore, Lateglacial soils underlying a telmatic-lacustrine sequence were investigated in the lignite open-cast mine 'Reichwalde', ca. 50 km south of Cottbus (Friedrich et al., 2001). It is divided into an upper buried soil ('Nano-Podsol-Braunerde' = podzolized Cambisol), an intermediate layer of aeolian sand, and a lower buried soil (Arenosol). Both soils have a thickness of ca. 10 - 15 cm. The lower soil yielded a radiocarbon age of 12,100 ± 130 BP (Bølling). Some kilometres to the north, a buried podzolized Cambisol was recorded. It was radiocarbon dated to 11,400 ± 190 BP (Allerød). The authors suggested that during the Lateglacial a multiphase soil formation from Arenosols via Cambisols to ('Nano'-) Podzols took place at both sites. Close to the Reichwalde site, further occurrences of Lateglacial soils underlying dunes were reported from the lignite open-cast mines 'Scheibe' and 'Nochten' (11,800 ± 140 BP, without designation of a soil type; Mol, 1997).

Finally, records on the Lateglacial to Early Holocene soil development in the surroundings of oligotrophic mires are available from the Berlin region (Brande, 1995; Alaily & Brande, 2004).

Summarising, the records of Lateglacial buried palaeosols in NE Germany can be dated between Bølling and early Preboreal. Most dates cluster into the Allerød and Younger Dryas. The soils were covered by aeolian sands, deposited mainly during the Younger Dryas.

Lateglacial palaeosols underlying the 'Younger Coversand II' from NW Europe are dated into the same period. In the Netherlands, 23 radiocarbon dates from charcoal in various Usselo soil occurrences comprise a time interval of about

1,400 ^{14}C-years (11,440 ± 120 BP to 10,365 ± 200 BP) and cluster around 11,000 BP (Hoek, 1997). Records of the Usselo soil from NW Germany were in general assigned to the Allerød (e.g. Roeschmann et al., 1982). However, these records yielded radiocarbon ages between Older Dryas and Younger Dryas (e.g. Kaiser & Clausen, 2005). Thus, strictly speaking, the buried soils of Usselo and Finow type in Germany represents no Allerød soil but rather a Lateglacial soil.

Conclusions

In NE Germany, patterns of buried Lateglacial soils have been recorded repeatedly. For the Altdarss area a multidisciplinary analysis was carried out in order to document the features and lateral arrangement of the palaeosols. Here, the buried soil cover (ca. 3.4 km^2) comprises a catena from relatively dry ('Nano'-Podzol, Arenosol) via moist (Histic Gleysol, Gleysol) to wet conditions (Histosol). Soils of the dry sites are similar to the Usselo soil, as described from NW Europe and Poland. Both the analysis of single pollen samples and a pollen diagram indicate that the palaeosol cover dates into the late Allerød. The radiocarbon dates are 500 to 1,000 years to young, probably due to the contamination with younger carbon. OSL dates suggest that the covering by aeolian sands occurred during the Younger Dryas. Large wooden remains were found in the palaeosols (roots, trunks, stumps, and branches of *Pinus* and *Betula*). Pollen and macrofossil analyses enabled the reconstruction of a vegetation pattern typical for the late Allerød. The forests at relatively dry sites were dominated by *Pinus*, while at wet sites mosses, sedges and stands of *Betula* occurred.

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