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The prehistoric human impact on slope development at the archaeological site in Smólsk (Kuyavian Lakeland)

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Abstract. Periods of intense human impact on the relief and lithology of the area of the Smólsk site were recorded during geoarchaeological research accompanying archaeological field work. The phases of occupation of the area are known in detail from the results of the large-scale archaeological research of the site. The slope deposits with buried soils were recorded at the site area and researched in detail with the use of sedimentological, geochemical and micromorphological analyses. Beside geochronological deterioration, the chronology of the artefacts found in layers played an important role in the strict recognition of the age of deposits. The lower part of the studied slope cover is constituted by deluvium and the upper part by tillage diamicton. The origin and the development of the slope deposits are correlated with the phases of an intense prehistoric human impact as defined by the archaeological research. Four main phases of acceleration of slope processes were documented at the site and date to the Early Neolithic, the Middle Neolithic, the Bronze Age and the Early Iron Age.

Key words
slope deposits,
buried soils,
geoarchaeology,
Prehistory,
central Poland

Introduction

Slope deposits are a very important source of knowledge about the phases of intensity of human impact and the range of land use of ancient communities (Kittel 2014 – and references within). It follows that slope surfaces devoid of plant cover are especially sensitive to the slope wash and mass movement processes and tillage erosion is also possible only on exposed surfaces. Human land use has been a main factor of deforestation or reduction in the density of plant cover in the central European territory since the Neolithic. Phases of increase in slope processes in the Middle and the Late Holocene are usually connected with periods of intense human impact while buried soils are recognised as a record of settlement hiatuses (see: Teisseyre 1991; Sinkiewicz 1995, 1998; Stochlak 1996; Zolitschka et al. 2003; Smolska 2005; Starkel 2005; Leopold, Völkel 2007; Dotterweich 2008, 2012; Twardy 2008, 2011; Szwarczewski 2009; Dreibrodt et al. 2010, 2013; Kittel 2014; Twardy et al. 2014). The first phases of slope processes accelerated by human impact were recorded in Central Europe and correlated with the Neolithic occupation (e.g. Godłowska et al. 1987; Stochlak 1996; Sinkiewicz 1998; Zolitschka et al. 2003; Dotterweich 2008, 2012; Starkel 2005; Dreibrodt et al. 2010, 2013). But in some regions, they were noticed for the first time in the Middle Bronze Age (Twardy 2008; Kittel et al. 2011; Twardy, Forysiak 2011; Kittel 2014; Twardy et al. 2014).

Slope deposit covers are quite often found at archaeological sites in central Poland (e.g. Kittel, Twardy 2003; Twardy et al. 2004, 2014; Dziubek, Twardy 2007; Twardy 2008; Kittel et al. 2011; Twardy, Forysiak 2011; Kittel 2014). Usually they are constituted by deluvia and tillage (agricultural) diamicton and sometimes with preserved buried soils (Twardy 2008; Kittel 2014; Twardy et al. 2014). The term "deluvium" is used for deposits originated from slope wash processes and "tillage diamictons" for sediments of anthropogenic agricultural denudation (described in detail by: Stochlak 1978, 1996; Starkel 1987; Teisseyre 1991, 1994; Twardy 2003, 2008; Smolska 2005; Kittel 2014). The deluvial deposit is a stratified or structureless sediment consisting of sands and silts and of humic sandy silts. The tillage diamicton is a structureless humic sediment of the agricultural denudation process resulting from a tillage erosion (Govers et al. 1994). These deposits occur on the slopes subjected to long-term cultivation and they are humic and poorly sorted as a result of ploughing (Sinkiewicz 1998; Smolska 2005; Twardy 2008; Twardy et al. 2014). In central Poland, tillage diamictons are characterised by the very large spread of the slope sediments, with the thickness up to 2.5 m (Twardy 2008; Twardy et al. 2014).

This paper presents the result of detailed research of the covers of slope deposits with buried soils found in the multicultural prehistoric settlement complex at the Smólsk site (Muzolf et al. 2012). The result of the palaeogeographical research corresponds to the archaeological reconstruction of the occupation of the site area and it documents the geomorphologic processes initiated by an intense human impact in the very early period (i.e. in the Early Neolithic).

The Site Setting

The Smólsk site is situated in the eastern part of the Kuyavian (Kujawy) Lakeland in the close vicinity of the border of the Płock Basin (Kondracki 1998). It is located within the recently glaciated area of the youngest Scandinavian Glaciation, the Last Glacial Maximum (LGM) and the geological substratum of the site is glacial till of the morainic plateau of the Weichselian Glaciation (e.g. Molewski 2007; Przegiętka et al. 2008; Nowaczyk 2008; Roman 2010). Roman (2003, 2010) has recorded in the Kuyavian Lakeland the presence of the only horizon of basal till of the Weichselian glaciation with a thickness of 2–5 m. The elevation of the morainic upland rises up to 84 m a.s.l. at the site area and the archaeological site is situated on the local culmination of the plateau, in the immediate vicinity of the edge of the Płock Basin. The Płock Basin is a part of the Vistula ice-marginal streamway (pradolina). A distinct morphological edge of the ice-marginal streamway reaches about 10 m in height. The kettle holes and the subglacial channels with the fill of organic deposits cause a distinct diversity in the terrain relief of the area. The site occupies, in the southern part, a long slope of the small (ca. 1 ha) kettle hole filled with gyttja and peat of 9.5 m thickness (Fig. 1).

The results of our palaeoenvironmental research based on analysis of the profile of organic deposits from the kettle hole basin will be the subject of a paper in preparation. The upper part of 3.5 m of the organic deposits, covering ca. 6000 years, has been examined so far. The results confirm the existence of a small (ca. 1 ha) relatively mesotrophic lake from the Late Weichselian/Holocene transition to the Middle Ages. Periodic fluctuations in the water level and changes in pH of the water were also documented. The dominance of littoral sub-fossil Cladocera remains suggests the generally low water level since the Neolithic. The lake shores were overgrown by plant communities requiring better trophic conditions and the occurrence of only infrequent remains of trees and shrubs in plant macrofossil analysis confirms either deforestation of the close surroundings or an intensively developed swamp belt on the lake shores. The presence of sediment-associated Cladocera taxa may be an effect of an intense delivery of terrestrial inorganic deposits to the lake (Kittel et al. 2014).

The Archaeology of the Site

The archaeological research at the Smólsk site encompassed an area of 8.7 hectares. More than two thousand archaeological features were uncovered, including clay huts, storage pits and waste pits, postholes, burials in clay huts, skeleton and cremation graves, ditches, isolated hearths and a concentration of ceramics. In total 63 thousand artefacts were recorded. The site is a multicultural complex with settlements and cemetery features of the nine main prehistoric chronological-cultural horizons (Muzolf et al. 2012).

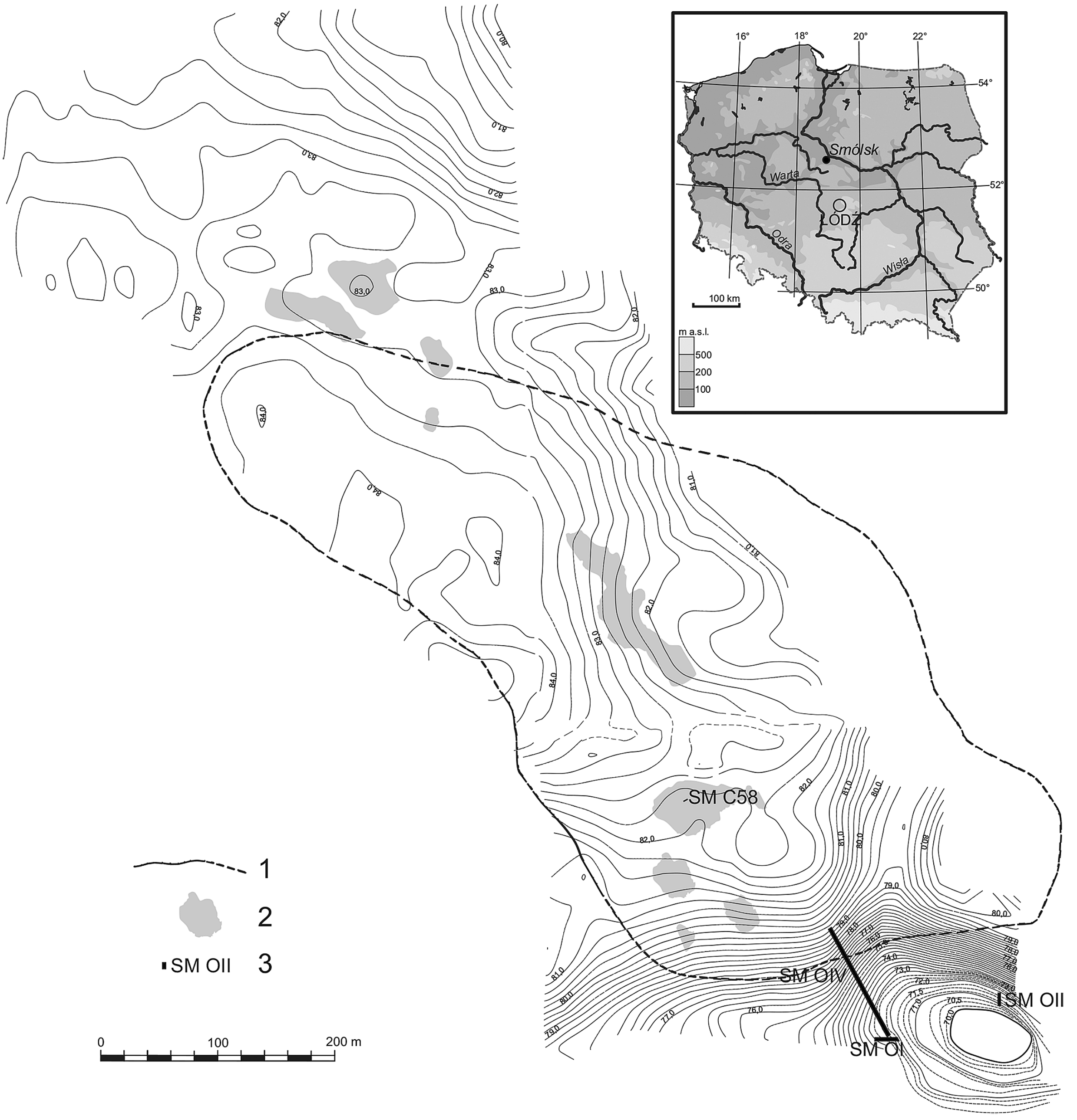

Fig. 1. Situation of the Smólsk site against the terrain relief (topographical map after J. Błaszczyk): 1 – range of the archaeological site, 2 – location of buried small closed depressions, 3 – location and symbols of geological outcrops and lithologic profiles (see Figs 2-4)

The oldest artefacts are associated withthe Late Palaeolithic and the Early Mesolithic. The next horizon is represented by two settlements of people of the Linear Band Pottery Culture (LBPC) with 114 features of relicts of huts, pits and graves situated in two clusters and 20 thousand artefacts (potsherds, stone, flint and bone wares). It was recognised as the basic chronological-cultural horizon at the site dated with the use of radiocarbon dating to 5300/5200–5000 BC. A very interesting discovery is the 5-metre deep LBPC well with a rich set of potsherds. The next Stroked Pottery Culture (SPC, ca. 4700–4550 BC) horizon is represented by 6 thousand artefacts and numerous animal bones and 23 objects clustered within three independent settlements. The settlement of communities of the Brześć Kujawski Group of the Lengyel Culture (BKG, ca. 4500–4000/3900 BC) consists of 26 features in two clusters and 7 human burials, as well as ca. 5 thousand potsherds and flint artefacts and animal bones. The settlements and a skeleton graveyard of people of the Funnel Beaker Culture (FBC, ca. 3950–3380 BC) are confirmed by 117 features, 6 thousand potsherds and 150 flint artefacts and animal bones. Relicts of this culture encompass an area of about 5 ha, forming three distinct clusters of different chronology. A settlement of the Early Bronze Age of people of the Iwno Culture (IC, ca. 2200–1900 BC) and the Trzciniec Culture (TC, ca. 1650–1450 BC) was found at the site also – these communities are represented only by 15 archaeological features. The eighth chronological-cultural horizon and simultaneously the second one in terms of the number of features and artefacts belongs to the Lusatian Culture (LC) with 255 features, 10 thousand potsherds, several thousand mussel shells, several hundred bones, and several dozen stone, flint, horn, and bone wares. These relicts were recognised as the remnants of a several-phase LC settlement from the transition of the Late Bronze Age and the Early Iron Age (VBE/HaC) to the Hallstatt D period (^{14}C dated to 970–790 BC). The later prehistoric horizon is represented by two severely damaged cremation graves of people of the Przeworsk Culture (PC) from the La Tène period (ca. 300–200 BC). Traces of medieval and modern time penetration of the site area are very rare (Muzolf et al. 2012 and B. Muzolf pers. com.).

Methods

Due to the age-old, initiated ca. 7500 year BP, occupation of the site area by successive prehistoric communities and the traces of a very intense occupation in several periods, a geoarchaeological research programme was undertaken. The geoarchaeological research on the evolution and changes in the relief and geology of the site under human impact was conducted during archaeological field work. Recognised slope deposit covers and buried soils were recorded in the small closed depressions of the morainic upland at the site area and on the long slope of the kettle hole situated south of the site (Fig. 1). Slope deposits reach a thickness up to 2.5 m and they contain an admixture of artefacts (mainly potsherds, flint and stone artefacts) and ecofacts (mainly fragments of shells and bones, and charcoal). The occurrence of artefacts is very helpful in the strict determination of the age of the deposition. The age of artefacts has been defined by B. Muzolf, MSc (Museum of Archaeology and Ethnography in Łódź) and P. Muzolf, MSc (Muzolf et al. 2012).

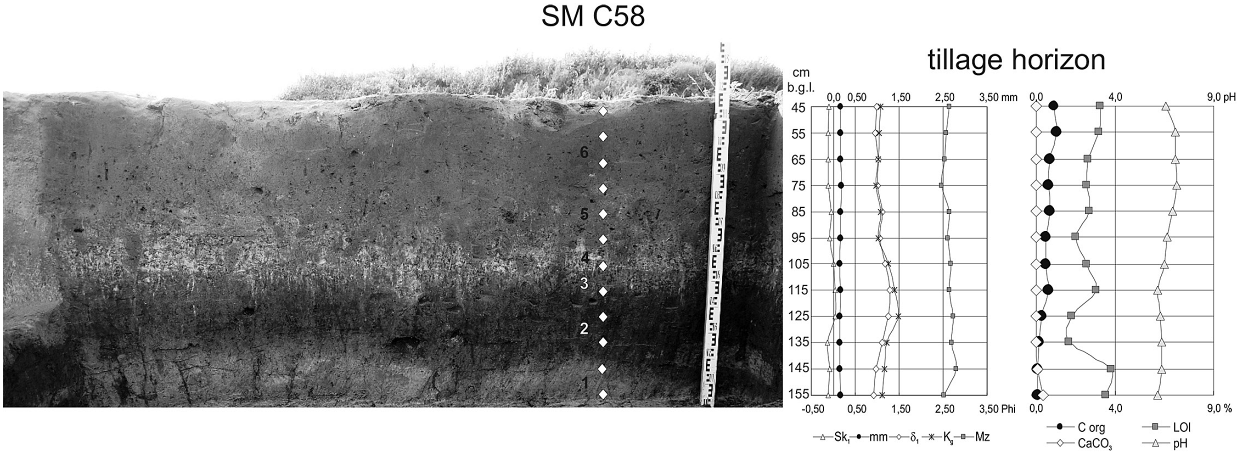

Fig. 2. Sedimentological features of deposits in the lithologic profile SM C58 (see Fig. 1) situated in the small closed depression: 1 – sandy till, 2 – humic clayey sand with LBPC potsherds (buried soil), 3 – silty sand partly humic (soil deluvia), 4 – poorly silty sand (deluvia), 5 – partly humic silty sand with (redeposited?) LC potsherds (tillage diamicton), 6 – humic silty sand (tillage diamicton); Sk_1 – skewness, mm – mean grain size [mm], δ_1 – sorting index (standard deviation), K_g – kurtosis, Mz – mean grain size [Phi], C org – content of organic carbon (%), LOI – Loss on Ignition (%), $CaCO_3$ – content of carbonates (%), pH – pH of deposits

The deposits of fills of the small closed depression were examined within the archaeological exposure (lithologic profile SM C58 – Figs 1 and 2). Three geological trenches were set for the detailed study of the slope cover: 1st 20 × 2 m (called SM OI) and 2nd 105 × 4 m (SM OIV) – both with the greatest depth up to 2.5 m – and the third test pit 10 × 1 m (SM OII) – Fig. 1. Within the research outcrops, five lithological profiles for sedimentological and geochemical analyses and two monolith cores of buried soils were sampled. Sedimentological and geochemical analysis was carried out totally for ca. 100 samples. Analyses were conducted in the Laboratory of the Department of Geomorphology and Palaeogeography at the University of Lódź. Particle size composition of the sediments was examined using sieve analysis (Rühle 1973). The textural features of the mineral material were complemented with Folk and Ward (1957) coefficients. The type of relationship between the mean grain size and the sorting index (the so called co-ordinate system) was defined after Mycielska-Dowgiałło (1995, 2007) and the C-M pattern after Passega and Byramjee (Passega 1964, Passega, Byramjee 1969). The geochemical analysis was conducted with the identification of the basic components of sediments, i.e.: organic matter – loss on ignition method (LOI) in a muffle furnace at a temperature of 550°C, calcium carbonate (volumetric method by means of Scheibler's apparatus), and reaction (potentiometric method – in distilled water). Organic carbon content was measured using wet oxidation of the Turin method (Bednarek 2004).

Three cores of deposits with macroscopically recognised buried soils were collected as monoliths into metal boxes (5 × 10 × 50 cm). These cores with undisturbed structure were examined by micromorphological research (an. A. Budek – see Budek 2010, Budek et al. 2012).

Selected samples of deposits with organic matter admixtures (soil organic matter) were dated by the radiocarbon (^{14}C) method with the use of the LSC technique in the Radiochemical Laboratory of the Archaeological and Ethnographical Museum in Łódź and the Laboratory of Absolute Dating in Skała. For the calibration of radiocarbon data, the OxCal v4.2 calibration program (Bronk Ramsey 2009) with atmospheric data after Reimer et al. (2013) was used. The ^{14}C data obtained from buried soils must be considered as a *terminus post quem* (minimum age) of accumulation of overlaying slope deposits. Because of the different rate of organic matter renewal in humic horizons (Alexandrovskiy, Chichagova 1998), the ^{14}C age of humic horizons can be older than the period of an overlay of researched buried soils. This "mean residence age" plays a very important role for the oldest buried soils but it is not crucial for humic horizons in slope deposits because the period of these soils' development is not so long. The age of layers was controlled by the ^{14}C age of younger (upper) strata and also by the chronology of artefacts found within.

The size and rate of the degradation of the slope and accumulation of the slope deposits were calculated based on parameters (average thickness and cubic capacity) of sediments' cover in the test pit SM OIV for a strip of 1 m in width (a similar method is described by Dreibrodt et al. 2013). The average rate of the accumulation of slope deposits was estimated taking into account the defined age of sediments.

Materials

Buried small closed depressions

The geomorphological investigation confirms the existence of numerous small closed depressions on the surface of the morainic plateau at the site area, which are unrecognisable in the present-day relief of the plateau surface. The immediate surroundings of these hollows were occupied by the settlements of people of the Linear Pottery Culture (i.e. LBPC, SPC and BKG) and later also of the LC. Within one of the depressions, an LBPC well was situated too. The area of the depressions reached from 200 m^2 up to 4,000 m^2 and the depth up to 1.8–2.0 m. The geological substrate of depressions is till. The humic horizon of buried soil of about 25 cm in thickness developed directly in the till surface and existed usually in the bottom of depressions (Fig. 2 strata 2). The content of humus admixture increases in the top of the humic horizon up to ca. 3.5% LOI. Deposits of the layer are typified by a mean size of grains 2.01–2.73 Phi (i.e. 0.15–0.25 mm), a sorting index (δ_1) 1.10-1.29 (i.e. poorly sorted) and a coarse (negative) skewness (Sk_1). The sediments of buried soil were only slightly transformed by very weak slope wash processes. Very well preserved traces of pedogenesis and lack of the movement of coarse fraction within the humic horizon are recorded in microscopic research. Due to the record of the soil forming processes and characteristic pedofeatures, the fossil hydrogenic Gleyic Phaeozems (locally called Black Earths) were recognised (Budek et al. 2012). In the buried soil horizon, Linear Pottery Culture artefacts were found. This fact proves the soil development at least before the early Neolithic and the activity of the slope wash processes from this period.

The buried soils in the bottom of closed depressions are usually covered with fine- and medium-grained silty sands with a low admixture of humic matter (LOI: 2.0–2.5 %). The thickness of that cover reaches up to 20 cm. The deposits are usually coarser than the substrate sediment, with a mean size of grains 2.61–2.68 Phi (i.e. ca. 0.16 mm), better sorted (δ_1: 1.06–1.16) and symmetrically skewed. The described deposit was recognised as deluvium, accumulated after a deforestation of the area as a result of slope wash processes. During the first period of slope wash processes, the humic horizon of existing soil was eroded and deluvium with humic admixtures – the "soil deluvia" (after Stochlak 1996) – was deposited. Traces of lessivage processes and shrinking field with clay and loamy clay were recorded within the horizon (Budek et al. 2012). Changes in environmental conditions led to periodic desiccation of the soil. Deposition of deluvial cover took place in (or after) the Neolithic and not later than in the Early Iron Age, because of the occurrence of the LC potsherds in overlain diamicton and LC features buried in the deluvial deposits.

The top of the fill of closed depressions consists of silty humic (LOI up to 2.5%) sands passing in the contemporary tillage horizon in the upper part. The deposit is marked with a mean size of grains 2.01–2.64 Phi (0.16–0.25 mm) and moderate values of the sorting index (δ_1: 0.8–1.0) with a symmetrical and weakly coarse skewness (Sk_1: -0.26–0.04). The sediments are not structured (massive), characterised by a speckled colouration. These features are typical for a tillage diamicton (after Sinkiewicz 1995, 1998) or an "agricultural deluvia" (after Stochlak 1978, 1996) recorded in numerous places in Poland (Sinkiewicz 1995, 1998; Twardy 2000, 2008; Smolska 2005).

Slope of the kettle hole

The thick (up to 2.5 m) cover of slope deposit occurs on the southern slope of the plateau occupied by the site declining to the kettle hole (Fig. 1). The studied slope decreases downwards with its highest inclination about 5 degrees. No archaeological features were uncovered on the slope but they did occur close to the moraine plateau edge. The artefacts were registered, however, within the slope cover and buried soils. The thickness of slope cover is reduced in the upper part of the slope – it documents a degradational zone in the upper part and an aggradational zone in the lower part of the slope. The buried soils contain a higher admixture of humic matter and organic remains such as plant remains, but also fragments of shells and bones.

The lowest (oldest) buried soil (Fig. 3 strata 7) has a thickness of 50 cm and was developed in the fine-grained sand with organic matter (LOI: 5.7%) on the ancient lake shore and the base of glacial till with carbonates. The sediment contains an admixture of sands of slope wash origin. The first buried soil is a hydrogenic Black Earth (Gleyic Phaeozem). The organic material from the top of the horizon was dated to 10,130 ± 90 BP (LOD 1481), but simultaneously a few early Neolithic artefacts of the Linear Pottery Culture were discovered in the top of the buried soil. The ^{14}C age is therefore too old because of the mean residence age effect resulting from long-lasting accumulation of soil organic matter.

The first buried soil is covered by silty fine-grained sands (strata 6) with a low content of organic matter (LOI: 3.5–4.4%). The lithological characteristic of the deposit is similar to the features of the substrate sediment, with a poor sorting index and a fine skewness as a result of clay content. The sediment was recognised as soil deluvia, which were accumulated about 5000–4000 BC, i.e. during Linear Pottery Culture people's occupation and before 5100 ± 60 BP (LOD 1481), 3967–3802 BC (prob. 68.2%). The second date is from the humic horizon of the second buried soil developed in the deluvia top. The second buried soil (layer 5) was related, based on archaeological chronology and radiocarbon determination, to the settlement hiatus between the BKG and the early FBC communities. The horizon of the second buried soil reached up to 50 cm in thickness in places. It consists of silty fine-grained sands typified by a mean grain-size: 3.22–1.87 Phi (0.11–0.27 mm); δ_1: 0.7–0.9 (moderately sorted); and a coarse skewness. The content of organic matter increases up to 3.15–5.95% – and it is higher in the lower part of the slope. The micromorphological analysis confirmed the traces of the pedogenic processes within the layer and also an admixture of charcoal and shells. The soil has been defined as being of hydrogenic origin and it was periodically submerged (Budek 2010) due to the situation on the former lake shore.

After 5100 ± 60 BP, i.e. ca. 3800 BC, the second buried soil was covered by moderately sorted (δ_1: 0.7–0.8) medium- and fine-grained silty sands with sandy laminas (strata 4); it is typified by a mean grain-size 2.42–1.94 Phi (0.19 do 0.26 mm) and Sk_1 from -0.26 to -0.15. The features of this deposit are typical for the "deluvial sands" after Stochlak (1978, 1996) and Twardy (2000, 2008), accumulated as an effect of a moderately intense slope wash process. It was related to the period of the FBC communities' occupation and the deforestation of the area. In the top of the deluvial sands, the humic horizon of the third buried soil (layer 3) was developed with the thickness of about 25–30 cm. The sedimentological features of the humic horizon are similar to the underling deluvia – a mean grain-size: 2.48–1.54 Phi (0.18–0.34 mm); δ_1: 0.7–0.8; Sk_1 from -0.17 to -0.24 – but the content of organic matter is higher up to 3.5–6.0%. The micromorphological analysis has resulted in the recognition of the features of long-lasting pedogenetic processes with the traces of bioturbations and fragments of shells and plant macrofossils (Budek 2010). The horizon has been dated in the top to 2100 ± 50 BP (LOD 1482), i.e. 182–51 BC (prob. 68.2%), but the LC and modern potsherds were also discovered in the layer.

The deluvial cover dated to Prehistory was recorded in the test pit SM OII (Fig. 4) situated in the northern shore zone of the former lake basin developed in the kettle hole (Fig. 1). Two horizons with rich content of organic matter, covered with the deluvial deposit, were recorded there and dated to 4350 ± 50 BP (LOD 1483), i.e. 3019–2907 BC (prob. 68.2%) and 2680 ± 50 BP (LOD 1484) 895–803 BC (prob. 68.2%). The deluvia were accumulated in the area after ca. 3000–2900 BC in the Late Neolithic or in the Early Bronze Age and after ca. 800 BC in the Bronze Age/Early Iron Age transition.

The upper part of the whole slope cover is formed by a tillage diamicton developed in Modern Times (Figs 3 strata 1–2 and 4 strata 2). These deposits cover a significant part of the modern slope of the plateau and their thickness reaches up to 2.0 m. In the upper part of the slope, the thickness of the tillage diamicton decreases. The layer gradually transforms in the upper part in the contemporary tillage horizon. The deposit is homogeneous, poorly to moderately sorted, formed by various-grained silty and loamy sands with a mean grain-size between 1.96 and 3.94 Phi (0.07–0.26 mm). In the lower part of the slope, sediment is finer and poorly sorted. The LOI of the strata varies from 1.68 to 5.95% indicating few sub-horizons with increased content of humic matter. They are the record of periods of a lower rate of the aggradation and they document intermittent stabilization of the slope surface. Artefacts from the Modern Period were collected in the layer. The layer is defined as tillage diamicton and it was deposited in Modern Times (acc. to Sinkiewicz 1995, 1998). In the lower unit of the slope, the admixtures of organic mud are in the bottom of the layer – it is evidence of ploughing, which included older humic horizons in the first period of the tillage erosion.

The average thickness of the slope cover is 1.45 m and it varies from 0 to 2.2 m in the test pit SM OIV. The average thickness of the agricultural diamicton is 0.93 m and of the deluvia 0.52 m. The cubic capacity of the slope sediment deposited in a strip with a width of about 1 m of the SM OIV is 116 cubic metres, of which agricultural diamicton comprises 75 cubic metres, and deluvia 41 cubic metres. The average thickness of the eroded layer is therefore 0.93 m. The average rate of the aggradation was estimated: for deluvia, for which the period of accumulation is between ca. 5000 BC and BC/AD transition, to 0.1 mm/yr; and for agricultural diamicton accumulated since the mid-19th century – 6.22 mm/yr (or since the mid-18th cent. – 3.73 mm/yr). The above estimates are in line with the calculations of Sinkiewicz (1998).

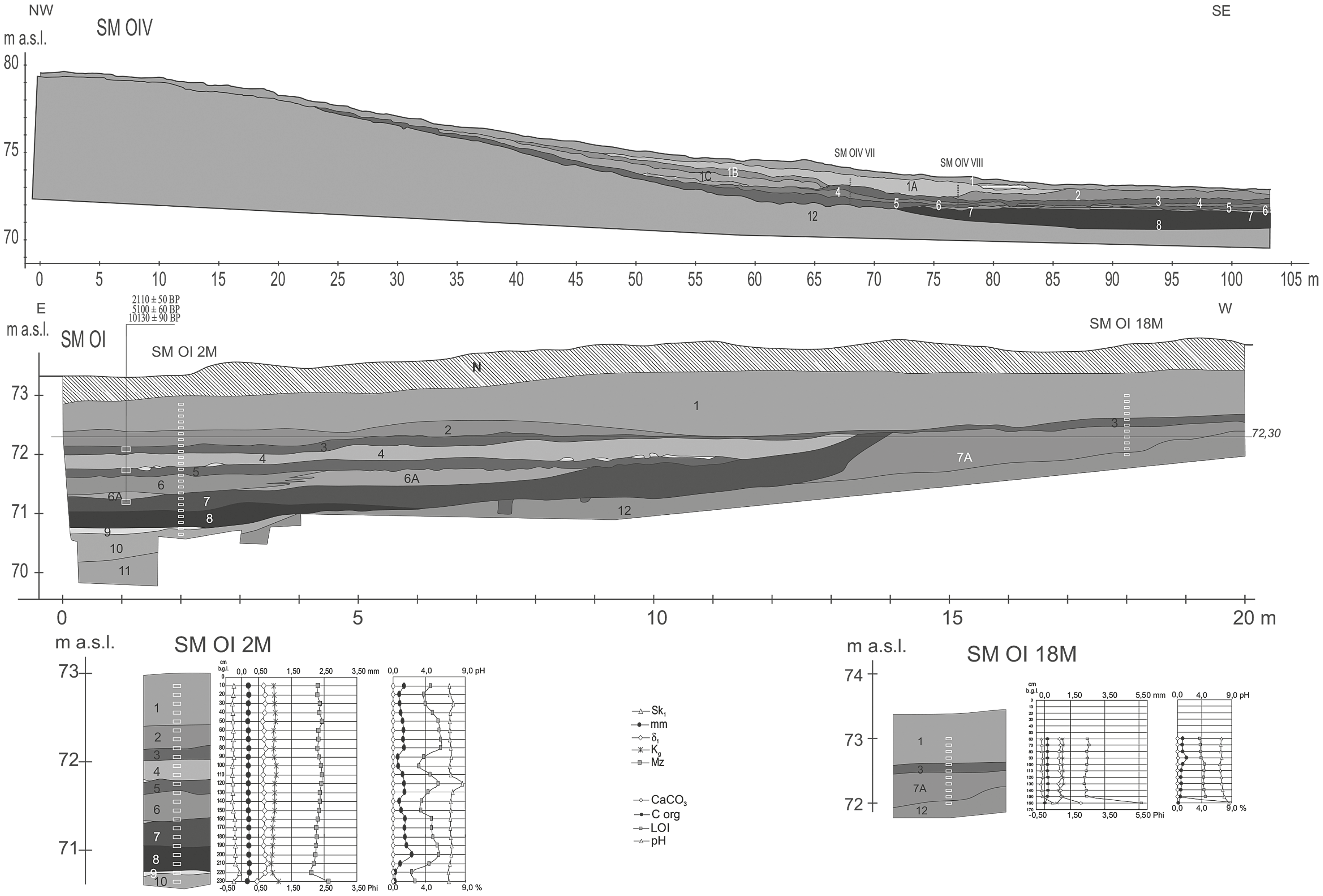

Fig. 3. Sedimentological features of the slope cover in outcrops SM OI and SM OIV (see Fig. 1):
N – embankment, 1 – humic silty sands with modern potsherds (tillage diamicton), 1A – more sandy with gravels, 1B – sub-horizon of buried soil, 1C – partly humic silty sands with modern potsherds, 2 – poorly humic silty sands with organic admixtures (tillage diamicton), 3 – humic sand silty in places with modern and LC potsherds (buried soil), 4 – poorly silty sand partly humic (deluvium), 5 – humic sand silty in places with Neolithic potsherds and fragments of bones and shells (buried soil), 6 – humic sand with gravels (6A) – soil deluvium, 7 – humic fine sand with organic matter, with Neolithic potsherds (buried black soil), 7A – humic silty sands, 8 – fine sand with organic matter, 9 – silty sand with organic mud, 10 – loam with sandy laminas, 11 – laminated loam, 12 – poorly sandy till; Sk_1 – skewness, mm – mean grain size [mm], δ_1 – sorting index (standard deviation), K_g – kurtosis, Mz – mean grain size [Phi], $CaCO_3$ – content of carbonates (%), C org – content of organic carbon (%), LOI – Loss on Ignition (%), pH – pH of deposits

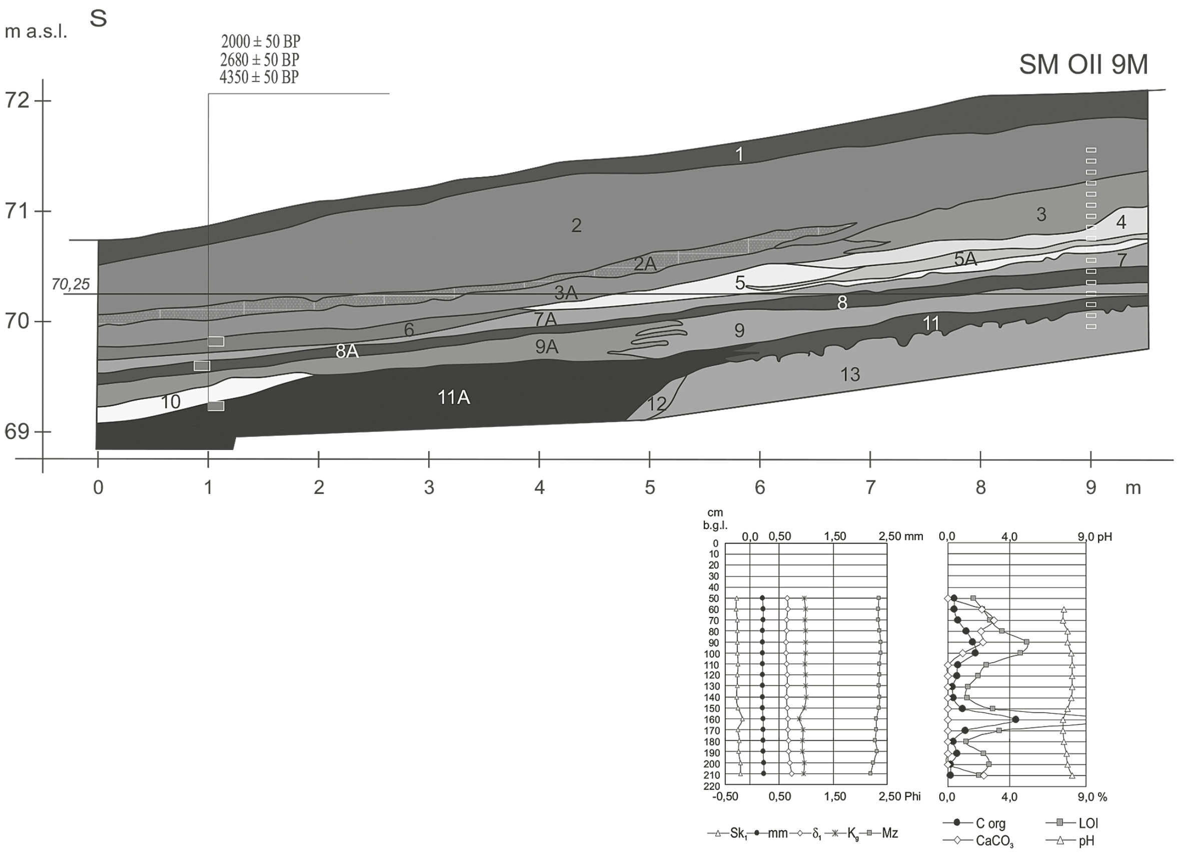

Fig. 4. Sedimentological features of slope cover in the outcrop SM OII (see Fig. 1): 1 – humic silty sand (tillage horizon), 2 – poorly humic silty sand (tillage diamicton) with (2A) ironic admixtures, 3 – humic fine sand, 3A – fine sand with organic matter (slope deposits), 4 – poorly humic fine sand (deluvium), 5 – poorly humic and (5A) humic sand (soil deluvium), 6 – sandy organic mud (lake sediments), 7 – fine sand with organic admixtures (deluvium), 7A –sandy organic mud with plant detritus (lake sediments with deluvial deposits), 8 – fine sand with organic matter (buried soil), 8A – organic mud with plant detritus (lake sediments), 9 – fine sand with organic admixtures (deluvium), 9A – gyttja, 10 – calcareous gyttja with sand, 11 – fine sand with organic mud, with bone fragments (buried black soil), 11A – coarse-detritus gyttja, 12 – sand with plant detritus, 13 – loam; Sk$_1$ – skewness, mm – mean grain size [mm], δ_1 – sorting index (standard deviation), K$_g$ – kurtosis, Mz – mean grain size [Phi], C org – content of organic carbon (%), LOI – Loss on Ignition (%), CaCO$_3$ – content of carbonates (%), pH – pH of deposits

Results and Discussion

The slope cover at the Smólsk site is characterised by the presence of two series of deposits. The upper unit is the modern tillage diamicton with a thickness up to 2.0 m underlain by the deluvium with the horizons of buried soils (the lower unit). The thickness of the slope cover is highest in the lower part of the slope and there reaches 2.5 m while the upper part of the slope was degraded. The thickness of the preserved deluvial cover with buried soils reaches up to 0.7 m. The original slope inclination was approximately 8 degrees, but today it is 5 degrees. The recognised duality of the Mid- and Late-Holocene cover of slope deposits is typical for the Kuyavian Lakeland area and it was described at other sites by Sinkiewicz (1998). A similar situation was documented in other lowland areas in Poland too (Sinkiewicz 1995, 1998; Twardy 2000, 2008; Smolska 2005; Majewski 2014).

In general, the deluvial deposit at the Smólsk site is formed by partly humic silty sands typified by a mean grain size between 1.54–2.73 Phi (i.e. 0.15––0.34 mm), a sorting index 0.6–1.25 (i.e. moderately to poorly sorted) and a coarse (negative) or symmetrical skewness. Down the slope, the sediment is finer. For the deluvia, the relation between the mean grain size (δ_1) and the sorting index (Mz) (Fig. 5) is close to the second co-ordinate system after Mycielska-Dowgiałło (1995) – it is typical for the deluvial deposits (Twardy 2000, 2008; Smolska 2005, 2008; Mycielska-Dowgiałło and Ludwikowska-Kędzia 2011). The relations between the skewness (Sk_1) and the sorting index and also between the mean grain size to the skewness are characteristic for deluvial deposits too (Smolska 2005). The decrease in the skewness simultaneously with the increase in the mean grain size was recognised for "deluvial sands" (Twardy 2008). The situation of samples within the I (1st), II (2nd) and V (5th) class of the C–M pattern after Passega (1964, Passega and Byramjee 1969) shows that the analysed sediments were deposited in a quite dynamic environment (see: Smolska 2005, Szmańda 2007, Mycielska-Dowgiałło 2007, Mycielska-Dowgiałło, Ludwikowska-Kędzia 2011). However, the decrease in the value of the indicators of the process dynamic down the slope was established.

In summary, the features of the analysed lower unit of the slope deposit are typical for the slope wash cover of "deluvial sands" after Stochlak (1978, 1996) and Twardy (2000, 2008), which was deposited as an effect of the moderately intense slope wash process and resulted above all in erosion of the humic horizon of the upper part of the slope. Part of the deluvial deposit contains some admixture of redeposited humic matter and it was recognised as "soil sands" after Teisseyre (1994) or "soil deluvia" after Sinkiewicz (1995, 1998) and Stochlak (1996). These sediments resulted from an erosion of the humic horizon of the original soil on the upper part of the eroded slope in the first stages of the slope wash process activity. This process might be efficient on the inclined surfaces with reduced plant cover, as a result of the human impact on the occupied area.

The phases of the development of the slope cover clearly correlate with human communities' activity at the site area and with distinct anthropogenic changes in the natural environment. The human land-use played a crucial role in an acceleration of the environmental changes resulting in slope wash processes. The deposition of the deluvial sediment has been therefore an effect of natural processes activated in the anthropogenically changed environment, during the periods of intense occupation (Kittel 2014). Starkel (1987) and Twardy (2011) underline the necessity of long-term periods of human impact, connected with a stable settlement, for the development of sedimentological records.

The buried soils recorded within slope cover are manifested by the increase in the humic matter content. Simultaneously, the micromorphological analyses confirmed the presence of the features of the buried soils within deluvial cover (Budek 2010; Budek et al. 2012). The buried soils document the periods of a discontinuation of the slope wash processes and the pedogenetic activity connected with a reforestation of the area as a result of the settlement hiatus. For the younger buried soils developed in the deluvial deposits at the Smólsk site, the radiocarbon data obtained for these horizons are close to the termination of pedogenetic processes and the time of the initiation of the slope wash cover deposition. We have to take into consideration, however, the possibility of a redeposition of an older organic material by the slope wash process. Therefore, for the strict recognition of the age of buried soil horizons, besides geochronometric deteriorations, the content of artefacts and their chronology were important. The documented periods of the soil development are in a strict correlation with the phases of occupation of the site in Prehistory recorded by archaeological research.

The cover of slope deposit (deluvia in Prehistory) was accumulated on the humic horizon of the Black Earth (Gleyic Phaeozem) in the slope-foot in the immediate vicinity of the lake basin shore. The deposition of this sediment was initiated in the Early Neolithic, which is evidenced by the presence of Linear Pottery Culture artefacts. In general, the four main phases of the deposition of the deluvial sediments in Prehistory were recognised at the Smólsk site, as follows:

- 1st phase – not older than the beginning of the occupation of the site area and younger than 5100 ± 60 BP (date from first buried soil) – i.e. between 5300/5200 and 4000 BC and connected with the settlement of people of the LBPC, SPC and BKG,
- 2nd phase – after 5100 ± 60 BP (date from the top of the second buried soil) – i.e. after ca. 3800 BC and connected with the settlement of people of the FBC early phase,
- 3rd phase – after 4350 ± 50 BP (date from the oldest organic layer in SM OII) and before 2680 ± 50 BP (younger buried soil in SM OII) – i.e. between ca. 3000-2900 BC and 900–800 BC and connected with the Late Neolithic and/or the Early Bronze Age settlement most probably of people of the IC and TC,

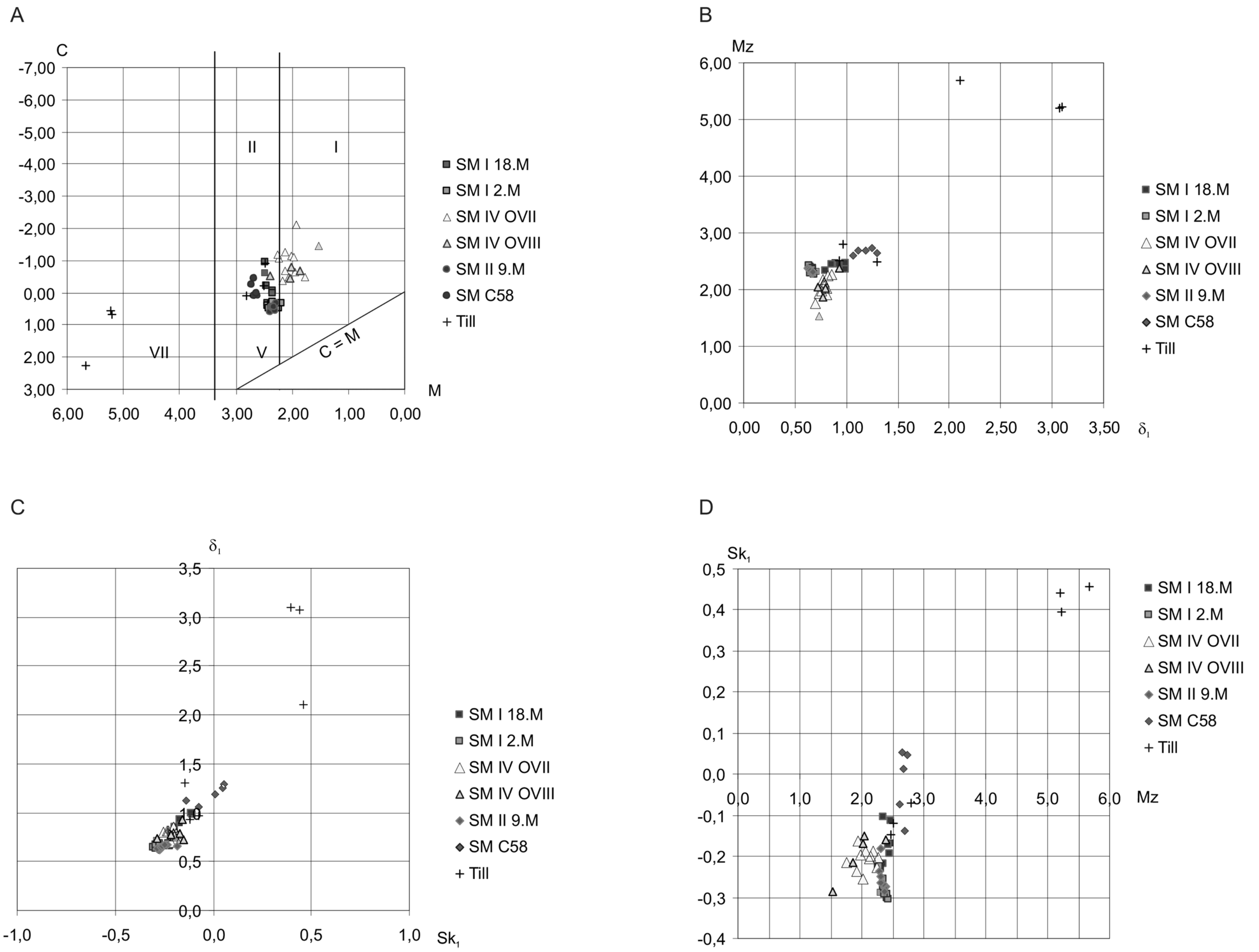

Fig. 5. C-M pattern after Passega (1964), Passega and Byramjee (1969) and relationship between Folk and Ward (1957) coefficients: Mz – mean grain size [Phi], δ_1 – sorting index (standard deviation), Sk_1 – skewness; SM – symbols of lithologic profiles (see Figs 2–4), Till – natural substrate sediments

- 4th phase – after 2680 ± 50 BP – i.e. after ca. 800 BC during the settlement of people of the LC in the Hallstatt Period.

As a result, the four main periods of soil development were determined:

- 1st period – dated to 5100 ± 60 BP – i.e. ca. 4000–3800 BC and connected with the settlement hiatus between the BGK and the FBC occupation,
- 2nd period – 4350 ± 50 BP – i.e. ca. 3000–2900 BC, the hiatus in the Late Neolithic,
- 3rd period – 2680 ± 50 BP – i.e. ca. 900–800 BC, the hiatus in the Late Bronze Age,
- 4th period – 2110 ± 50 BP and 2000 ± 50 – i.e. ca. 200 BC-50 AD, the hiatus in the Pre-Roman Period and the Early Roman Period.

The accumulation of the oldest deluvial deposit was earlier than 4000 BC at the Smólsk site and it was induced in the environment transformed by the Early Neolithic land use. It is one of the oldest records in Poland of the anthropogenic relief transformation. Of great interest is the record of settlement hiatus between BGK and the FBC occupation (ca. 4000–3800 BC) and then the distinct increase in slope processes during the early phase of FBC people's occupation (ca. 3900/3800–3400 BC) at the site area. The slope processes, which were activated in the Neolithic, were recorded in the Kuyavian Lakeland in central Poland (Sinkiewicz 1998) and in southern Poland (Wasylikowa et al. 1985, Kruk et al. 1996; Starkel 2005; Szwarczewski 2009), where the human occupation was more intense in that period. In Pleszów, the slope wash process was dated to ca. 3800 conv. BP (Wasylikowa et al. 1985; Godłowska et al. 1987), i.e. ca. 4300-4100 cal. BP. More often, the earliest deluvial deposits are dated to the Bronze Age in central Poland (Czebreszuk, Hildebrandt-Radke 2007; Twardy 2008, 2011; Dotterweich et al. 2012; Twardy et al. 2014; Kittel 2014). In Germany, the impact of communities of the Linear Pottery Culture is recorded in the acceleration of the slope processes at ca. 7500 cal. BP (ca. 5500 BC), but the increase in their activity occurred ca. 6300–6000 cal. BP (ca. 4300–4000 BC) above all in the southern part of the country. In northern Germany, the first more intense erosion phases are dated to ca. 5600-5400 cal. BP (ca. 3600–3400 BC, connected with the FBC) and 4900–4000 cal. BP (ca. 2900–2000 BC, the late Neolithic). In central Germany, two peaks are recorded: the early Neolithic and, more significant, the late Neolithic. A sharp increase in the number of episodes is visible in the Bronze Age (Dreibrodt et al. 2010). Dotterweich (2008) proves a higher soil erosion activity in the Late Bronze Age in central Europe.

Until now we do not have the results of detailed palaeoenvironmental reconstructions for the close vicinity of the site based on palaeoecological analyses of a lake deposit core from the kettle hole. It is difficult to synchronise the recognised phases of accumulation of slope deposits with natural environmental changes (mainly climatic). However, the defined phases of deluvial deposition are synchronic with the main stages of human occupation of the site area documented by archaeological studies. The topographical and geological conditions at the site were also suitable for the development of slope wash processes.

Conclusions

The thick (up to 2.5 m) cover of the slope deposit was researched at the Smólsk sites, as a source of knowledge about the relief evolution since the Early Neolithic. The slope cover consists of the deluvial deposit unit overlain by the tillage diamicton. The sedimentological features of the lower unit are most typical for the "soil deluvia" and the "deluvial sands". The deluvial cover was deposited as an effect of moderately intensive slope wash processes.

Based on the results of the multidisciplinary research, the main phases of the evolution of the terrain relief under human impact were recognised. The beginning of the slope processes at the Smólsk site was determined for the period as early as ca. 5300–4000 BC and the processes are an effect of the land use of the Linear Pottery Culture communities. After this period, almost three phases of more intense slope processes took place and resulted in the deposition of the deluvial cover in the Middle Neolithic (after 3800 BC, FBC communities), the Early Bronze Age and/or the Early Iron Age. The very intense morphological processes occurred during the FBC people's occupation (Kittel et al. 2014). The slope wash processes were taking place on a slope surface inclined originally up to 8 degrees. The deluvial deposit was accumulated above all on the slope-foot close to the former lake shore. The slope wash deposit was accumulated also within the small closed depressions, which diversified previously the surface of the morainic upland. The surroundings of those depressions were particularly eagerly inhabited and were partly levelled in Prehistory.

The phases of the slope process activity are in strict accordance with the archaeological phases of the occupation of the site. Numerous archaeological relicts were found and they document the intense activity of human communities in the following periods and archaeological records confirmed the intense land use in a few phases, above all in the Neolithic and in the Early Iron Age. The accumulation of the deluvial deposit was an effect of the natural process, initiated, however, by the human factor during the periods of intense settlement and economic activity. The human factor is responsible for environmental changes, which resulted in the creation of suitable conditions for the initiation and development of the slope processes. The human impact must be therefore defined as an indirect factor of geomorphologic (slope) processes (Kittel 2014). The buried soils recorded within slope covers prove the periods associated with the settlement hiatuses resulted in reforestation and finally in the development of the pedogenic processes. The examined phases of soil development were synchronic with the settlement hiatuses registered in the archaeological research.

Thanks to the strict cooperation of the environmental research and the archaeological examinations, it was possible to elaborate detailed studies of the changes in the natural environment elements under human impact from the Early Neolithic. At the Smólsk site, the oldest slope cover in Poland, and one of the oldest in Europe, was recorded, which was deposited as an effect of the early Neolithic communities' activity. The results significantly expand the knowledge about the relation between the natural environment and the human groups in the Neolithic.

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