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Colluvial sequences on till plains in Vorpommern (NE Germany)

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with 8 figures and 4 tables

Summary. This study presents a comparative discussion of colluvial sequences on till plains in Vorpommern (NE Germany). Soil erosion on till plains in Vorpommern is a widespread phenomenon, which has a disturbing effect on biotopes in the wet basins and valleys. A post-colluvial soil development is demonstrated in older colluviae of currently forested regions, contrary to younger colluviae of agricultural localities. Though too little observations are available to specify phases with intensified soil erosion in the history of landscape development of Vorpommern, at least the "Modern Period" is indicated as a phase during which many colluviae were formed.

1 *Introduction*

The state of knowledge of soil erosion by water in Vorpommern is rather differentiated. Various studies were carried out in the 1980's by the research group around Professor K. BILLWITZ at the Geographical Institute of the University of Greifswald which deal with the problem of sensibility of soils to erosion and its consequences and give recommendations for the agricultural practice (e.g. K. AMELANG 1987, N. AMELANG 1987, BILLWITZ 1986, BILLWITZ 1996) and adjacent areas (e.g. FRIELINGHAUS 1998, GLA M-V 1998). Only incidental studies deal with (pre)historic erosional processes in Vorpommern (e.g. KAISER et al. 2000, KAISER & JANKE 1998, AMELANG et al. 1983, SCHATZ et al. 1997); few studies deal with erosional processes on till plains in adjacent regions in NE Germany (e.g. DIECKMANN & KAISER 1998, BORK et al. 1998). Typical colluvial sequences on till plains from Brandenburg are presented by FRIELINGHAUS (1998), FRIELINGHAUS et al. (1993) and SCHMIDT (1991), in Vorpommern by K. AMELANG (1987).

Since the present state of knowledge of Anthrosols/colluviae on till plains in Vorpommern still is very incomplete, we decided:

1. to present maps and cross-sections which show the spread and positions of selected truncated and colluvial sequences;
2. to discuss the colluvial input into moist depressions in particular;
3. to discuss specific properties and features of colluvial sequences;
4. to make a preliminary comparison between sequences on agricultural fields and forested areas, especially with regard to post-colluvial soil development;
5. to discuss the chronological position of soil erosive processes.

In this text, the terms Anthrosol and colluvium are used synonymously.

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2 *Methods*

Study and description of soil profiles and cores follow AG Boden (1994). The english translations of the designation of soil horizons and soil types are according to WRB for Soil Ressources (ISSS-ISRIC-FAO 1998).

Grain size frequencies were determined with the combined sieve-pipet method after KOHN (cf. (BARSCH & BILLWITZ 1990). Under middle-european climatic conditions the grain size fractions <2.0 µm and >600 µm are not resistant against weathering. Furthermore, the content of the clay fraction in soil profiles is strongly influenced by vertical translocation processes. A calculation of grain size frequencies based on the 2.0–630-µm eliminates the effect of weathering (ALAILY 1983). In this study, this method is used to compare grain size fractions of different profiles situated in different slope positions, and to compare grain size fractions of different horizons in one profile.

Micromorphological analyses follow BULLOCK et al. (1985), STEPHAN (1996) and FITZPATRICK (1993).

Statistical analyses were carried out with the computer program SPSS for Windows Version 6.

Pollen sample preparation (cf. FÆGRI & IVERSEN 1989) included treatment with HCl, KOH, sieving (120 µm), HF, and acetolysis (7 min). Counting was carried out with 400 × magnification. Pollen types were identified and named after: (f): FÆGRI & IVERSEN (1989), (m): MOORE et al (1991), (p): PUNT & BLACKMOORE (1991)/PUNT et al. (1988). Types not identified after these studies are marked with an asterisk (*) and described by DE KLERK (in press).

3 *Study area*

The landscape of Vorpommern is particulary characterised by its flat and slightly undulating till plains (cf. Fig. 1). These till plains mainly were formed by the last glacial advance of the Weichselian, the Mecklenburgian glacial advance (RÜHBERG et al. 1995). According to JANKE (1996), the Weichselian glaciers – compared to the preceding Saalian and Elsterian glacials – are the result of a relative warm, rapid, soft and short-lived inland ice body. They modified the pre-existing relief to a less extent and left in general less thick sediments than the Saalian and Elsterian glaciers. Characteristic for the study area are many small basins ("Sölle") which predominantly are the result of melting of buried dead ice. Many of such basins, however, also may be of anthropogenic origin (JANKE & JANKE 1970, KLAFFS et al. 1973).

The typical soil profile of the widespread albi-cambic Luvisols on the till plains consists of the following soil horizons: Ap (Ah)/Bw/E/(E+Bt)Bt/C. Usually, these horizons show stagnic features. The upper horizons (Ap (Ah), Bw, E) mainly are derived from the morainic loam sand parent material as the consequence of 1. periglacial geomorphological processes during the end of the Weichselian Pleniglacial and during the Lateglacial, and 2. pedogenetic processes during the Holocene, especially silicate weathering and neoformation of clay minerals (formation of Bw-horizons) and clay translocation (formation of Bt-horizons) (HELBIG 1999-a, 1999-b). On many agricultural fields this horizon sequence is more or less strongly modified by erosional and accumulational processes.

Fig. 1 shows the locations of the sites discussed in this text.

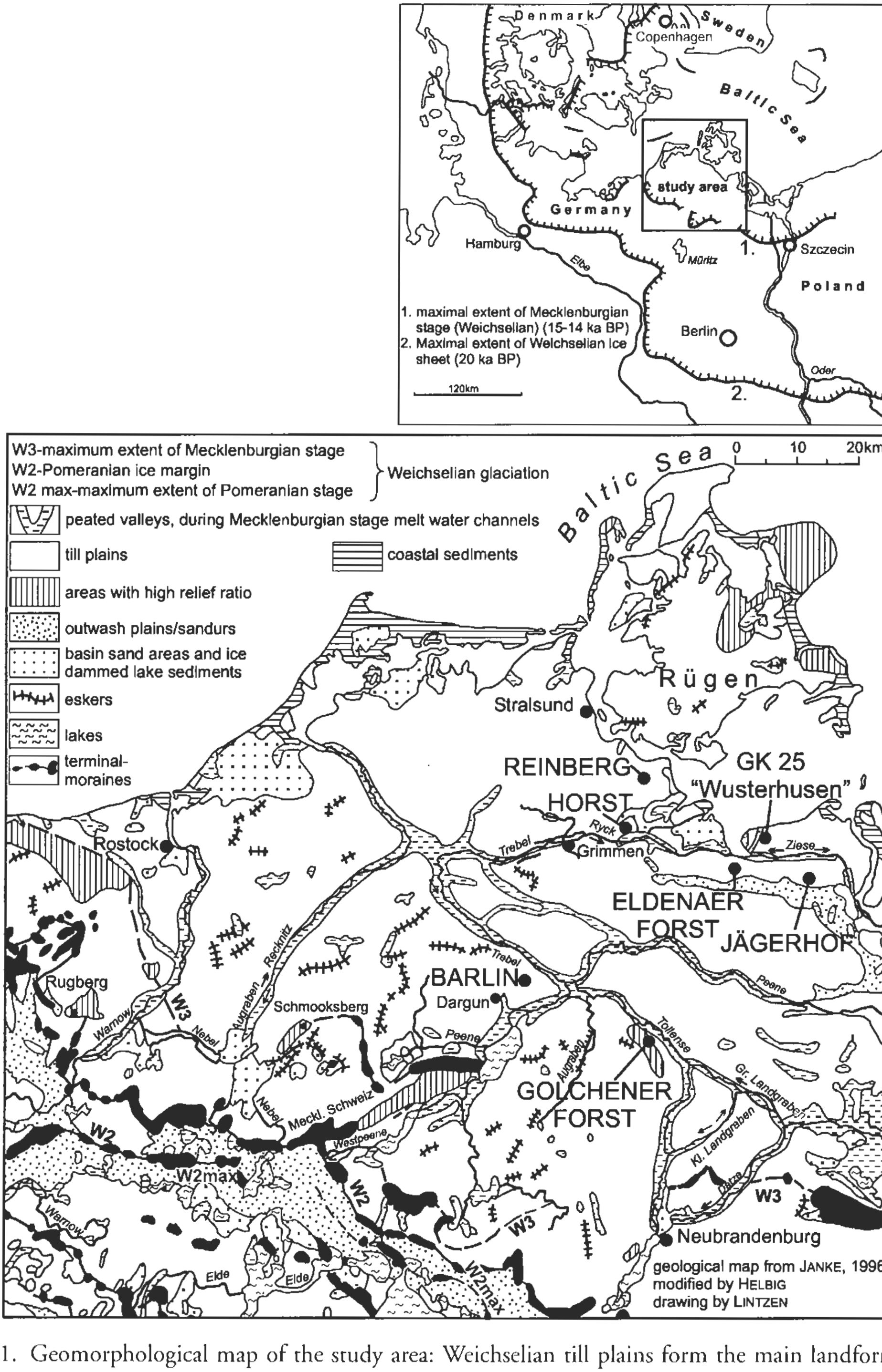

Fig. 1. Geomorphological map of the study area: Weichselian till plains form the main landform in Vorpommern.

4 *Colluvial sequences on agricultural sites*

The study of the geological maps of Prussia (1:25.000) and the maps of the "Deutsche Reichsbodenschätzung" (soil assessment in the first half of the 20th century) already shows the influence of soil erosion on the landscape. An extract from the geological map of Prussia (sheet 1847), redrawn in black-and-white (Fig. 2) displays the typical slightly undulating till plains in Vorpommern. Holocene peat is covered by Anthrosols/colluviae denounced as "Abschlämmassen". Narrow channels can be buried completely, while broader depressions only marginally are buried. The colluvial sediments also can be determined from the maps of the "Deutsche Reichsbodenschätzung": the channels in our example were provided with different reviation signs: ground water influenced loamy sands and very loamy sands (lS 4 Wa+, SL 4 and 5 Wa+, lSIIa3 and 4).

Our own field studies supplement the information from these maps by means of vertical cross-sections. The sequences HORST 1, HORST 2 and REINBERG (Fig. 3), primarily

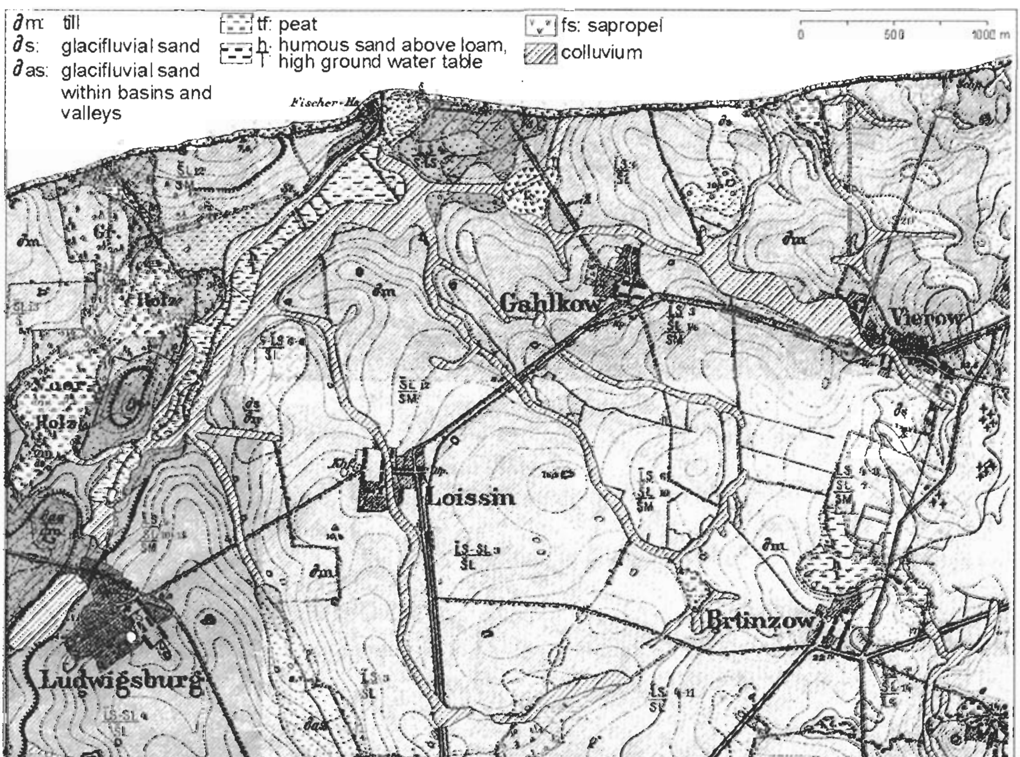

Fig. 2. Extract of the geological map of Prussia (sheet 1847 Wusterhusen) from 1920, which shows the typical slightly undulating till plains of Vorpommern. Anthropogenically induced soil erosion transported soil material into the moist depressions and caused burial, filling-in and destruction of wet biotopes.

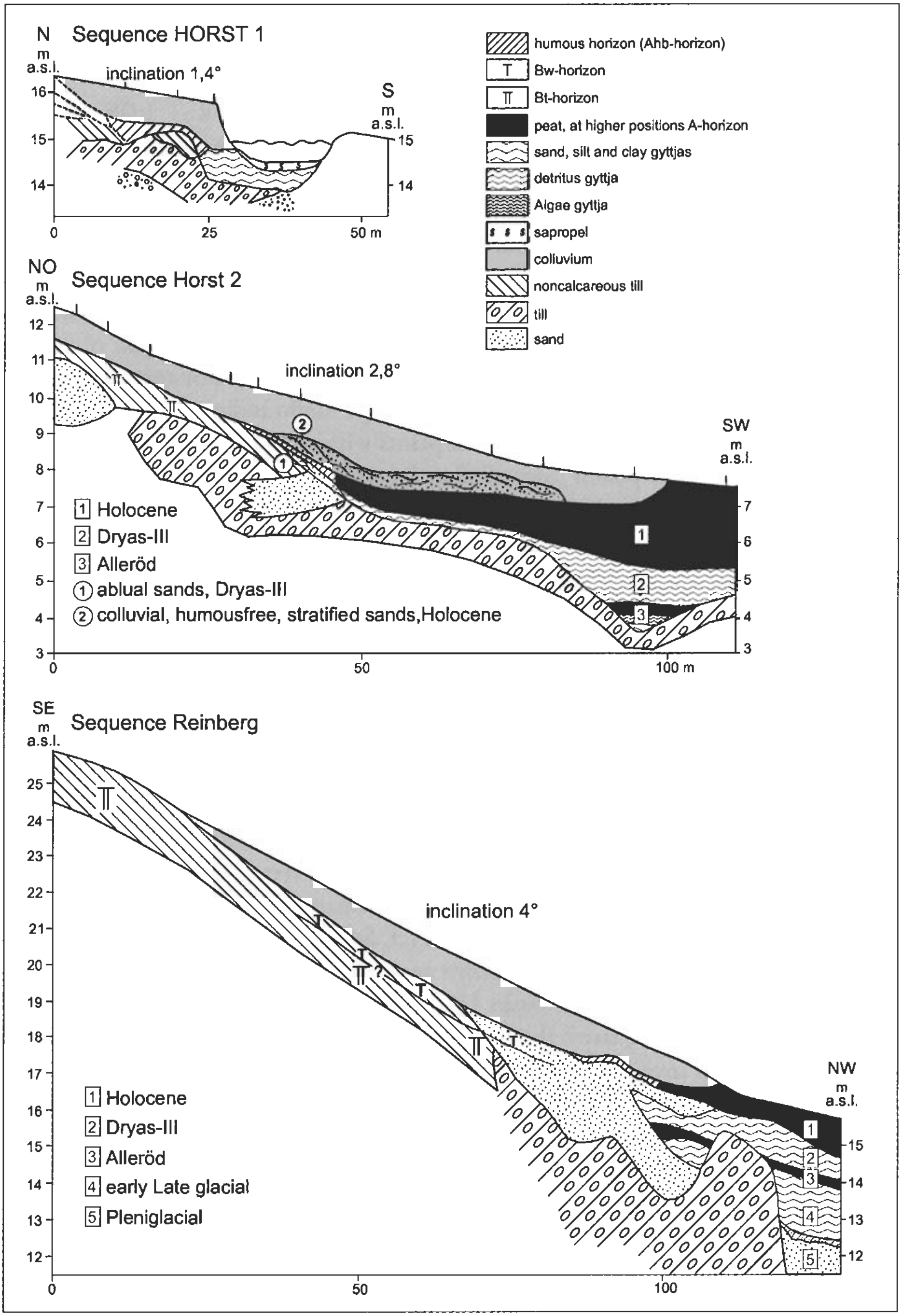

Fig. 3. Colluvial sequences on till plains in Vorpommern: HORST 1, HORST 2 and REINBERG. Young homogenous colluvial soils in lower slope position penetrate into the kettle holes ("Sölle"), which are a typical landscape element of NE Germany.

studied in order to reconstruct Pleni- and Lateglacial geomorphodynamic processes (HELBIG 1999-a, 1999-b, DE KLERK et al., in press-a), show dischargeless depressions; the sequence JÄGERHOF (Fig. 5) intersects the small valley of the Prägelbach.

The 45 cm thick sediments in the centre of the kettle hole HORST 1 (Fig. 3) consist of detritus and minerogenic gyttjas, a fine sand layer and at the top sapropel. Along the margins of the depression an Ahb-horizon, marking the former basin margin, covers calcareous till and is buried by a homogeneous brown loamy sandy colluvium.

In order to date these sediments four samples from the centre of the basin were palynologically studied. The pollen counts (Table 1) show that within the basin a wetland vegetation existed consisting of *Typha*, *Sparganium*, *Filipendula* and probably more taxa. The pollen attributed to cultivated plants and agricultural weeds point to cultivation of winter cereals on the fields surrounding the basin and of summer cereals and/or root crops at not too large distances (cf. BEHRE 1981). Pollen of *Sinapis* type might indicate cultivation of *Brassica napus*, but might also originate from wetland plants within the basin. Prominent is the presence of *Forsythia europaea* pollen (identified at "species" level within the *Forsythia europaea* type of PUNT & BLACKMORE 1991). Though not generally introduced in central and northern Europe, *Forsythia europaea* was planted in Vorpommern a.o. in the Arboretum of the University of Greifswald (SCHUSTER 1989); the asiatic species *F. suspensa* and *F. viridissima* were introduced in Europe in 1833 and 1846 respectively (ROTHMALER 1988). *F. suspensa* produces a slight different pollenmorphological entity, but the pollen of *F. viridissima* and the hybrid *F. x intermedia*, which were not studied by PUNT & BLACKMORE (1991), might be similar to that of *F. europaea*. This indicates an extreme young age for the studied sediments: sample 4b (Table 1) probably dates from the period after 1846; since the pollen spectrum of the deepest sample 4d (Table 1) closely resembles the spectrum of the other samples, it can not be considerably older. The pollen of *Zea mais* might even indicate a younger age: though introduced in Europe in 1492, maize was not cultivated in northern Europe until the end of the 19th Century (cf. BENNIK 1942), and then only on a very small scale. *Pinus haploxylon* type pollen, produced by taxa not native in NE Germany, probably originates from introduced exotic *Pinus* species planted e.g. in parks (cf. SCHUSTER 1989, VETVICKA 1985).

The extreme young age of these sediments as well as the absence of older sediments point to an anthropogenic genesis of the basin HORST 1, e.g. as marlpit (cf. KLAFS et al. 1973, JANKE & JANKE 1970), and stress the importance of modern soil erosion for the formation of colluvial sediments covering organic sediments.

The sediments/sedentates of the basin HORST 2 (Fig. 3) show two terrestrialisation phases, of which a pollen diagram (DE KLERK 1998, HELBIG 1999-a) dates the lower phase in the Lateglacial. The colluvium at the top of the section represents the youngest geomorphological phase. A Holocene peat layer (covered by the colluvium) shows in near-surface positions strong mineralisation features, attributed to anthropogenic drainage and lowering of ground water level before it was buried. A layer of non organic stratified sand (with variable portions of clay and silt) incidentally occurs between the peat layer and the brown homogeneous loamy sandy colluvium. Though the age of the colluvium can not be exactly dated, the geographical position only 1250 m to the west of HORST 1 suggests that it might be of similar Late Holocene age.

Table 1. Pollen/spore counts (absolute numbers) of the samples Horst 1 (analyzed by P. de Klerk). The pollen types are ordered in groups according to the assumed present-day ecological demands of their producers. For pollen type nomenclature: see chapter 2. Sample 4a: detritus gyttja, 20 cm below basin floor; sample 4b: sand layer, 32 cm below basin floor; sample 4c: detritus gyttja, 36 cm below basin floor and sample 4d: minerogenic gyttja, 42 cm below basin floor.

	SAMPLE 4a	SAMPLE 4b	SAMPLE 4c	SAMPLE 4d
POLLEN ATTRIBUTED TO TREES				
Alnus (m)	15	6	7	8
Betula (m)	29	8	10	17
Carpinus type (m)	2	-	-	1
Corylus (m)	3	-	6	5
Fagus (m)	1	2	2	7
Forsythia europaea (p)	-	1	-	-
Picea (f)	-	1	4	-
Pinus diploxylon type (f)	47	50	52	56
Pinus haploxylon type (f)	3	5	-	1
Pinus undiff. type (*)	6	12	8	6
Quercus (m)	12	3	15	8
Tilia (m)	-	1	1	1
Ulmus (m)	1	1	-	1
POLLEN ATTRIBUTED TO CULTIVATED PLANTS				
Avena-Triticum group (m)	41	43	49	57
Secale cereale (m)	94	81	134	143
Zea mais (f)	-	1	2	-
POLLEN ATTRIBUTED TO AGRICULTURAL WEEDS				
Artemisia (m)	34	17	55	52
Centaurea cyanus type (m)	9	6	9	14
Chenopodiaceae and Amaranthaceae (m)	4	6	14	6
Knautia (m)	-	1	-	-
Plantago lanceolata type (m)	6	5	4	11
Polygonum aviculare type (p)	2	16	50	7
Rumex acetosa group (p)	1	2	2	1
Rumex acetosella (p)	2	6	2	14
Viola arvensis type (m)	-	-	-	1
POLLEN ATTRIBUTED TO WETLAND PLANTS				
Filipendula (m)	1	10	15	1
Monolete spores without perine (*)	1	-	-	2
Potamogeton type (*)	1	-	-	4
Sparganium erectum type (m)	1	-	-	-
Sphagnum (m)	2	-	-	-
Typha angustifolia type (m)	1	-	-	3
Typha latifolia type (m)	22	21	32	46
ECOLOGICAL INDETERMINATE				
Anthemis type (m)	3	3	6	7
Apiaceae undiff. type (*)	1	-	11	2
Aster type (m)	-	1	-	-
Calluna vulgaris (m)	2	-	-	4
Caryophyllaceae undiff. type (*)	2	10	1	2
Chamaenerion angustifolium type (m)	-	1	14	1
Cyperaceae (m)	26	33	11	44
Equisetum (m)	4	7	1	3
Fabaceae undiff. type (*)	5	14	8	3
Galium type (m)	1	1	27	1
Lactuceae (m)	-	-	-	3
Mentha type (m)	-	-	1	-
Ranunculus acris type (p)	-	-	-	1
Rumex conglomeratus group (m)	-	-	-	1
Sinapis type (m)	23	40	28	31
Thalictrum (m)	1	3	-	2
Trifolium type (m)	11	2	-	26
Wild grass group (m)	45	79	65	144
Indet.	9	12	5	15

Recent soil mapping on agricultural fields of slightly undulating till plains indicates that, next to the small depressions, also the concave footslopes of small elevations (e.g. eskers and kames) may act as colluvial accumulation sites (SCHNEIDER & KÜHN 2000).

Hummocky till plains with steeper slopes (above approximately 6–8°) only incidentally occur in Vorpommern. Such areas contain extremely truncated soil profiles, as for instance shown in Fig. 4: an 8° inclined slope (site BARLIN) north of Dargun (Fig. 1). The profile was truncated partly up to the calcareous till; the boundary between the Bt-horizon and the calcareous till is strongly undulating.

The site JÄGERHOF (SE of Greifswald) (cf. Fig. 1) clearly demonstrates the occurrences of pronounced colluviae at lower slope positions as the result of land cultivation on the hummocky till plains (BILLWITZ et al., in press). The cross-section (Fig. 5) shows a homogenous brown Anthrosol with thicknesses up to 1 m at a footslope (soil profiles J5/4 to J5/5). On the higher grounds only truncated soil profiles of albic and stagnic Luvisols occur (J5/1 to J5/3) as the consequence of agricultural activities. The study of the Swedish register map of 1694 (RUBOW-KALÄHNE 1960) and the "Urmesstischblatt" of 1835 shows that at the end of the 17th century west of the Prägelbach, small strips of land were deforested and cultivated, especially at lower slope positions; at the beginning of the 19th century the entire area

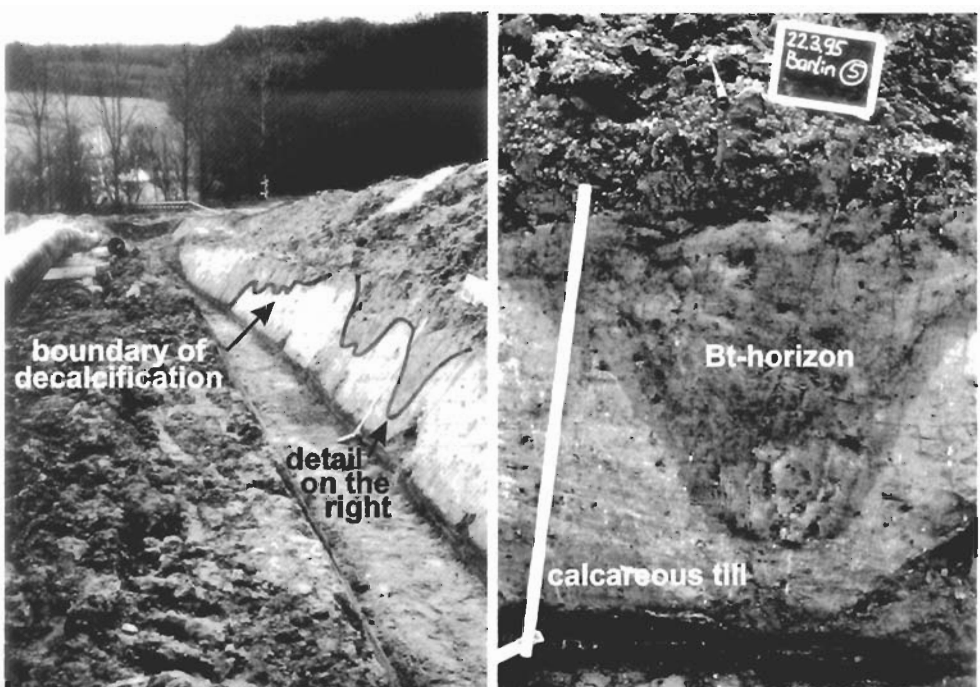

Fig. 4. Site BARLIN (north of Dargun): soil erosion on an agricultural field within hummocky till plains with a slope inclination of 8°. The soil profile partly was truncated up to the calcareous till, the lower boundary of the Bt-horizon is strongly undulating.

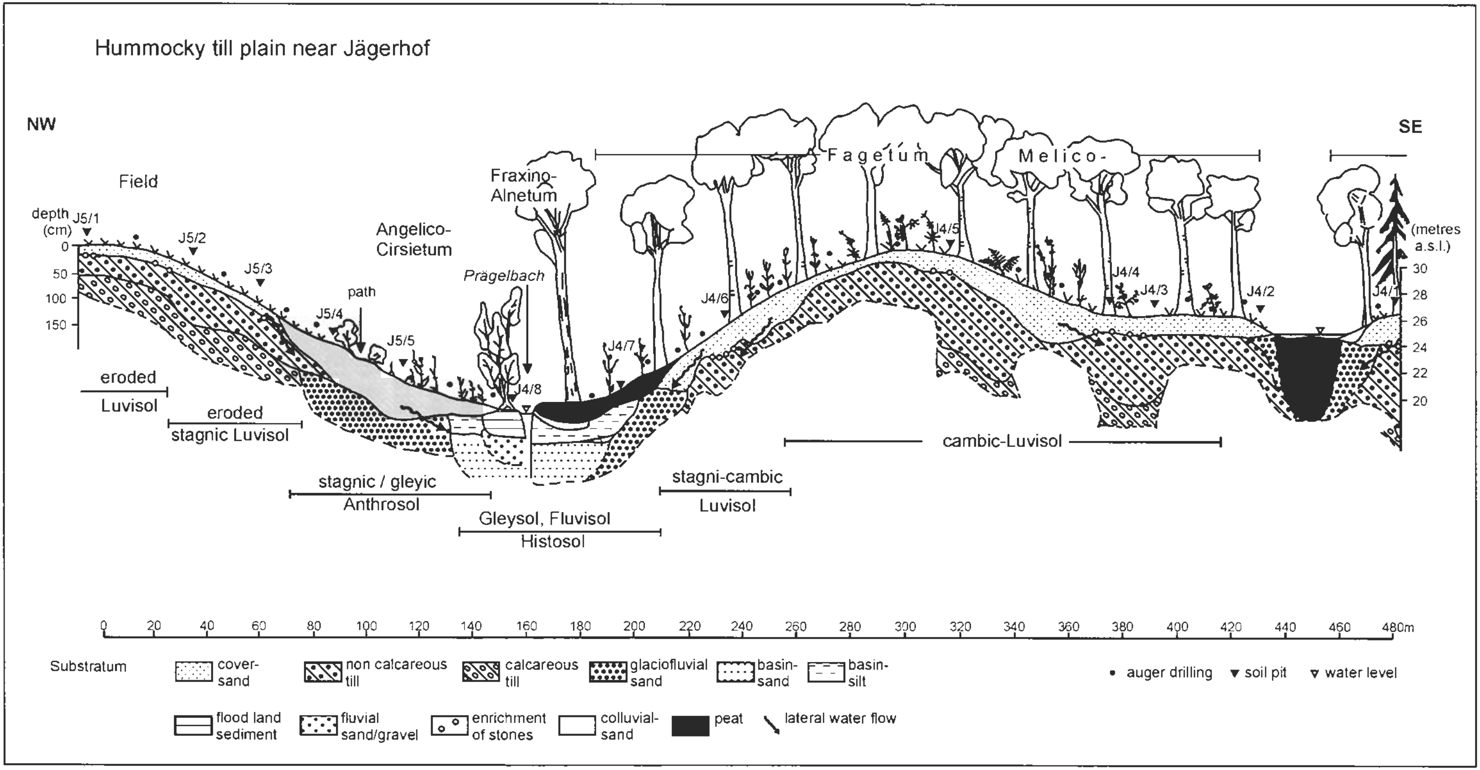

Fig. 5. Sequence JÄGERHOF (modified after BILLWITZ et al., in press): valleys become smaller by colluvial infill. There is not only an input of soil material into the water, but also of nutrients and pesticides.

west of the Prägelbach was agriculturally used. This indicates that the formation of the Anthrosol started at the latest in the 17^{th} century; erosional/accumulational processes currently probably still go on. Since in the forested area east of the Prägelbach only small colluvial deposits occur despite its high relief energy, it can be assumed that agriculture never was performed there.

In the basin REINBERG (Fig. 3), of which interdisciplinary researches focus on late Pleniglacial and Lateglacial vegetation history and landscape development (DE KLERK et al., in press-a.), colluvial sediments occur at lower slope positions. Similar to the sites HORST 1, HORST 2 and JÄGERHOF the Anthrosol/colluvium again appears as a homogeneous brown loamy sandy unstratified sediment, differentiated only by increasing soil moisture in the lower part of the sequence. The upper samples of the pollen diagram "Reinberg 11" (DE KLERK et al., in press-a), derived from the upper humous layer connected with the uppermost peat layer, date in the early Holocene period. This is only a maximum age for the soil erosion, since erosion and oxidative humus reduction probably caused loss of the younger sediments and humus.

The colluviae in the sequences HORST 1, HORST 2, JÄGERHOF and REINBERG predominantly are situated on cultivated till plains with slopes gradients up to 8° and represent a recent phase of landscape development. The colluvial sediments commonly cover margins of kettle holes and valleys and in some cases even have reached the centre of these depressions (cf. KLAFFS et al. 1973, AMELANG et al. 1983). They frequently show a homogeneous appearance: brown colour, unstratified loamy sand, partly differentiated by groundwater influence. The parent material of these Anthrosols are eroded Bt-, Bw-, albic E-, and Ah/Ap horizons of the decalcified till, sometimes encompassing horizons with stagnic features. In these young brown colluviae, no traces of postsedimentary pedogenic processes are recognizable, apart from stagnic or ground water features.

Soil erosion obviously had a substantial negative influence on kettle holes and valleys of till plains in Vorpommern. Accumulation of translocated soil material along the margins of depressions in the Modern Period also is caused by a cultivation direction parallel to these margins combined with cruising (AMELANG et al. 1983). The burial and filling-in of moist depressions by colluvial sediments diminish their habitat function within the already species-poor agricultural lands not only by the input of soil material, but also by a considerable input of nutrients and pesticides (GLA M-V 1998, BILLWITZ 1995, FRIELINGHAUS 1998). It is important to mention that already a great number of kettle holes were eliminated in the past by relief amelioration and drainage (KLAFFS et al. 1973).

5 *Colluvial sequences of forested sites*

The nature conservation area ELDENAER FORST, a beech forest SE of Greifswald, recently became the subject of interdisciplinary studies into landscape development and land occupation history (DE KLERK et al. in press-b, HELBIG 1999-a, KWASNIOWSKI 2000). One research priority was the investigation of four basins in the southern part of the area.

An extract of the soil map of the ELDENAER FORST (Fig. 6) shows the typical spatial distribution of the colluviae, which encircle both the depressions and the higher areas. The

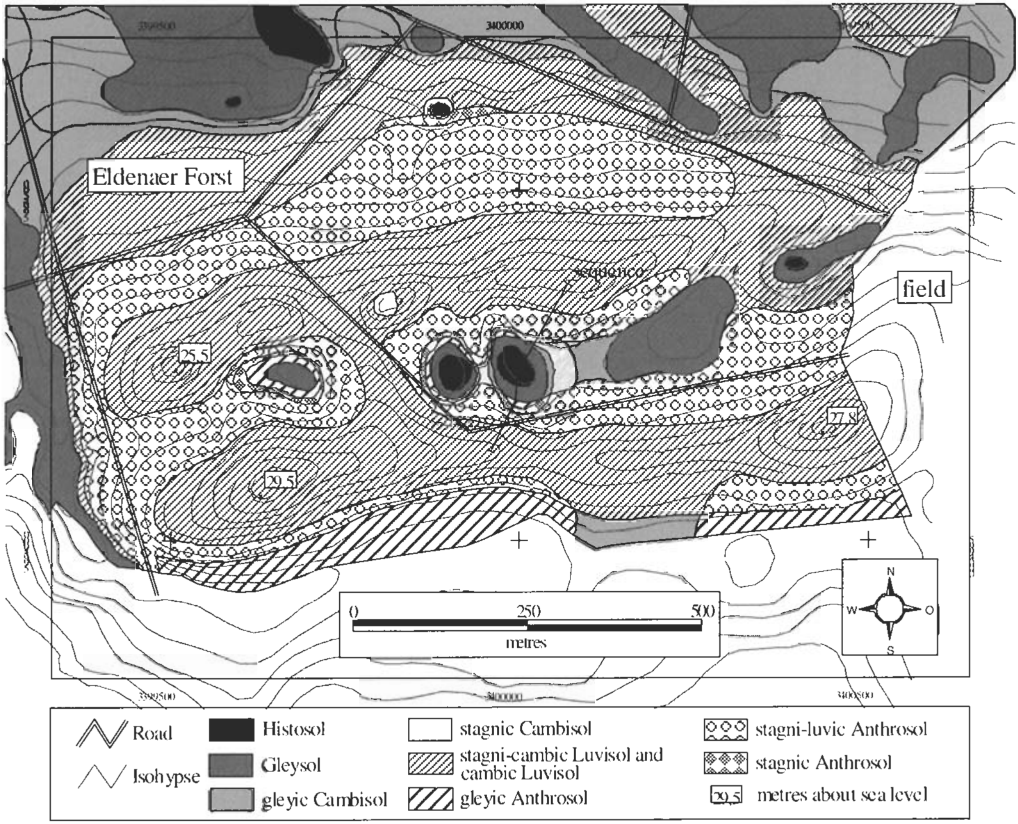

Fig. 6. Extract from the soil map and slope inclination map of the ELDENAER FORST (KWASNIOWSKI 2000). Colluviae dominate the lower relief areas. Indicated is the location of the sequence shown in Fig. 7.

colluviae mainly are deposited at the concave downslope positions, but sometimes reach up to the middle slopes, reaching thicknesses of 1 metre and more. From numerous soil pits and corings nine toposequences were prepared, of which two are presented in Fig. 7. Part of the basal sands in the depressions might originate from periglacial ablation (HELBIG 1999-a), otherwise the parent material for soil formation consists of calcareous till.

Depth of decalcification is often the least on the higher grounds and in the upper and lower parts of the slopes (between few decimeters up to 150 cm, partly more), in the middle slope positions it might reach up to two metres. This is not only due to the fact that soil water at higher elevations flows downslope as interflow without great vertical percolation, but also to the erosion of the upper (noncalcareous) soil material which causes truncated soil profiles. In downslope positions the near soil water prevents deep reaching solution of lime.

In the downslope areas of the sequences, the predominantly humous-free colluvial material covers a humous zone (Fig. 7, 8) which marks the former basin margins. This humous

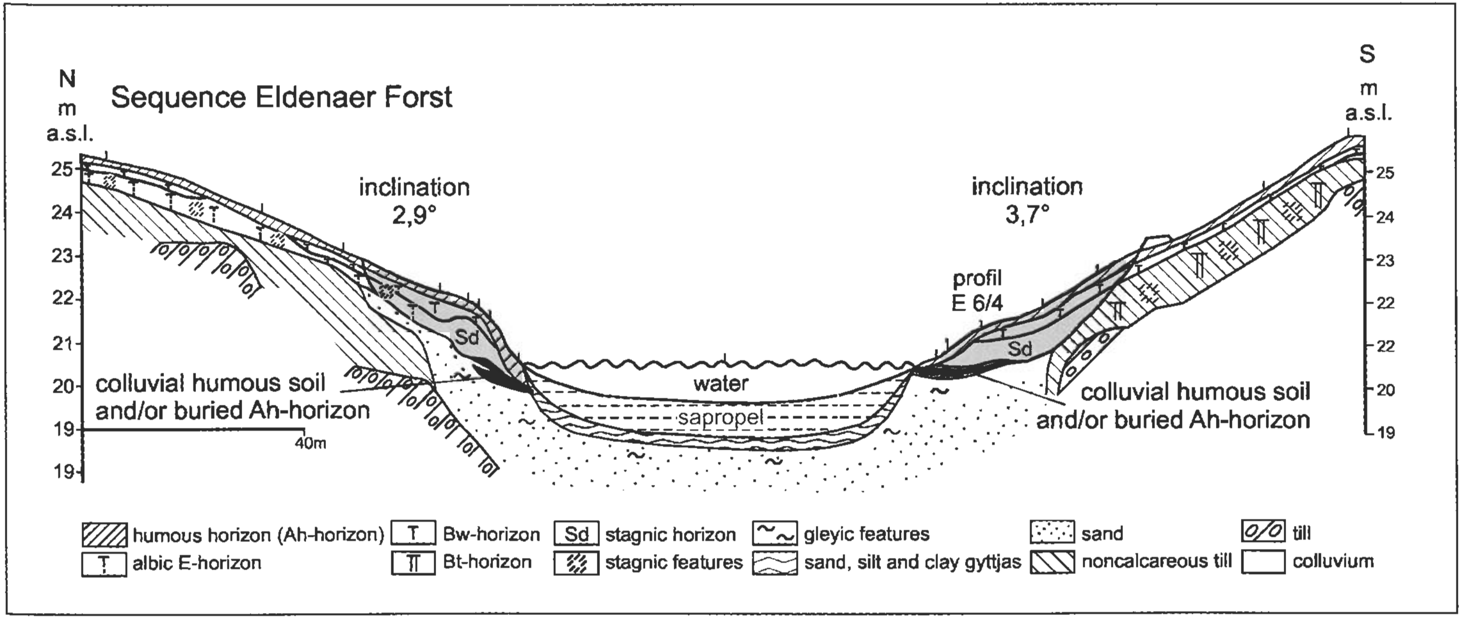

Fig. 7. Sequence ELDENAER FORST. Soil erosion already caused sediment transport in early historical times. Forest regeneration and geomorphological stability enabled development of soil horizons on the erosional and accumulational positions of the toposequences.

zone is recognisable in some profiles as in-situ soil formation, in other profiles as redeposited soil material (layering, grain size distribution). For example in profile E6/4 (Fig. 8), the complete humous zone seems to consist of redeposited erosional material, as is indicated by its grain size distributions (Table 2). All grain size fractions of the humous erosional material show great differences with those of the basal ablual sands, but are similar to those of the covering stagnic horizon and Bw-horizon (HELBIG 1999-a). The humous zone always is covered by a horizon consisting of eroded soil material, in which afterwards stagnic features were formed (cf. Fig. 7, 8): these are mainly Fe/Mn-concretions and brown hydromorphic spots. The top of the soil profiles along the lower parts of the slopes consists of a Bw-horizons (including in this context also Ah-Bw-horizons and Bw-horizons with stagnic features) (cf. Fig. 7, 8), which seem to have developed postsedimentary in the colluvial material.

The colluviae reach their greatest thicknesses at the base of the slopes immediately bordering the depressions and become thinner at higher elevations. The Bw- and E-horizons

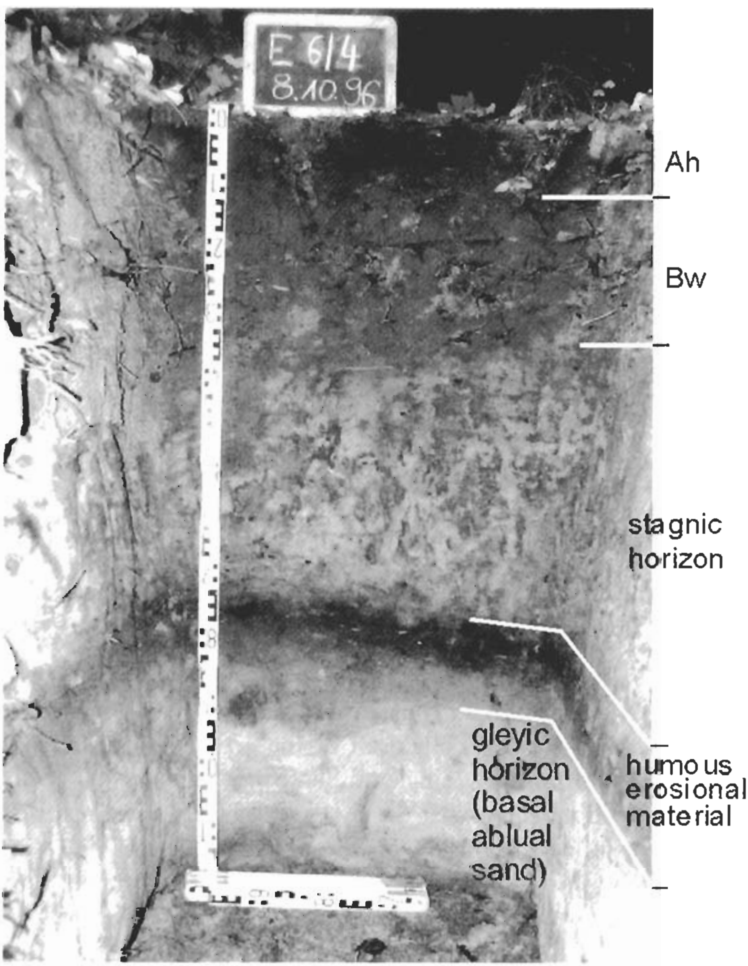

Fig. 8. Profile E6/4 of the ELDENAER FORST (location is indicated in Fig. 7). From top to bottom: Ah-horizon, Bw-horizon, stagnic horizon, humous erosional material and basal sand. Bw- and stagnic horizon are developed in a colluvium from the Roman Iron Age.

Table 2. Grain size distribution of soil profile E6/4. * Basis of calculation are fractions 2.0–630 µm (see chapter 2)

	630–200 µm*	200–63 µm*	63–20 µm*	20–6.3 µm*	6.3–2.0 µm*
Bw-horizon (colluvium)	24.4	48.1	15.4	9.2	2.9
stagnic horizon (colluvium)	26.2	47.8	14.5	8.2	3.4
upper humous erosion material	22.0	48.8	15.1	10.2	3.9
lower humous erosion material	29.3	46.3	16.7	5.9	1.9
gleyic horizon (ablual sands)	25.1	60.9	10.7	2.2	1.1

Table 3. Grain size distribution from the colluvium and upper soil horizons on different slope positions in comparison with the underlying noncalcareous till (* basis of calculation: fractions 2.0–630 µm); calculated from soil profiles of 5 sequences around kettle holes in the study area ELDENAER FORST.

	630–200 µm*	200–63 µm*	63–20 µm*	20–6.3 µm*	6.3–2.0 µm*	n
Bw- and stagnic horizons (colluvium) lower slope position	25.3	50.2	13.7	7.8	3.0	7
Bw- and E-horizons middle and upper slope position	25.5	53.2	101.4	7.9	3.0	12
Bw- and E-horizons hill tops	24.1	49.8	12.7	9.7	3.7	3
Bt-horizons (noncalcareous till)	20.5	47.0	15.2	12.7	4.5	10

along the slopes above the colluviae often still have considerable thicknesses and only partly show a distinct erosionally truncated profile. Comparison of the grain size distributions (Table 3, cf. HELBIG 1999-a) of soil horizons in a single profile (Bw/E with Bt) and of different profiles on different slope positions shows that the Bw- and E-horizons are relatively more sandy than the not erosionally influenced Bt-horizon: this indicates that during erosion the silt fraction was more strongly washed away than the sand fraction. This probably also applies for the clay fraction, but can not be demonstrated due to post-sedimentary vertical translocations.

Micromorphological investigations of some profiles of the ELDENAER FORST (E9/2, E5/5, E6/4 cf. HELBIG 1999-a) show that considerable portions of the finer material between the pores of the Bw-horizons of noncalcareous till and of the colluviae is of organic origin. The pore content of two samples of a Bw-horizon (E9/2, cf. HELBIG 1999-a) was estimated at circa 30%. Fe/Mn-concretions in Bw-horizons indicate hydromorphic influence. Plant remains and charcoal particles are present in almost every Bw-horizon; clay coatings, however, predominantly are absent. The stagnic horizons (E5/5, E6/4 cf. HELBIG 1999-a) from colluvial parent material along the basin margins (cf. Fig. 7, 8), compared to the Bw-horizons, hardly contain organic fine substance and have a smaller pore content; plant remains and charcoal particles, however, also frequently occur. Abundant Fe/Mn-concretions on the pore walls indicate strong influence of stagnic soil moisture. Some dozens of intact clay coatings show rather intensive clay transportation after sedimentation. The micromorphological studies suggest that the higher content of fine organic material, charcoal and plant remains are due to intensive biogenic influence by plants and soil fauna in the Bw-horizons. Bioturbation probably also is responsible for the higher pore volume in the Bw-horizons.

In the colluviae, after deposition, formation of Bw-horizons, lessivation and formation of stagnic features took place. AMELANG et al. (1983) demonstrate similar formation of Bw-horizons in Holocene sediments in Vorpommern.

Soils influenced by perched ground water are widespread in the ELDENAER FORST. Only the higher elevated areas (17–29 m a.s.l.) hardly were influenced by perched ground water (KWASNIOWSKI 2001) and, therefore, were suitable for agriculture. These higher areas are characterised by higher slope inclinations (> 1 – < 10°). The occurrence of (at least temporary) bare slopes are the cause for formation of colluviae: presence of colluviae in forested areas, therefore, is an undeceivable indication for past clearances and agricultural activities (BORK et al. 1998).

This former agricultural activity and subsequent soil erosion in the ELDENAER FORST could be dated by means of the radiocarbon method and palynology. A ^{14}C-date of charcoal from the buried humous horizon along the depression margins (NLfB 1997, laboratory number Hv-21649; cf. HELBIG 1999-a) ranges between 80–420 cal AD, corresponding with the Roman Iron Age. A prominent agricultural phase during this period followed by a forest regeneration during the Migration Period is recorded in a pollen diagram from a basin in the eastern part of the ELDENAER FORST (DE KLERK et al., in press-b).

Indications of erosion and postcolluvial soil formation in forested regions also are found in the GOLCHENER FORST (southern Vorpommern) (HELBIG & BECKMANN 2001). Studies in this area focus on the effects of medieval land occupation and forest clearance on landscape development. In a not yet dated, but probably medieval colluvium a 40 cm thick, a weakly pronounced soil profile was developed consisting of an Ah-, Bw-, E- and Bt-horizon covering an Ahb-horizon. Similar to the ELDENAER FORST the parent material of this soil formation is *not* unweathered till, but predominantly redeposited Ah-, Bw-, E- and Bt-horizons of noncalcareous till, i.e. a sediment which had already undergone intensive weathering processes before it was eroded. Such postcolluvial soil formation is assumed to be only possible during periods of prolonged geomorphological stability under forest cover (FRIELINGHAUS et al. 1993, BORK et al. 1998).

Probably because the area became property of the convent Eldena, no new agriculture was performed in the ELDENAER FORST. The abandonment of agricultural fields in other areas might be related to the fact that agricultural exploitation appeared to be unprofitable, e.g. the RODDER FORST (BECKMANN 1998), the GOLCHENER FORST, and numerous other presently forested sand regions in which presence of fossil fields, inland dunes and colluviae indicate agricultural activities in the past.

6 *Conclusions*

Soil erosion on agricultural fields in Vorpommern hardly gets public attention, although prominent burial and filling with sediments of depressions, and the input of nutrients and pesticides (GLA M-V 1998) in these moist landscape elements largely affected their habitat function within the species poor agricultural lands.

The widespread occurrence of colluviae can be demonstrated with aid of the geological map of Prussia and the maps of the "Deutsche Reichsbodenschätzung". Colluviae predominantly occur in channels, valleys, kettle holes and other depressions. Furthermore, also the concave footslopes of hilly morainic localities and of small elevations (such as eskers and kames) (SCHNEIDER & KÜHN 2000) may act as colluvial accumulation sites.

Often the first erosion buried peat layers along the basin margins (HORST 2, REINBERG) or Ahb-horizons (ELDENAER FORST, HORST 1, HORST 2, REINBERG). But not all buried organic horizons were formed in situ. Partly they were formed during the beginning of erosion by transportation of organic material from the higher slope positions (Fig. 8, Table 2).

It was shown that in the ELDENAER FORST during erosion the silt fraction was more strongly washed away than the sand fraction.

On present-day agricultural fields homogenous brown colluviae occur which show no further postsedimentary pedogenic development, with the exception of stagnic or ground water features. "Older" colluviae in forested areas show signs of post-sedimentary formation of Bw-horizons, lessivation and formation of stagnic features. Preposition for such postsedimentary soil formation are geomorphological stability and forest cover for longer time periods (FRIELINGHAUS et al. 1993, BORK et al. 1998).

General conclusions about phases during which intensive soil erosion occurred can not be drawn from the data presented in this study and in previous studies (Table 4), though colluviae from Modern Period are prominently dominant. It still has to be studied if homogeneity (colours, grain sizes) is a criterion for young age of colluviae. The colluviae dating from the Middle and Late Medieval must be related to the german colonisation in eastern directions during this period. Colluviae from the Slavonic Period still have to be discovered in Vorpommern, though KAISER et al. (2000) present an insecure occurrence on a glacilimnic plain near a till area of north-west Vorpommern; a slavonic colluvium in eastern Mecklenburg is presented by MÜLLER (1997). This might be related to a delayed settlement and agricultural use of till plains (HERMANN 1985), especially in areas with heavy loamy soils and/or in areas located at large distance to running water or lakes. Prominent in Vorpommern are colluviae from the Roman Iron Age, which are, however, not a regional phenomenon for the Greifs-

Table 4. Chronology of colluviae of the till plains in Vorpommern.

SITE/AUTHOR	LOCATION	AGE OF COLLUVIA	DATING BASED ON	OTHER INDICATIONS FOR DATING
HORST 1	northern Vorpommern	Modern Period	palynology	Homogeneous colluvium without signs of soil formation as test for Modern Period age??
HORST 2	northern Vorpommern	probably primary Modern Period	geographical position near HORST 1	dito
REINBERG	northern Vorpommern	younger than Atlanticum Age; possibly primary Modern Period	palynology	dito
JÄGERHOF	eastern Vorpommern	probably primary Modern Period	historical maps	dito
ELDENAER FORST	eastern Vorpommern	Roman Iron Age	^{14}C and palynology	
GOLCHENER FORST (studies still in progress)	southern Vorpommern	older than 17. century; possibly Middle Ages	historical maps, fossil field forms („Wölbäcker")	pedogenesis
WACKEROW Kaiser & Janke (1998)	eastern Vorpommern	Bronze Age Roman Iron Age Middle Ages/ Modern Period	archaeology, palynology	
WOLFSSCHLUCHT Amelang et al. (1983)	Rügen	Roman Iron Age	palynology	
GLASOW Schatz et al. (1997)	southern Vorpommern	Bronze Age, Middle Ages/ Modern Period; period 1935-95	archaeology	pedogenesis

wald area only (cf. ELDENAER FORST and WACKEROW cf. Table 4). This area was relatively densely populated in this period around the crossing of several trading routes, as was demonstrated in archaeological studies (MANGELSDORF 2000). For this time period, however, colluviae also are demonstrated in other regions of Vorpommern (AMELANG et al. 1983, KAISER et al. 2000). Based on palynological studies, LANGE et al. (1986) postulate a rather restricted agriculture on the isle of Rügen during the Roman Iron Age, though a single pedological/geomorphological observation exists (AMELANG et al. 1983). A further possible phase of soil erosion is indicated in the Bronze Age (Table 4 and KAISER et al. 2000: 176).

References

AG Boden (1994): Bodenkundliche Kartieranleitung. – 4. Aufl., 392 pp., Hannover.

ALAILY, A. (1983): Rekonstruktion des Ausgangszustandes und Bilanzierung von Böden einer Moränenlandschaft. – Z. Pflanzenernähr. Bodenk. **146**: 72–88.

AMELANG, K. (1987): Zur Intensität und Vorausschätzung des wassererosiven Bodenabtrags im küstennahen Jungglazial. – Wiss. Z. Univ. Greifswald, Math.-nat. Reihe **36** (**2–3**): 127–130.

AMELANG, N. (1987): Untersuchungen zum Problem der Winderosion auf Ackerflächen im küstennahen Jungmoränengebiet der DDR. – 119 pp., PhD-thesis, Universität Greifswald. (unpubl.)

AMELANG, K., JANKE, W. & KLIEWE, H. (1983): Formenveränderungen und Substratumlagerungen an Grenzsäumen zwischen Naturraumeinheiten des Küstengebietes. – Wiss. Z. Univ. Greifswald, Math.-nat. Reihe **32** (1-2): 81–92.

BARSCH, H. & BILLWITZ, K. (ed.) (1990): Physisch-Geographische Arbeitsmethoden. – 612 pp., Verlag Hermann Haack, Gotha.

BEHRE, K.-E. (1981): The interpretation of anthropogenic indicators in pollen diagrams. – Pollen et Spores **23**: 225–245.

BECKMANN, H.(1998): Mittelalterliche Flurrelikte im Rodder Forst. – ASMUS, I., PORADA, H. & SCHLEINERT, D. (ed.): Geographische und historische Beiträge zur Landeskunde Pommerns. – pp. 211–215; Thomas Helms Verlag, Schwerin.

BENNIK, H. A. (1942): Mais-mogelijkheden in Nederland en België. Beknopte handleiding voor Maiscultuur op akker en in tuin; Maisrecepten voor de keuken. – Second revised ed., 76 pp., N. V. uitgevers-Maatschappij "Kosmos", Amsterdam.

BILLWITZ, K. (1986): Bodenheterogenität und Bodenverlagerungsprozesse im Jungmoränengebiet und ihre Interpretation anhand von Luftbildern. – Veröff. Zentralinst. Physik d. Erde **82**: 160--67.

BILLWITZ, K (1995): Bodenentwicklung, Böden und Bodenschutz. – In: ALBRECHT, G. (ed.): Historischer und geographischer Atlas von Mecklenburg und Pommern. Band 1: Mecklenburg-Vorpommern. Das Land im Überblick. – Landeszentrale für Politische Bildung: 20–25, Schwerin.

BILLWITZ, K. (1996): Konzepte für eine umweltgerechte Landnutzung in Mecklenburg-Vorpommern. – Schriftenr. Ges. Deutschlandforsch. **51**: 129–138.

BILLWITZ, K., KÜHN, P. & HELMS, S. (in press): Substrate und Böden des Jungmoränengebietes: Ein Bodenlehrpfad in der Greifswalder Umgebung. – Mitt. Dt. Bodenkdl. Ges. **96**.

BORK, H. R., DALCHOW, C., FAUST, B., PIORR, H. & SCHATZ, T. (1998): Landschaftsentwicklung in Mitteleuropa. Wirkungen des Menschen auf Landschaften. – 382 pp., Justus Perthes Verlag, Gotha/Stuttgart.

BULLOCK, P. et al. (1985): Handbook for soil thin section description. – Waine research publications, 152 pp., Albrighton, Wolverhampton.

DE KLERK, P. (1998): Late Glacial and Early Holocene vegetation history in northern Vorpommern: a preliminary review of available pollen diagrams. – 34 pp., Project Report, Greifswald University.

DE KLERK, P. (in press): Changing vegetation patterns in the Endinger Bruch area (Vorpommern, NE Germany) during the Weichselian Lateglacial and Early Holocene. – Review of Palaeobotany and Palynology.

DE KLERK, P., HELBIG, H, HELMS, S., JANKE, W., KRÜGEL, K., KÜHN, P., MICHAELIS, D. & STOLZE, S. (in press-a): The Reinberg Researches: palaeoecological and geomorphological studies of a kettle hole in Vorpommern (NE Germany), with special emphasis on a local vegetation during the Weichselian Pleniglacial/Lateglacial transition. – Greifswalder Geogr. Arb..

DE KLERK, P., MICHAELIS, D. & SPANGENBERG, A. (in press-b): Auszüge aus der Weichsel-spätglazialen und holozänen Vegetationsgeschichte des Naturschutzgebietes Eldena. – Greifswalder Geogr. Arb.

DIECKMANN, O & KAISER, K. (1998): Pedologische und geomorphologische Befunde zur historischen Bodenerosion im Müritz-Nationalpark (Mecklenburg-Vorpommern). – In: ASMUS, I., PORADA, H. & SCHLEINERT, D.(ed.): Geographische und historische Beiträge zur Landeskunde Pommerns. – pp. 59–65, Thomas Helms Verlag, Schwerin.

FÆGRI, K. & IVERSEN, J. (1989): Textbook of pollen analysis. – 4th edition. (Revised by FÆGRI, K., KALAND, P. E. & KRZYWINSKI, K.), 328 pp., Chichester.

FITZPATRICK, E.A. (1993): Soil microscopy and micromorphology. – 304 pp., Wiley, Chichester.

FRIELINGHAUS, M. (1998): Das Bodenschutzproblem in Ostdeutschland. – In: RICHTER, G (ed.): Bodenerosion. Analyse und Bilanz eines Umweltproblems. – pp. 204–221, Wissenschaftliche Buchgesellschaft, Darmstadt.

FRIELINGHAUS, M, KOCMIT, A. & RATZKE, U. (1993): Veränderungen an wassererosionsbeeinflußten Hängen und Auswirkungen auf die Bodenerodibilität im Jungmoränengebiet. – Mitt. Dt. Bodenkdl. Ges. **72**: 1169–1172.

GLA M-V (ed.) (1998): Beiträge zum Bodenschutz in Mecklenburg-Vorpommern – Bodenerosion. – 80 pp., Schwerin.
HELBIG, H. (1999-a): Die spätglaziale und holozäne Überprägung der Grundmoränenplatten in Vorpommern. – Greifswalder Geogr. Arb. 17, 110 pp.
HELBIG, H. (1999-b): Die periglaziäre Überprägung der Grundmoränenplatten in Vorpommern. – Petermanns Geogr. Mitt. 143/5+6: 373–386.
HELBIG, H. & BECKMANN, H. (2001): Mensch und Umwelt im Mittelalter – Interdisziplinäre Studien zur mittelalterlichen Siedlung und ihren Auswirkungen auf die Umwelt in ländlichen Räumen Mecklenburg-Vorpommerns. – 13 pp., unpubl. report.
HERMANN, J. (ed.) (1985): Die Slawen in Deutschland. – Veröff. Zentralinst. Alte Geschichte Archäol. Akad. Wiss. DDR, Band 14, 629 pp., Berlin.
ISSS-ISRIC-FAO (1998): World reference base for soil resources. – FAO World Soil Resourc. Rep. 84, 3, 88 pp., Rome.
JANKE, W. (1996): Landschaftsentwicklung und Formenschatz Mecklenburg-Vorpommerns seit der Weichsel-Eiszeit. – Z. Erdkundeunterricht 12: 495–505.
JANKE, V. & JANKE, W. (1970): Zur Entstehung und Verbreitung der Kleingewässer im nordostmecklenburgischen Grundmoränenbereich. – Arch. Naturschutz Landschaftsforsch. 10: 3–18.
KAISER, K., ENDTMANN, E.& JANKE, W. (2000): Befunde zur Relief-, Vegetations- und Nutzungsgeschichte an Ackersöllen bei Barth, Lkr. Nordvorpommern. – Bodendenkmalpflege in Mecklenburg-Vorpommern, Jahrbuch 1999 (47): 151–180.
KAISER, K. & JANKE, W. (1998): Bodenkundlich-geomorphologische und paläobotanische Untersuchungen im Ryckbecken bei Greifswald. – Bodendenkmalpflege in Mecklenburg-Vorpommern, Jahrbuch 1997 (45): 69–102.
KLAFFS, G., JESCHKE, L. & SCHMIDT, H. (1973): Genese und Systematik wasserführender Ackerhohlformen in den Nordbezirken der DDR. – Arch. Naturschutz Landschaftsforsch. 13/4: 287–302.
Königlich Geologische Landesanstalt (ed.) (1920): Geologische Karte von Preußen, Blatt 1847 Wusterhusen. – Berlin.
KWASNIOWKI, J. (2000): Boden- und Reliefanalyse zur Abschätzung anthropogener Landschaftsveränderungen im Naturschutzgebiet Eldena (Vorpommern). – 94 pp., MSc. thesis, Universität Greifswald.
LANGE, E., JESCHKE, L. & KNAPP, H.D. (1986): Ralswiek und Rügen: Landschaftsentwicklung und Siedlungsgeschichte der Ostseeinsel Rügen. Teil 1: Landschaftsgeschichte der Insel Rügen seit dem Spätglazial. – Schriften zur Ur- und Frühgeschichte 38, 174 pp.
MANGELSDORF. G. (2000): Zur Ur- und Frühgeschichte des Greifswalder Gebietes, zu den Anfängen des Klosters Eldena und der Stadt Greifswald im 12./13. Jahrhundert. – In: WERNICKE, H. (ed.): Greifswald: Geschichte der Stadt. – pp. 15–32, Helms, Schwerin.
MOORE, P. D., WEBB, J. A. & COLLINSON, M. E. (1991): Pollen analysis. – 216 pp., Blackwell Scientific Publications, Oxford.
MÜLLER, J. (1997): Anthropogene Einflüsse im Uferbereich eines Solls: Bodenverlagerungen als Indikatoren lokaler Landnahme. – Archäolog. Ber. Mecklenburg-Vorpommern 4: 22–29.
PUNT, W. & BLACKMORE, S. (eds.) (1991): The Northwest European Pollen Flora VI. – 275 pp., Elsevier, Amsterdam.
PUNT, W., BLACKMORE, S. & CLARKE, G.C. S. (eds.) (1988): The Northwest European Pollen Flora V. – 154 pp., Elsevier, Amsterdam.
ROTHMALER, W. (1988): Exkursionsflora für die Gebiete der DDR und der BRD, Band 4, Kritischer Band. – (Revised by SCHUBERT, R. & VENT, W.). 812 pp., Verlag Volk und Wissen, Berlin.
RUBOW-KALÄHNE, M. (1960): Matrikelkarten von Vorpommern 1692–1698 nach der schwedischen Landesaufnahme. – Wiss. Veröff. Dt. Inst. Länderkde. Leipzig, NF 17/18: 189–207.
RÜHBERG, N., SCHULZ, W., VON BÜLOW, W., MÜLLER, U., KRIENKE, H.-D., BREMER, F. & DANN, T. (1995): Mecklenburg-Vorpommern. – BENDA, L. (ed.): Das Quartär Deutschlands. – pp. 95–115, Borntraeger, Berlin, Stuttgart.

SCHATZ, T., BORK, H.-R. & DALCHOW, C. (1997): Bodenkundlich-landschaftsökologische Untersuchungen an einem Hangstandort im südlichen Vorpommern. – Mitt. Dt. Bodenkdl. Ges. **83**: 111–114.
SCHMIDT, R. (1991): Genese und anthropogene Entwicklung der Bodendecke am Beispiel einer typischen Bodencatena des Norddeutschen Tieflandes. – Petermanns Geogr. Mitt. **135/1**: 29–37.
SCHNEIDER, R. & KÜHN, P. (2000): Böden des Karlshofes in Groß Methling, Mecklenburg-Vorpommern. – Trierer Bodenkdl. Schr. **1**: 66–71.
SCHUSTER, R. (1989): Bäume und Sträucher von Abies bis Zelkova. Wissenwertes über Freilandgehölze des Botanischen Gartens der Ernst-Moritz-Arndt-Universität Greifswald. – 152 pp., Ernst-Moritz-Arndt-Universität Greifswald, Sektion Biologie.
STEPHAN, S. (1996): Scriptum zur Vorlesung Bodenkunde. – unveröff. Scriptum, Bonn.
VETVICKA, V. (1985): Bäume und Sträucher. – 308 pp., Artia-Verlag, Praha.

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