A palaeoenvironmental reconstruction of the rampart construction of the medieval ring-fort in Rozprza, Central Poland

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Abstract

During archaeological excavations of a medieval stronghold in Rozprza, a buried thick deposit of deep black (Dark Earth type) soil was discovered. A multianalytical (sedimentological, geochemical and archaeobotanical) study was carried out in order to identify traits the Rozprza Dark Earth. The analyses demonstrated that the soil was formed as an effect of surface accumulation of organic deposits from swampy areas and waste materials with rich admixtures of organic materials. The organic carbon content of the soil of the Rozprza Dark Earth was twice as high, and the total concentration of P was many times higher as compared with the adjacent soil outside the stronghold. Plant macroremains which were recorded within the buried soil and a cultural layer are evidence for human activity, mainly wood gathering and agriculture. In the Early Middle Ages, summer crops could be cultivated there with the use of tilling methods characteristic for root crops or gardens. The accumulation of the Rozprza Dark Earth commenced in the second half of the tenth century AD. In the period between the eleventh and thirteenth century, a ring-fort was established there. The deep black soil is partly covered by the ring-fort's rampart. The rampart was built with the use of re-deposited earlier cultural layers and sand of the subsoil. It was then clad with sod bricks. Such a construction of a medieval rampart has been recorded for the first time in the territory of Poland. A new interpretation of archaeological structures and cultural layers offers a basis for new conclusions concerning the chronology and the development stages of the medieval settlement and ring-fort in Rozprza.

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Introduction

Remains of the defensive system of the medieval ring-fort in Rozprza are still clearly visible in the terrain relief. The site is currently covered by meadows and fallow fields, whereas shrubs and trees cover the main mound relicts. Due to the poor state of preservation of the stronghold remnants, an archaeological trench from 1963 was re-opened and re-examined with the use of new methods. The re-excavated trench uncovered full sections of what remained of the rampart. The trenching allowed for a detailed recognition of archaeological structures and cultural layers of the stronghold's rampart on the basis of methods of modern environmental archaeology. Sediments from both the core of the rampart as well as from deposits covered by the rampart were examined with the use of sedimentological, geochemical, archaeobotanical and geochronological analyses. Our results allowed for an identification of deposits and structures which have not been recorded previously in the territory of Poland, such as a “Dark Earth” soil and “sod bricks” used for the construction of the early medieval rampart. The use of various methods of environmental archaeology also enabled us to re-interpret former research results from the 1960s.

Our studies are focused on the depositional history of the medieval buried soil of “Nordic Dark Earth” type (as defined by Wiedner et al. 2015) which was discovered at the site of Rozprza. The aim of the research is the reconstruction of environmental conditions of the “Dark Earth” soil formation at Rozprza, including an intense human impact on this process. The soil is covered by the rampart of the medieval ring-fort from the eleventh to thirteenth century AD. This circumstance ensured the preservation of the early medieval buried soil and allowed to examine its original traits. The construction of the rampart is also unusual in the territory of Poland in that period. Therefore, we intended to reconstruct the building process of the rampart where “sod bricks” were used, with special stress on the environmental condition which accompanied the building activity.

The use of sod bricks from heather, grass or turf was one of the key elements in early medieval building traditions of north-western Europe. It is well known from Scandinavia and north-western Germany. Sod bricks were used for the construction of ramparts of Saxonian fortifications from the ninth to eleventh century AD (Lemm 2013) as well as in several ring-forts in the nearby Slavic territories in the same period (Struve 1975; Donat 1984; Brandt and Schneeweiss 2017). However, this building technique has not been recorded so far in the territory of medieval Poland.

In the Eastern Europe Forest Zone, numerous early medieval settlements are characterised by rarely noticeable deep black cultural layers (e.g. Ambrosiani 2013; Domschke and Wolff 1960). A recent study of Wiedner et al. (2015) suggests that these horizons might be a result of early medieval subsistence economy. However, agricultural areas close to Viking or Slavic settlements are not known and thus intensive horticulture cannot be excluded. Wiedner et al. (2015) demonstrated that the soil within the Slavic settlement of Brünkendorf was comparable to the most fertile man-made soil, the so-called *Terra Preta de Índio* in tropical Amazonia (Brazil). Further systematic interdisciplinary research is needed in order to gain a deeper insight into the development of comparable soils in temperate Europe. Horizontal layers of dark, strongly humic deposits were more or less frequently found at medieval sites in Poland (e.g. Niewęgłowski 1984; Olczak and Krasnodębski 2002; Buko and Dzieńkowski 2008; Sokołowski et al. 2008; Pluskowski et al. 2014). Difficulties in the interpretation of such deposits can be demonstrated by the example from Bonikowo (com. Kościan), where a layer described as “black”, “clay humus” was discovered below embankments of the ring-fort ramparts. It was 0.2–0.65 m thick and contained a large amount of animal and plant remains, as well as fragments of stones bearing traces of burn-out. This stratum was initially recognised as a remnant of the older open settlement (Hołowińska 1956; Hilczérówna 1967). Recently, however, the idea of interpreting this layer as a remnant of the sacrifice and cult activity appeared (Kara 2009). So far, dark, strongly humic horizons have not been regarded as traces of former agricultural or horticultural activity. Therefore, they have not been discussed in reference to the “Nordic Dark Earth” phenomenon, either.

We therefore investigated the remains of the defensive system of the medieval settlement in Rozprza, which are also characterised by the presence of deep black soil.

Thus, the aims of our study are as follows:

- (i) Identification of basic properties of the deep black Rozprza soil
- (ii) Reconstruction of the chronology of the deep black Rozprza soil development
- (iii) Reconstruction of the conditions and chronology of the medieval ring-fort's rampart construction with the use of “sod bricks”
- (iv) Re-interpretation of the traits, chronology and development stages of the medieval settlement and ring-fort at Rozprza

Study area

The site (51° 18' 07" N; 19° 40' 04" E; 182–183 m a.s.l.) is situated in Central Poland ca. 60 km south of Łódź. The remnants of the ring-fort in Rozprza are located in the middle sector of the Luciąża River (third-order river in the Vistula River basin) valley. The valley morphology is crucial for the conditions of the settlement's location and for functioning of the moat. Three river terraces were identified in the Luciąża River valley in the surroundings of Rozprza: the highest Wartanian glacifluvial, the high Pleni-Weichselian and the low Late Weichselian fluvial terrace (Wachecka-Kotkowska 2004).

The ring-fort remnants are situated in the central part of the Luciąża River valley floor on the Pleni-Weichselian residual terrace, which adjoins a floodplain formed in the Late Vistulian and the Holocene. The age of terrace deposits was assessed by optically stimulated luminescence (OSL) dating: 24.7 ± 3.7 ka BP (UJK-OSL-72). The valley floor is strongly expanded in the ring-fort area. An overbank deposit cover with a thickness up to 1 m was identified there. It can be dated back to the Roman Period(?) and the Modern Period (Kittel et al. 2015, 2018a; Sikora et al. 2018) (Fig. 1).

Contemporary climatic conditions in the area are highly variable because of the influence of oceanic and continental

air masses. The average annual temperature is from 8.6 to 8.9 °C and the average annual precipitation varies from 537 to 626 mm per year (<http://www.tutiempo.net>). The mean temperature of the warmest month (July) is 18 °C and the mean temperature of the coldest month (January) is −3.3 °C for the Łódź region (Kłysik 2001).

Potential natural plant communities of the Luciąża River valley near Rozprza would be mostly composed of lime–oak–hornbeam forests representing the *Tilio-Carpinetum* association and to a lesser extent the *Potentillo albae-Quercetum typicum*. East and south of Rozprza, *Vaccinio uliginosi-Pinetum*, *Leucobryo-Pinetum* and *Quercus-Pinetum* would occur in smaller areas. Lowland ash-alder forests and alder of *Fraxino-Alnetum* and *Carici elongatae-Alnetum* associations would grow along river channels (Matuszkiewicz 2008).

Study of the site

Historical data

According to written sources, the stronghold in Rozprza was one of the most important medieval ring-forts in Central Poland in the period from the eleventh to thirteenth century,

Fig. 1 Location of the site

along with Łęczyca, Sieradz and Spycimierz (Kamińska 1953, 1971; Chmielowska 1975; Kajzer 2007; Sikora 2007, 2009). For the first time, the stronghold (*castrum*) is mentioned in the “Mogilno Forgery” (1065 AD). In the “Gniezno Bull” (1136 AD), it is referred to as a one of the most important ducal forts (*castellum*) in Central Poland, paying tribute to such ecclesiastical institutions as the monastery in Mogilno and the Archbishopric of Gniezno.

On the basis of the knowledge of the chronology of the First Piasts Monarchy, we can assume that Rozprza was incorporated to the Polish state in the second part of the tenth century. In the patrimonial monarchy, it was certainly a ducal property. It was governed by officials who in the thirteenth century began to be called “castellans” and who are known from written sources (Zajączkowski and Zajączkowski 1970; Chmielowska 1966, 1982).

One of the best identified castellans was Florian. He served under Duke Leszek Czamy and was the castellan in Rozprza in the 1250s and 1260s. Szyszka (2007) assumes that Florian could be an initiator of redevelopment of the stronghold. A necessity for redevelopment of the fort could be related to supposed military operations in the close vicinity of Rozprza in the mid-thirteenth century in the course of the Mongol invasion in 1241 AD. In 1247 AD, Duke Kazimierz of Kuyavia also had to use force to gain control over the fort.

In the Middle Ages, the name “Rozprza” can be assigned to both the fort and a neighbouring town. The town was situated about 1 km to the west of the stronghold. The fort is undoubtedly earlier than the town, which was probably founded in the second half of the thirteenth century (Zajączkowski 1961; Wlaźlak 2009). The fort and the town could have different owners at the same time (Zajączkowski 1961)—a duke and a private person. Most scholars point out that the stronghold came into private hands in the second half of the thirteenth century or the first half of the fourteenth century (Zajączkowski 1961; Chmielowska 1982; Szyszka 2007).

The town of Rozprza became private property ca. 1324 AD (DFKR). The new owners of the stronghold and the town (the Nagodzice-Jelitzycy clan) (Szyszka 2007) most probably decided to rebuild their residence (fort). In 1344 AD, King Kazimierz Wielki abolished customs in Rozprza. This implies that the town was not royal property anymore (Zajączkowski 1961; Wlaźlak 2009), or the king merely legitimised the actual status quo (Szyszka 2007).

It is likely that castellans did not reside in Rozprza in the fourteenth century, and from that time, the town began to lose its position to neighbouring Piotrków (Zajączkowski 1961). Probably in the fifteenth century, the owners ceased to invest in the fort. In the sixteenth century, this area belonged to a local Catholic church and was used as a meadow (Łaski 1521; DFKR 1521; ADKPwR 1588; KDMiPR 1754; KH 1885). In 1685 (KDMiPR), it was also mentioned as a meadow under a local name “kopiec” (mound—motte).

Previous archaeological data

The ring-fort was archaeologically excavated for the first time in the 1960s by Chmielowska (1966, 1982). This researcher distinguished four phases of the stronghold’s development between the ninth and fourteenth century AD. The last phase was dated to the thirteenth and fourteenth century. In this period, the stronghold was supposed to be a noble family’s private residence, probably of the motte type. It was built at the site of the earlier early medieval ring-fort.

Chmielowska (1982) dated the first phase of the feature to a broad framework between the sixth and ninth century AD. A distinctive layer of “burned material with a distinctive dome-shaped elevation on the edge of it” was identified as remains of this settlement phase. The earliest ring-fort had a diameter of about 25 m, with the rampart being 2.5 to 3.0 m wide. The diameter of the inner yard was about 18–20 m. The height of the preserved rampart would be only a few dozen centimetres (!) (Fig. 2).

In the second phase, dated to the ninth century, the ring-work had to be rebuilt after a previous “total disaster”. The aforementioned layer of burned material was believed to be a result of this event (according to Chmielowska 1982). It was assumed that the rampart of the second phase was reconstructed with the use of earth and timbers. It was supposed to be about 7 m wide and was reinforced with “two diagonally arranged piles of beams lying along the rampart” (Chmielowska 1982). An axe of the Great Moravian bradatic type was found “on the outer slope of the rampart”. This artefact is considered as a confirmation of the chronology of this phase (Chmielowska 1966, 1982; Sikora 2009; Kotowicz 2014).

The third phase of the stronghold was assumed to be related to the Piasts’ State. Such an assumption implies that this phase should be dated to the second half of the tenth century. The most significant period of the stronghold’s existence in this phase was dated to the twelfth–thirteenth century. The rampart had to be enlarged on the top of the earlier phase by adding timber boxes filled with rocks and by constructing an additional wooden front structure. This way, the entire premise reached a width of approximately 11 m. Outside the rampart, a moat with a width of 12 m was dug, and an external embankment of approximately 8 m width was made (Chmielowska 1982).

The last phase extends from the mid-thirteenth to the second half of the fourteenth century. A further development of the fortifications took place and it is even possible that “they were shaped in the conical (motte-type) form”. Remains of four open settlements were believed to have been discovered around the stronghold relics. These settlements were arranged on “hillocks” (Chmielowska 1982) (in fact, it was one elevated surface of a terrace remnant).

The results of archaeological research have been closely linked with the written sources and works of historians, who indicated the importance of Rozprza in the early medieval settlement network. The aforementioned references in the

Fig. 2 Cross-section of the Rozprza stronghold rampart after Chmielowska (1982). Original drawing of the southern wall of trench 1/1963 was digitally processed and mirrored for a better compression with Fig. 4 (J. Sikora). Description after Chmielowska (1982)—and interpretation after the authors: 1. “present-day humus”—stratigraphic unit (S.U.) 1: contemporary humic sand of topsoil. 2. “clay”—S.U. 258: humic sand mixed with clay (slope deposit). 3. “daub”—S.U. 265,

266: humic sands (slope deposits), and S.U. 262: clay. 4. “dark grey earth”—several S.U.s. of the late medieval motte relics. 5. “Burnt timbers”—S.U. 263: humic sand and S.U. 270: sod bricks. 6. “Burnt earth”—S.U. 273A and S.U. 273B: humic sand of the “Dark Earth” soil. 7. and 8. “Vertical posts” and “horizontal beams”—several S.U.s. of the late medieval moat slope timber construction. 9. “Yellow-greyish sand”—S.U. 271, S.U. 272: sandy core of the ring-fort rampart

Mogilno Forgery and the Gniezno Bull from 1136 AD are usually interpreted as lists of administrative centres of the Piasts’ monarchy (Zajaczkowski 1961; Chmielowska 1966; Lalik 1967; Rosin 1970; Sikora 2009). References to the castellans in later sources (thirteenth–fourteenth century) sources were also interpreted as a proof for a relatively high importance of Rozprza in the administrative system of the medieval Polish state. It seemed that the results of archaeological research “confirmed” these observations (Chmielowska 1966, 1982).

The aforementioned results of research carried out by A. Chmielowska were widely accepted and quoted in the literature of the subject—see: Kamińska (1971) and Chmielowska and Marosik (1989). However, Sikora (2009) questioned the reconstruction of the earliest phase proposed by Chmielowska (1966, 1982). Sikora rather suggested the existence of an open settlement. He also paid attention to the fact that layers of the rampart’s second phase contained potsherds which may not be dated back to the period before the mid-tenth century AD in Central Poland. This ceramic assemblage with a number of wheel-made vessels could not appear there before the mid-tenth century. Its presence indicated a need to correct the chronology of the origins of the fort. Furthermore, in the opinion of Sikora (2009), the last phase of the fortifications (the fourth phase after Chmielowska 1982) was rather related to the fourteenth century. It is confirmed also by the results of detailed research on the moat fill (Kittel et al. 2018a, b).

The result of our study is a re-interpretation of previous conclusions about the chronology, shape and development stages of the ring-fort in Rozprza (see “Stratigraphy—a new archaeological re-interpretation” section).

Materials and methods

The interdisciplinary approach combined several geoarchaeological and bioarchaeological methods in order to gain a comprehensive insight into the environmental history of the medieval ring-fort in Rozprza and the impact of intensive land use by man.

Field work

In 2013–2015, a non-destructive survey of the ring-fort surroundings was carried out at Rozprza. The research included analytical field walking, aerial photography and geochemical and geophysical prospection (magnetic gradiometry and earth electrical resistance), along with detailed geological mapping with the use of a dense network of coring. The combined results provided new data which is useful in the reconstruction of the distribution of the moat system, ramparts and other features of the ring-fort complex (Kittel et al. 2015; Sikora et al. 2015a, b).

In 2015–2016, an intense field work was undertaken with the use of archaeological trenches (Fig. 3). This allowed for recording of archaeological structures and cultural layers of preserved rampart features as well as moat fills (Kittel et al. 2018a, b). The trench marked as “1/1963” (Fig. 4), 3 m width and 27 m long, crossed the preserved part of the stronghold’s earthwork. It was the aforementioned re-opened trench from the field work of Chmielowska in 1963. The aim was to re-document it with the use of modern digital tools (such as photogrammetry), to re-analyse the stratigraphy of the remnants of the earthwork and to collect finds and samples for establishing the chronology of subsequent phases of the stronghold’s development. First, the northern wall of the trench was analysed and documented. Only the lowest contexts, preserved in the “steps” left in 1963 in order to secure the stability of the sandy sections underwent exploration according to the stratigraphic units (S.U.) order.

Sampling strategy

After documentation of the trench wall, three profiles of samples taken every 5 cm were collected both from the rampart layers and underlying units (Fig. 4; Table 1). The main profile (RP WW) was situated in the central part of the rampart’s remnants. It covered the deep black “Dark Earth” buried soil (partly re-deposited) (S.U. 273A and 273B) and underlying layers (S.U. 274, 275, PLV). The samples were collected for plant macroremains and phytoliths, as well as for textural and

Fig. 3 Plan of the location of trenches and research profiles

geochemical analyses. For the analysis of plant macroremains, two separate samples were also taken from humic sand layers within the rampart's earthwork, i.e. within S.U. 272 (samples 272a and 272b). Also, one separate sample for the plant macroremains analysis and six samples for phytoliths were collected from “imbricatus” structures of humic sands identified as relicts of sod bricks fastening the rampart surface S.U. 270 (samples T1, T2, T3—Fig. 4). Profile RP M was situated below the inner slope of the rampart of the first phase. The third profile RP M2 was located below the preserved rampart relicts in the courtyard area. Both profiles RP M and RP M2 covered the “Dark Earth” (S.U. 273B), underlying layers of yellowish sand and brownish soil (S.U. 274 and 275), as well as basement deposits (S.U. PLV). Next, one sample for plant macroremains and six samples for phytoliths analyses were collected.

Two referential profiles were also prepared: the first one (RP RM) from the area outside the main moat of the ring-fort and the second one (RP GE) from the isolated terrace remnant 150 m NE of the stronghold. In profile RP RM, samples were collected from buried soils and basement deposits for plant macroremains and textural and geochemical analyses. Textural and geochemical analyses were carried out for profile RP GE.

Bulk soil samples from profiles RP M2 and RP GE were analysed in terms of pH, soil organic matter composition (C and N), isotope signature ($\delta^{15}\text{N}$) and total P. In profile RP M2, bulk soil samples were taken at 10 cm increments down to the depth of 80 cm from the “Dark Earth” (S.U. 273B). In profile RP GE, bulk soil samples were taken from the adjacent reference soil with no visible traces of anthropogenic influence, also at 10 cm intervals.

Fig. 4 Trenches 1/1963 and 6/2016: section of the Rozprza stronghold's rampart (orthophotoplan of the northern wall of the exposure after Sikora 2015). Research profiles RP WW, RP M and RP M2 and radiocarbon dates are marked

Table 1 Deposits profiles studied by archaeobotanical, sedimentological and geochemical analyses at Rozprza

Symbol of profile (for the location, see Figs. 3 and 4)	Stratigraphical unit (S.U.) analysed (see Figs. 6, 7, 8, 9 and 10)	The number of samples for plant macroremain analysis	The number of samples for phytolith analysis	The number of samples for textural analysis	The number of samples for geochemical analysis
RP WW	PLV, 275, 274, 273B, 273A, 272, 270	18 + 3	17 + 6	22	22
RP M	PLV, 275, 274, 273B	12		16	16
RP M2	PLV, 275, 274, 273B	13		17	17 + 8 bulk samples
RP RM	PLV, 165, 164, 163, 162	16		22	22
RP GE				12	12 + 8 bulk samples

Stratigraphic, sedimentological and geochemical analyses

Stratigraphic analysis

The basic stratigraphic layout consisted of several subsequent layers, which were analysed in terms of their archaeological and geological characteristics as well as their mutual stratigraphic relationships with the use of the Harris (1979) method, with further improvements (Herzog 2004). The S.U. were defined, described and numbered (Fig. 4). Their stratigraphical relationships were defined during the field work. They were recorded with the use of basic field description (using Strati5 and Stratify software (Sikora et al. 2016) as well as by means of 2D and 3D digital photogrammetry methods with subsequent digital post-processing in GIS and vector drawing software (Sikora and Kittel 2018). The stratigraphy of the site which was analysed with these tools helped to establish the relative chronology based on the sequence of the following units (or contexts): deposits; cuts; structures, such as timber constructions; as well as key contacts between them.

Sediment texture analysis

For profiles RP WW, RP M, RP M2, RP RM and RP GE, the analysis of particle size distribution for silty sediments was made with the use of a Malvern Instruments Mastersizer 3000 Particle Analyzer. This device allows for measurements of the particle size in the range of 0.01–3500 µm. For the sieve analysis of sandy deposits, a 200 × 25-mm sieve set was used, in accordance with DIN ISO 3310-1 and BS 410-1 norms (sieve size 63–2800 µm). The sieve was coupled with a Retsh AS 200 basic Vibratory Sieve Shaker. All samples had the same weight (100 g), and they were measured with an amplitude of 0.8 for 10 min without the interval function. And then the textural features were evaluated using Folk and Ward (1957) coefficients. GRANULOM software (with some modifications) was used for the graphic presentation of results. The relationship between the mean grain size

and the sorting indexes (the so-called co-ordinate system) was analysed with the use of methods proposed by Mycielska-Dowgiałło (2007). Sedimentological analysis is crucial for the recognition of depositional environments and geomorphologic processes responsible for accumulation of deposits, especially sediments with massive structure.

Geochemical properties of soil and sediment

pH For profiles RP WW, RP M, RP M2, RP RM and RP GE and for bulks from profiles RP M2 and RP GE, soil pH was measured using suspensions with distilled water (1:2.5) and 0.01 M CaCl₂ (1:5) for determining absorbable forms of magnesium according to the Schachtschabel method. Soil pH for all samples was determined in the supernatant, after at least 1 h of shaking in a low-speed shaker and sedimentation of solids for at least 1 h at room temperature.

Carbonate Calcium carbonate content (both for profiles RP WW, RP M, RP M2, RP RM and RP GE and bulk soil samples from profiles RP M2 and RP GE) was determined by volumetric methods. Scheibler's calcimeter (Jackson 1958; Bengtsson and Enell 1986; Woszczyk and Szczepaniak 2008) was used for the calculation of organic C stocks.

Elemental composition (C and N) and $\delta^{15}\text{N}$ The organic matter was measured by the loss-on-ignition method (LOI). Samples were first dried in 105 °C with constant weight. Then, they were roasted at the temperature of 500–550 °C for at least 5 h (Bengtsson and Enell 1986). The next stages were 3 h, and the last one consisted in roasting the samples for 1 h. In the case of the weight loss after the third burning, analyses were repeated until a constant sample weight was achieved. A SNOL muffle furnace was used for the loss-on-ignition analysis.

Total organic C, total N and $\delta^{15}\text{N}$ of bulk soil samples (RP M2 and RP GE) were measured using a EURO EA Elemental Analyzer (EuroVector, Hekatech, Germany) coupled via a Conflo III Interface to an isotope ratio mass spectrometer

(IRMS; Finnigen Delta V Advantage, Thermo Scientific, Bremen, Germany).

Total P content For total P extraction, 3 g of dried and sieved bulk soil (RP M2 and RP GE) was weighed in glass tubes and digested with 21 mL HCl and 7 mL HNO₃ for 16 h without heating and then for 90 min at 120 °C. After cooling (1 h), samples were filtered into a 100-mL volumetric flask. Volumetric flasks were filled with deionised water. Diluted samples were analysed using an inductively coupled plasma optical emission spectrometer (ICP-OES, ULTIMA 2, HORIBA Scientific S.A.S, Jubin-Yvon, France).

Archaeobotanical analyses

Plant macroremains

The samples for the analysis of plant macrofossils were collected from three profiles RP WW (21 samples), RP M (12 samples) and RP M2 (13 samples) situated below the rampart and one profile RP RM (16 samples) outside the rampart. One sample RP T1 was taken from a sod brick used for fastening of the rampart (Fig. 4). In the laboratory, each soil sample of known volume was soaked in water and the floating fraction was poured through sieves with 0.5 mm mesh. Heavy fraction was sieved with the use of ca. 2 mm mesh sieves in order to collect mineralised plant remains and other heavy artefacts (potsherds, bones, etc.). Both charred and uncharred plant remains were sorted out. The greatest total volume of examined soil originated from profile RP WW (65.1 L). Next, there were profiles RP M (9.5 L), RP M2 (3.96 L), RP RM (4.2 L) and RP T1 (0.8 L). Macrofossils were identified with the use of keys and atlases (e.g. Greguss 1945; Grosser 1977; Berggren 1969; Cappers et al. 2006; Kats et al. 1965; Schweingruber 1978; Schweingruber et al. 2011; Velichkevich and Zastawniak 2006, 2008), as well as the reference collection of modern seeds, fruits, wood and charcoal and the collection of fossil floras stored in the Palaeobotanical Museum of the W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków. Diagrams were prepared with the use of POLPAL software (Nalepka and Walanus 2003).

Phytoliths and other biogenic microparticles

The main method involves a consecutive microscopic study of different types of biomorphs. Samples of 50 g each are treated with a 30% solution of hydrogen peroxide. They are then separated from quartz and other mineral grains by flotation in a heavy liquid, usually a mixed cadmium iodide and potassium iodide solution with a specific gravity of 2.3. After centrifugation, the floating siliceous and organic microbiomorphs are collected and washed several times with distilled water. Next, they are immersed in oils (glycerine) for optical microscope study at

magnifications ranging from $\times 200$ to $\times 900$. The entire assemblage of microbiomorphs is identified and counted including phytoliths, diatoms, spicules, detritus and others. Nomenclature of microbiomorphs is given after Golyeva (2007). Quantitative assessment allows for comparisons of their distribution between samples. At Rozprza, a total number of 23 samples were studied from profile RP WW and from sod bricks.

Geochronology

Four samples of selected plant macroremains from the RP WW core and the humic layer within S.U. 272 (Fig. 4) were dated with the radiocarbon (¹⁴C) method, using accelerator mass spectrometry technique (AMS) (see Goslar et al. 2004 and Krapiec and Walanus 2011 for details). The OxCal ver. 4.2.3 calibration software (Bronk Ramsey 2009) was used for the calibration of radiocarbon dates, using atmospheric data provided by Reimer et al. (2013). The absolute chronology determinations were carried out in the Laboratory of Absolute Dating in Skala (Poland) in cooperation with the Accelerator Mass Spectrometry Laboratory in Seattle (D-AMS signature) (see Zoppi et al. 2007 for details).

Results

Absolute chronology of the buried soil and the rampart earthwork

Two radiocarbon dates available from profile RP WW indicate that plant remains recovered from layers 273A and 273B are of more or less the same age (Fig. 4; Table 2). A charred wheat grain (*Triticum aestivum/spelta*) from the top of layer 273B was dated to 690–872 AD with a probability of 68.2% and 659–962 AD with a probability of 95.4% (D-AMS 015984). Charred millet grains (*Panicum miliaceum*) from the top of layer 273A yielded the date of 677–868 AD (68.2%) and 649–968 AD (95.4%) (D-AMS 015983). The date of 568–679 AD (68.2%) and 433–770 AD (95.4%) (D-AMS 015985) was obtained from wood charcoal from the bottom of layer 275. It probably documents (as a *terminus post quem*) the very beginning of medieval occupation of the area.

It must be emphasised that potsherds from layers 273A and 273B were of a later age than the radiocarbon data set. The pottery is dated to the period between the mid-tenth and the beginning of the twelfth century AD. We cannot exclude that the soil (S.U. 273B) which formed before the construction of the ring-fort was mixed with later artefacts. However, these potsherds were recorded within the whole thickness of the buried soil. Therefore, the buried soil most probably formed in the tenth–eleventh century AD with admixture of deposits containing (partly) earlier ecofacts, such as charred cereal grains. Alternatively, we can relate the age of the grains to the mid-

Table 2 Radiocarbon data set from trench 1/1963

Stratigraphical units (S.U.)	Dated material	Depth in the WW profile [cm]	^{14}C age years BP	Laboratory code	Calibrated age (cal AD, prob. 68.2%)	Calibrated age (cal AD, prob. 95.4%)	Remarks
272	<i>Picea abies</i> (charred leaf)		1185 $\pm$ 55	MKL-3505A	770–941 AD	690–975 AD	Sample 272a (see Table 3)
273A (top)	<i>Panicum miliaceum</i> (4 charred grains)	0–5	1250 $\pm$ 80	D-AMS 015983	677–868 AD	649–968 AD	
273B (top)	<i>Triticum aestivum/spelta</i> (charred grain)	20–25	1236 $\pm$ 71	D-AMS 015984	690–872 AD	659–962 AD	
275	charcoal	75–80	1402 $\pm$ 71	D-AMS 015985	568–679 AD	433–770 AD	

tenth century, as confirmed by 95.4% probability of the ^{14}C data range.

The radiocarbon date of 770–941 AD (68.2%) and 690–975 AD (95.4%) (MKL-3505A) for charred spruce leaf from a humic lamination within layer 272 (Fig. 4) is too early if compared with the chronology of the archaeological material from this layer (see “[Archaeological chronology of stratigraphic units](#)” section). Therefore, what was actually dated was an effect of a re-deposition of sediments containing charred plant macroremains.

Archaeological chronology of stratigraphic units

Typological and technological analyses of potsherds were also used for establishing the chronology of the archaeological contexts. Almost 30,000 (29,553 finds) potsherds were excavated in the years 2015 and 2016 at the site in Rozprza; 386 potsherds were found altogether in layer 273B. Parts of this assemblage were hand-made vessels, with only upper parts having been processed with the use of wheel. They were ornamented with carved waves, which are typical for the ninth and tenth centuries. Among them, a certain number could be related to type Menkendorf, which was popular in north-western Slav areas (Schuldt 1956; Łosiński and Rogosz 1986; Cnotliwy et al. 1983). On the other hand, a large number of wheel-made potsherds which were ornamented with horizontal lines were typical for the period after the mid-tenth century. The entire assemblage is typical for the so-called phase D of development of early medieval pottery in Greater Poland (Hensel 1948; Hilczerówna 1967; Dzieduszycki 1982). Therefore, it should be dated to between the mid-tenth and mid-eleventh century.

The chronology of later layers of the ring-fort rampart is not clear. One hundred and four potsherds were found in layers 273A and 272. Some of them are similar to those from layer 273B and should be considered as re-deposited during the development of the earthwork. Several potsherds of later wheel-made vessels were also found. These can be dated to the eleventh–twelfth century. It should be mentioned that in S.U. 272 a very small number of potsherds which are datable to the

thirteenth century was found. These are two pieces which are typical rather for the so-called group A according to Kajzer (1991). Taking into account a possible re-deposition caused by soil fauna, whose activity traces were noticed in some parts of the layer, all we can suggest is a wide chronological framework between the eleventh and thirteenth century.

In the layers of the motte mound and the bottom strata of the moat (in trenches 1/1963, 1/2015 and 3/2015), late medieval pottery was found, including “traditional” as well as more advanced black or grey vessels. Grey and black pots were fired in reducing atmosphere, and such pottery appears in the territory of Poland territory in the thirteenth century (Kruppe 1981). The whole assemblage of pottery from the moat and motte mound should be dated to the second half of the thirteenth and to the fourteenth century.

Stratigraphy—a new archaeological re-interpretation

The analysis of features uncovered in 2015 in trench 1/1963 led to a need for important changes in the interpretation of stratigraphy, as well as in the chronology of the rampart’s development, as compared with observations proposed by Chmielowska (1982) (see “[Previous archaeological data](#)” section; Fig. 5; Table 3).

The section of the rampart obtained after the unveiling of the trench fill from the 1960s generally corresponds to the situation documented by Chmielowska (Chmielowska 1982: Fig. 2—see Fig. 2). However, there are some differences, which were a result of inaccurate field documentation in the 1960s. Uncovering the section allowed for making necessary corrections in the interpretation of several stratigraphical units. Additional difficulties in the observation and interpretation of the layers resulted from bioturbation associated with the activity of wild animals (such as fox and badger), which disturbed the medieval stratigraphic systems. Moreover, it was possible to acquire artefacts and ecofacts from key contexts, including the layer of “burned material”, discussed by Chmielowska (1966, 1982). It turned out that it was deep black and strongly humic sand with admixture of charcoal, wood and other plant

Fig. 5 Stratigraphy and chronology of stratigraphic units (S.U.) in trench 1/1963: top: after Chmielowska (1982); 1. first phase; 2. second phase; 3. third Phase; 4. fourth phase (according to Chmielowska); 5. parts destroyed by animal burrows. Bottom: re-interpreted by the authors. 1. Prehistoric or early medieval cultural layers (between the fifth and eighth century AD); 2. “Dark Earth” soil (second half of the tenth to first half of the eleventh century AD); 3. rampart of the medieval ring-fort (between the second half of the eleventh and thirteenth century AD); 4. slope deposits from the destruction of the rampart; 5. fill of the late medieval moat and the motte mound (fourteenth century AD); 6. timber constructions of the late medieval moat (ca. 1330 AD); 7. pits which remained after the demolition of the foundation of the late medieval manor house or a keep; 8. slope deposits—erosion of the late medieval mound; 9. early modern posts (sixteenth century AD); 10. parts destroyed by animal burrows

macroremains, as well as with sand and clay additions. This layer was recognised in the field as “Dark Earth” buried soil and was marked as S.U. 273B. The layer which was considered by Chmielowska (1982) as a remnant of the earliest stronghold can in no case be regarded as a relic of the defensive rampart. The nature and origin of the “buried material” layer (S.U. 273) is one of the main issues discussed in this paper. In terms of stratigraphy, it should be separated (in profile RP WW) into two levels: the horizontal layer 273B, which is a vestige of the settlement occupation processes, and layer 273A, which is a small dome-shaped mound of a base width of 2.3 m and a height of 0.25 m. Layer 273A layer is composed of material of layer 273B, which was re-deposited in the process of building the rampart embankment. This process was identified as the second phase of the stronghold by Chmielowska.

The second phase of the stronghold as proposed by Chmielowska should also be interpreted differently. The development of the rampart’s structure can be divided into two stages. The original face of this construction was not a clay layer (S.U. 262) but a level that was interpreted as a diagonally arranged stack of “beams lying along the course of rampart” (S.U. 270) (Chmielowska 1982). These structures were called “roofing tile-shaped” or “placed in a roofing tile manner” and were believed to have been made up of logs which were not longer than a half of a metre. However, the discussed layer (S.U. 270) is certainly not a remnant of mineralised and/or burnt pieces of wood. This layer consists of structures whose shapes in their cross-sections are similar to deformed rectangles, triangles or trapezoids. These structures are composed of strongly humic various-grained sands mixed with charcoal and single plant macroremains. Already at the stage of field research, we hypothesised that we were dealing here with relics of cubes made of turf or sod together with the top layer of the soil humus horizon. These cubes were used for facing the slopes of the rampart, both external (S.U. 270) and internal (S.U. 339) ones. Relics of such “sod bricks” were perfectly recognisable during the exploration of “steps” left in 1963. “Sod bricks” facing of the rampart is also manifested by slight

post-depositional deformations, consisting of micro-scale crawling of their edges on the surface of the rampart slope.

The core of the rampart at this stage of development was a sandy embankment, with clearly legible interbeds of darker, humus and brawn ferriferous sand. It was therefore identified as a reversed and slightly impaired sequence of original (i.e. before the construction of the rampart) layers of subsurface deposits. The embankment of the rampart (S.U. 273A, 272 and 271) arose as a result of digging of a moat or ditch and a successive re-deposition of earlier strata. These consisted of early medieval dark humic sands horizon containing numerous early medieval artefacts and ecofacts, mainly bones of livestock and plant macroremains (S.U. 273B); early medieval (?) deluvium (S.U. 274); brownish poorly humic sand of prehistoric and/or early medieval buried soil with a cultural layer (S.U. 275); and lightly yellow sand of the terrace remnant (S.U. PLV). The re-deposited layers forming the core of the rampart are characterised by a typical structure spotted in the embankments, with clearly visible layers arranged in parallel to the shape of the rampart’s surface. Well-legible structures are created during micro-scale gravitational landslides of loose layers of the successively formed embankment. Layer 273B strata can be recognised as the “Dark Earth” buried soil dated to the tenth and not later than the mid-eleventh century, on the basis of the analysis of potsherds. It was covered by the rampart embankment not later than in the fourteenth century AD.

A different interpretation should also be proposed on the basis of the analysis of the relics which were linked by Chmielowska (1982) to the third phase of the development of the fortifications. This phase was supposed to be represented by a sandy unit (S.U. 261). According to Chmielowska (1982), sandy covers (S.U. 269 and 267) and also thin levels of humic sand (S.U. 263) and clay (S.U. 262) formed the embankment of the second phase of the rampart. The presence of a 15-cm-thick layer of clay was interpreted as a kind of face of the extended rampart (Chmielowska 1982). However, the sand cover (S.U. 269, 267 and 261) is an effect of slope processes, which resulted in erosion associated with the destruction of the already existing rampart of the first phase. The clay layer (S.U. 262) has a varied thickness of only a few millimetres up to 15 or even 20 cm. Fingerprints were observed on larger fragments of clay, which may indicate the covering of the surface with clay. On the other hand, these relics and bulks of humic sands (S.U. 268 and 263) could be interpreted as elements of the earlier rampart construction. They were most probably re-deposited by slope wash processes. A similar stratigraphy was also recorded at the inner slope deposits of the rampart—laminated humic sandy deluvia (S.U. 338, 336, 337, 310 and 309) and solids of clay (S.U. 333) were observed there.

A number of stratigraphic units that covered earlier structures were interpreted by Chmielowska (1982) as the fourth phase of the stronghold development. However, “the mantle

Table 3 Re-interpretation of chronology and description of layers of the rampart remnants at Rozprza

Description of layers after Chmielowska (1982)	No. of layers after Chmielowska (1982) (see Fig. 2)	Chronology of layers after Chmielowska (1982)	Stratigraphical unit (S.U.) no. after authors (see Figs. 4 and 5)	Description of layers after authors	Chronology of layers after authors
Present-day humus	1	Modern period	1	Contemporary humic sand of topsoil	Modern period
Clay	2	Mid-thirteenth to second half of the fourteenth century AD	258	Humic sand mixed with clay (slope deposit)	Modern period
Daub	3	Mid-thirteenth to second half of the fourteenth century AD	265, 266 262	Humic sands (slope deposits) clay	Modern period
Dark grey earth	4	Second half of the tenth to mid-thirteenth century AD	257, 259, 261, 304, 306, 313–317, 330–335	Humic sands of the Late Medieval motte remnants	20s–30s of the fourteenth to the fifteenth century AD
Burnt timbers	5	Ninth century AD	263 270	Humic sand sod bricks	Second half of the eleventh/twelfth to end of thirteenth century AD
Burnt earth	6	Sixth–ninth century AD	273A 273B	Re-deposited “Dark Earth” Deep black humic sand of the “Dark Earth” soil	Second half of the eleventh/twelfth to end of the thirteenth century AD Second half of the tenth to half of the eleventh century AD
Vertical posts	7	Second half of tenth to mid-thirteenth century AD	Several S.U.	Vertical posts of the Late Medieval moat slope timber construction	20s–30s of fourteenth century AD
Horizontal beams	8	Second half of tenth to mid-thirteenth century AD	Several S.U.	Horizontal beams of the Late Medieval moat slope timber construction	20s–30s of fourteenth century AD
Yellow-greyish sand	9	Ninth century AD	271, 272 and also: 261, 262, 263, 267, 268, 269, 309, 310, 333, 336, 337, 338	Yellow-greyish sand of the rampart core interbedded humic, brownish and yellowish sands sandy of the rampart core Yellow-greyish laminated humic sands and solids of clay (slope deposits)	Second half of the eleventh–end of the thirteenth century AD End of the thirteenth century AD (?) to 20s–30s of fourteenth century AD
Yellow-greyish sand	9		274	Deluvial yellow-greyish sand	Ca. tenth/eleventh century AD (?)
Yellow-greyish sand	9		275	Brownish poorly humic sand (buried soil with cultural layer)	Prehistory and Early Middle Ages (before tenth/eleventh century AD)
Yellow-greyish sand	9		PLV	Pleni-Weichselian lightly yellow sand of terrace remnant	ca. 25 ka BP

of clay” covering the rampart remains from outside has not been identified by the authors of this paper. It can probably be identified with sands mixed with clay and tiny fragments of charcoal and burnt clay (this unit was marked as S.U. 258). This layer is inclined and should be rather regarded as a result of erosion of the embankment (slope deposits). Numerous

stones mentioned by Chmielowska (1982), laid in the top part of the rampart relics, may be remains of some defensive structures, maybe even the fill of timber boxes (“izbice”) which did not survive.

The new re-interpretation of the stratigraphic structure studied in trench 1/1963 (Fig. 5) allows for the definition of the following

phases of the development of the settlement structures at the site of the stronghold in Rozprza (Sikora et al. 2018):

1. Prehistoric and/or early medieval (?) open settlement—S.U. 275 and 274(?).
2. Early medieval (?) open settlement which functioned between the second half of the tenth and the first half of the eleventh century AD—S.U. 274(?) and 273B (accumulation of the “Dark Earth” soil).
3. Ring-fort which was constructed in the period between the second half of the eleventh or the beginning of the twelfth and the end of the thirteenth century AD—S.U. 273A, 272, 271 (re-deposition of earlier units) and 270 (sod bricks on the rampart slope surface).
4. Destruction of the ring-fort’s rampart—several S.U.: 261, 262, 263, 267, 268 and 269 on the outer slope and 309, 310, 333, 336, 337 and 338 on the inner slope. These can be interpreted as slope deposits. It can point to the abandonment of the stronghold.
5. Motte-and-bailey with a system of moats. This phase could last from the 1320s–1330s to the fifteenth century AD.

Sedimentological traits of deposits

The lowest samples of all studied profiles (RP WW, RP M, RP M2, RP RM and RP GE) represent substratum deposits of the Pleni-Weichselian terrace (PLV). Twenty-five samples of fluvial Pleni-Weichselian sediments were analysed altogether. These river sands consist mostly of a medium-grained sand fraction between 0.5 and 0.25 mm. The percentage of coarse-grained sand and gravel (i.e. > 0.5 mm; < 1.00 φ) ranges from 17.9 to 31.7% (only in two samples there was more than 40%) and of mud (i.e. < 0.1 mm; > 3.32 φ)—from 1.0 to 3.1%. These deposits are characterised by a mean grain size of 1.02–1.58 Phi (φ) (i.e. 0.49–0.34 mm) and a sorting index of 0.64–0.78 (i.e. moderately well-sorted and moderately sorted) (Fig. 6). The relationships between the mean grain size and the sorting indexes, the skewness and the mean grain size, as well as between the sorting index and the skewness, demonstrate that the features of the studied sediments are situated on the border between channel deposits and overbank deposits as defined by Mycielska-Dowgiałło (2007). In the C-M diagram after Passega and Byramjee (1969), these samples can be placed within class I and within segment O-P according to Passega (1964). This demonstrates that the analysed sediments have been transported by rolling and saltation (Passega and Byramjee 1969; Mycielska-Dowgiałło and Ludwikowska-Kędzia 2011).

Traits which are similar to the substratum deposits can also be seen in the brownish buried soil (S.U. 275) (Fig. 6a–e). However, the percentage of coarse-grained sand and gravel

ranges from 21.2 to 28.8% and that of mud—from 1.6 to 3.6%. The mean grain size is 1.41–1.58 Phi (0.38–0.34 mm) and a sorting index is 0.73–0.78. This demonstrates that this topsoil was formed on the surface of the Pleni-Weichselian terrace. The layer covering the brownish buried soil is constituted by yellow-greyish sands (S.U. 274), characterised by a mean grain size of 1.53–1.67 Phi (φ) (i.e. 0.35–0.31 mm) and a sorting index of 0.78–0.89 (i.e. moderately sorted). The relation between the mean grain size and the sorting indexes for S.U. 274 represents the second co-ordinate system after Mycielska-Dowgiałło (2007). It is characteristic for overbank alluvia but also for slope-wash deposits (deluvium) (Twardy 2000, 2008; Smolska 2008; Mycielska-Dowgiałło 2007; Kittel 2014). The admixture of fine-grained fractions can reach up to 6% for these deposits, but it can be an effect of in-wash from the covering layer.

Both textural and geochemical (see below) traits of the “Dark Earth” layer (S.U. 273B) differ distinctly from the characteristics of underlying deposits. This stratum is characterised by a mean grain size from 1.73 to 1.99 Phi (φ) (i.e. 0.25–0.26 mm) and a moderate and poor sorting index of 0.87–1.36. A high percentage of coarse-grained sand and gravel (from 19.4 to 26.6%) and of fine-grained fractions (from 3.1 to 16.1%) is very significant. An increase in the amount of very coarse sands, gravels and mud fraction is clearly visible for this layer (Fig. 6a–e). This trait strongly differs S.U. 273B from the underlying deposits. It is a proof for (at least partly) artificial origin of the earthwork of the “Dark Earth” soil deposits at Rozprza. It means that they were accumulated (at least partly) as a result of intentional and direct human activity.

Geochemical traits of deposits

Profiles RP WW, RP M, RP M2, RP RM and RP GE

The pH values for the substratum deposits of the Pleni-Weichselian terrace are from 5.8 to 6.6 and no organic carbon stocks were detected (Fig. 6a–e). The LOI values are below 1% and C_{org} —0.12%. These traits testify to a trivial admixture of organic matter within fluvial terrace sediments. The brownish buried soil (S.U. 275) is characterised by pH from 6.1 to 6.8 and the content of carbonates is very low—up to 0.04%. An admixture of organic matter (LOI) reaches up to 1.2% and C_{org} —0.25%. It could be however (partially) caused by the presence of iron compounds. As confirmed by archaeobotanical research, charcoal fragments were found within this layer.

Geochemical traits of the deluvial deposits (S.U. 274) differ in the studied profiles. The pH values range from 5.5 to 7.3—the lowest are in profile RP M2 and the highest in profile RP WW (i.e. below the rampart earthwork). The organic content also differs in selected profiles—the highest is in profile RP WW (LOI 0.8–7.4; C_{org} 0.2–

Fig. 6 Stratigraphic diagrams of the lithological and geochemical composition of research profiles. **A.** Lithologic profile. **B.** Folk and Ward coefficients: mm—mean grain size [mm], Mz—mean grain size [Phi], δ_1 —sorting index (standard deviation), Sk₁—skewness, K_g—

kurtosis. **C.** Geochemical parameters: C_{org}—content of organic carbon (%), LOI—loss-on-ignition (%), CaCO₃—content of carbonate (%), pH—pH of deposits. **a** Profile RP WW. **b** Profile RP M. **c** Profile RP M2. **d** Profile RP RM. **e** Profile RP GE

2.1%) and the lowest in profile RP M (LOI 0.6–1.0; mC_{org} 0.2–0.3%). Very numerous charcoal fragments were recorded in profile RP M2.

The layer recognised as the “Dark Earth” soil (S.U. 273B) is characterised by a distinct increase of the amount of carbonates (up to 4.8%) in the studied profiles. An

Fig. 6 continued.

increase of organic matter admixture, both LOI (7.6–13.0%) and C_{org} (3.1–4.9%), is evident in all profiles.

Only pH values differ from 5.4 to 5.7 in profile RP M2 up to 6.7–7.3 in profile RP WW.

Fig. 6 continued.

Bulk soil samples from profiles RP M2 and RP GE

The pH value of profile RP M2 ranges from 5.5 (0–10 cm) to 6.4 (70–80 cm). In contrast, pH values of the reference profile (RP GE) are more acidic, ranging from 3.8 (0–10) to 5.3 (70–80 cm) (Table 4).

The total N concentration in profile RP M2 and in the reference soil (profile RP GE) displays a high variability and the same can be said about differences within both profiles (Table 4). The total N concentration in profile RP M2 ranges between 0.1 g kg⁻¹ (60–70 cm) and 2.1 g kg⁻¹ (10–20 cm), whereas the content of N was below the detection limit at the depth of 70–80 cm. Total N concentrations in the reference soil (RP GE) are 8 g kg⁻¹ in the upper 10 cm with a rapid decrease to 0.2 g kg⁻¹ at the depth of 30–40 cm. The content of N was not detectable between the depths of 40 and 80 cm in the reference soil.

The $\delta^{15}\text{N}$ values are highly enriched in profile RP M2 and the same can be seen in the reference soil (Table 4). However, $\delta^{15}\text{N}$ values of RP M2 are throughout highly enriched, ranging from +5.1‰ (50–60 cm) to +8.6‰ (30–40 cm). In comparison, $\delta^{15}\text{N}$ values of RP GE are the highest at the depth of 20–30 cm (+6.3‰). Soil organic carbon (SOC) stocks of profile RP M2 are the highest between the depths of 10 and 40 cm, ranging between 27.6 and 46.2 g kg⁻¹. In contrast, the highest SOC concentrations in the reference soil were detected in the upper 0–10 cm (87.9 g kg⁻¹). Hectare soil organic carbon stocks show high differences between the reference soil (98 Mg ha⁻¹) and the “Dark Earth” (173.5 Mg ha⁻¹). High total P concentrations up to 4318.2 mg kg⁻¹ (10–20 cm) were

detected in profile RP M2. In reference profile RP GE, the content of P was only detectable in the upper 40 cm, ranging from 1470.5 mg kg⁻¹ (0–10 cm) to 19.4 mg kg⁻¹.

Archaeobotany of the buried soil and the rampart earthwork

Plant macroremains

The main components of plant macrofossils from profiles RP WW, RP M, RP M2 and RP RM were wood charcoal and charred fruits and seeds. Uncharred diaspores were much less numerous, and very few specimens were mineralised. The occurrence of charred and uncharred specimens in one and the same archaeological feature or layer provokes a question about the origin and age of these two different types of remains. In deposits lying above the ground water level, uncharred specimens usually quickly decay and their relation to a given archaeological context may be doubtful (Lityńska-Zajac et al. 2014). At Rozprza, these two types could correspond to two different “histories” of remnants of the same age. Namely, charred specimens could be evidence for intentional human activity and uncharred ones could be accidental admixtures. On the other hand, numerous traces of animal activity observed in several trenches indicate that post-depositional downward transportation of uncharred material from the surface could take place. Therefore, the uncharred specimens are considered here to be secondary intrusions and they are not taken into

Table 4 Geochemical traits of bulk soil samples from profiles RP M2 and RP GE profiles

Soil depth [cm]	C _{org} [g kg ⁻¹]	C _{org} [Mg ha ⁻¹]	N [g kg ⁻¹]	d ¹⁵ N [‰]	P [mg kg ⁻¹]	C/N	pH [CaCl ₂]	Bulk density [g cm ⁻³]	Colour ^a	Texture ^b	Horizon ^c	Stratigraphical units
RP M2												
0–10	7.7	10.4	0.5	8.1	1231.7	15.1	5.5	1.3	10YR 3/1	Sandy loam	Ap	273B
10–20	46.2	51.7	2.1	8.6	4318.2	21.9	5.9	1.1	2.5YR 2.5/1	Silt loam		273B
20–30	43.9	56.9	1.9	8.3	4307.6	23.0	5.9	1.3	2.5YR 2.5/1	Silt loam	Ah	273B
30–40	27.6	38.1	1.1	8.6	3796.9	24.3	5.9	1.4	10YR 2/1	Sandy loam		274
40–50	7.0	9.7	0.4	8.1	2939.6	18.3	6.1	1.4	10YR 3/1	Sandy loam		274
50–60	3.3	4.7	0.3	5.1	3294.1	11.7	6.3	1.4	10YR 3/2	Loamy sand	Bw	275
60–70	0.8	1.1	0.1	7.5	851.1	12.2	6.4	1.5	10YR 4/1	Loamy sand		275
70–80	0.5	0.7	nd	nd	327.2	nd	6.4	1.4	10YR 5/2	Loamy sand		PLV
RP GE												
0–10	87.9	61.2	8.0	4.9	1470.5	11.1	3.8	0.7	10YR 3/1	Sandy loam	Ap	
10–20	18.1	27.4	1.8	5.3	208.9	10.5	4.3	1.5	10YR 4/1	Sandy loam		
20–30	3.3	5.4	0.3	6.3	89.4	10.9	4.5	1.6	10YR 4/2	Sandy loam	Bw	
30–40	1.8	3.0	0.2	5.1	19.4	12.1	4.6	1.6	10YR 4/1	Loamy sand		PLV
40–50	0.3	0.5	nd	nd	nd	nd	4.6	1.6	10YR 5/2	Sand	C	PLV
50–60	nd	nd	nd	nd	nd	nd	4.6	1.7	10YR 6/2	Sand		PLV
60–70	0.4	0.5	nd	nd	nd	nd	4.7	1.5	10YR 6/2	Sand		PLV
70–80	nd	nd	nd	nd	nd	nd	5.3	1.7	10YR 6/3	Sand		

^a Munsell Soil Colour Chart^b According to Jahn et al. (2006)^c World Reference Base

consideration in the discussion below (All data, including uncharred, are listed in Supplementary Tables 1–4 while in diagrams, Figs 7, 8, 9, only charred remains are considered).

The spectra of plant macroremains recovered from geoarchaeological layers are very similar in profiles RP WW and RP M (Tables 5 and 6; Figs. 7 and 8). Bottom layers (S.U. 275 and 274) contain only a small number of wood charcoal pieces. The cultural layer 273B (and 273A in RP WW), recognised as the “Dark Earth” soil, is characterised by a great amount and taxonomic diversity of wood charcoal. Furthermore, the appearance of charred cereals and wild herbaceous plants is noticeable. Profile RP M2 (Table 7; Fig. 9) differs from the former two in the composition of layer 274. This layer contains a higher amount of wood charcoal, one millet grain and a few species of wild herbs. In layer 273, the plant assemblage is similar to that from layer 273A in RP WW. The poorest plant material which is differently distributed in the samples comes from profile RP RM situated outside the rampart (Table 8). A few cereal grains appear as early as layer W3 (corresponding to layer 274 in the other profiles). Their number does not increase in layer W2 which should correspond to layer 273B. Very few plant remnants were found in the sample from a sod brick (S.U. 270) (sample T1, Table 9).

Phytoliths and other biogenic microparticles

Practically, all microparticles in all samples from profile RP WW (nos. 7–23) are charred (Table 10). It means that fires often took place in the area or some sort of a hearth (of a kitchen?) was located here in the past. A secondary dump of deposits with charred remains cannot be however ruled out too. The last five samples (nos. 19–23; 65–85 cm; S.U. 274 and 275) have a natural-like phytolith distribution, with a maximum at the top and a decrease with the depth. All the other part of the column is of artificial origin—it is a cultural layer or (most probably) several cultural layers one by one. This confirms the artificial origin of the earthwork of the “Dark Earth” deposits. All samples from this part of the profile contain lot of phytoliths, and their content is higher than at the top of the modern soil. It is possible only in artificial concentration of organic material here. The quantitative content of phytoliths is similar but it is possible to divide them into three parts: samples 7–9 (5–15 cm; S.U. 273), 10–16 (20–50 cm; S.U. 273A, 273B) and 17–18 (55–60 cm; S.U. 273B). We can see the different contents of mosses and reed phytoliths. Samples 11–13 (25–35 cm; S.U. 273B) contain no indicator forms of grasses of steppe land habitats and cereals. Such differences could be random but perhaps they testify to some differences in the history of this site. Sample 23 (85 cm; S.U.

Rozprza profile RP WW

Fig. 7 Simplified plant macrofossil diagram from profile RP WW

275) can be used as a diagnostic one for the original landscape before it came to an intense human impact connected with the “Dark Earth” soil development. The site had been covered with a broad-leaved forest with admixture of coniferous trees, before people came there.

All particles from the sod bricks—i.e. T1 (nos. 1–2), T2 (nos. 3–4) and T3 (nos. 5–6)—are charred (Table 11). There are no differences between top and bottom samples: all are rich in aboreal large detritus and soil fungi. The content of phytoliths differs but there are no rules for it. For example, in feature T1, we can see more phytoliths in the top sample (no. 1), but a reverse situation can be seen in feature T2. Furthermore, there are no quantitative differences in phytoliths in feature T3. The phytolith assemblages are practically the same in all samples except for the top of T2 (no. 3). Samples are rich in mosses, forms of meadow grasses and herbs. They contain phytoliths of reed and cultural cereals (except for the top and bottom of T2). Three samples (T1’s top and bottom and T3’s bottom—nos. 1 and 6) contain fragments of diatoms (i.a. *Hantzschia amphioxys* and *Pinnularia borealis*—M. Rzedkiewicz pers. com.). There are no pollen grains in any samples. Such a microbiomorphological content is

typical for meadow–forest litter, which was wet but not bog. Phytoliths of cereals allow to assume that there was some human impact in this area. The charred nature of the samples can be a result of fire.

Discussion

Landscape reconstruction of the Rozprza Dark Earth development

Archaeobotanical interpretation is based on the plant material found in layers 273B, 273A and 273, which were interpreted as cultural layers (“Dark Earth”) or re-worked cultural layers.

The most distinctive trait of the “Dark Earth” horizon as compared with the underlying layers is an increased amount and taxonomic richness of wood charcoal, as well as the appearance of charred seeds and fruits of cereals and wild herbs which are typical for anthropogenic habitats. The analysis of this material provides some data about plant cultivation and gathering. Indirectly, it also informs us about the vegetation in

Rozprza profile RP M

Fig. 8 Simplified plant macrofossil diagram from profile RP M

the surrounding terrains which were exploited by the Early Medieval communities, as indicated by the radiocarbon dates.

The sets of arborescent taxa are similar in all profiles (Tables 5, 6, 7 and 8; Figs. 7, 8 and 9). The most abundant are charcoal fragments of spruce or larch *Picea abies/Larix* sp., oak *Quercus* sp., pine *Pinus sylvestris* and alder *Alnus* sp. Fairly numerous are birch *Betula* sp., hornbeam *Carpinus betulus* and ash *Fraxinus excelsior*, while beech *Fagus sylvatica*, fir *Abies alba*, poplar *Populus* sp., maple *Acer* sp., lime *Tilia* sp., elm *Ulmus* sp. and willow *Salix* sp. are less abundant. Sporadically, and mainly in profile RP WW, there appear yew *Taxus baccata*, juniper *Juniperus communis*, dogwood *Cornus sanguinea*, mistletoe *Viscum album*, evonymus *Euonymus* sp., viburnum *Viburnum* sp., plum tree *Prunus* sp. and some undetermined species from Pomoideae and Rosaceae. Proportions of various trees are slightly different in individual profiles but this may be insignificant. All these trees and shrubs were undoubtedly available in the near surroundings, though some of them could have been looked for on purpose. Their ecological demands described by the ecological numbers (Zarzycki et al. 2002) suggest that most of them grew on fresh (soil moisture index W 3) or moist soils

(W 4). These soils were fertile (trophy index Tr 4) or moderately poor (Tr 3), neutral (acidity index R 4) or moderately acidic (R 3) (Fig. 10).

According to the reconstruction of the potential natural vegetation in the surroundings of the settlement at Rozprza (Czyżewska 1982), all trees and shrubs identified among charcoal could be gathered in various forest and thicket stands growing in the area. Spruce, pine, fir and larch could originate from pine and pine–oak forests growing on drier soils in the upland. Oak–hornbeam forests covering fresh soils of the upland could be the source of oak, hornbeam, lime and maple wood. Alder, ash and dogwood could be collected in low-lying wet and moist habitats.

Cereal cultivation is documented by numerous grains present in all profiles (Tables 5, 6, 7 and 8; Figs. 7, 8 and 9). Most frequently, there occur millet *Panicum miliaceum*, bread wheat *Triticum aestivum* and rye *Secale cereale* (Fig. 11), which belonged to the most common cereals in the Early Middle Ages in Poland (Lityńska-Zajac 2005). The cultivation of other plants is indicated by the occurrence of single seeds of flax *Linum usitatissimum*, opium poppy *Papaver somniferum* and perhaps field pea *Pisum* sp. (*sativum*?) as

Rozprza profile RP M2

Fig. 9 Simplified plant macrofossil diagram from profile RP M2

well as hulled wheats (*Triticum monococcum* and *T. dicoccum* or *T. spelta*) and oats (*Avena* sp.) (Tables 5, 6, 7 and 8).

All wild herbaceous plants, among which 27 species were identified (Tables 5, 6, 7 and 8), could grow in anthropogenic habitats, most of them in corn fields, some in ruderal places or in meadows. The largest group of field weeds is nowadays typical for root crop and garden cultivations but it also appears in millet fields (Matuszkiewicz 2001). This weed group includes *Digitaria ischaemum*, *Setaria pumila*, *S. viridis/verticillata* (if *viridis*), *Chenopodium album*, *Ch. polyspermum*, *Ch. ficifolium*, *Polygonum minus*, *P. lapathifolium*, *Echinochloa crus-galli*, *Rumex acetosella*, *Galium spurium* and *G. aparine*. In cereal fields, *Polygonum persicaria*, *Fallopia convolvulus*, *Sinapis arvensis*, *Melandrium album* and *Galium aparine* could also grow. It is worth noticing that typical segetal weeds, which until recently have infested particularly winter crops, are represented by only one species, namely *Agrostemma githago*. This suggests that summer crops together with garden cultivations played (at least locally) a significant role in the surroundings

of Rozprza during the Early Middle Ages. All these species often appear in association with cereal grain at archaeological sites of different ages in Poland (Lityńska-Zajac 2005). Some species could also come from other habitats, e.g. *Malva neglecta*, *Urtica urens* and *Chenopodium ficifolium* from ruderal places which are rich in nitrogen; *Polygonum persicaria*, *P. minus* and *P. lapathifolium* from periodically flooded shores of water reservoirs; and *Rumex acetosa*, *Plantago media* and *Silene nutans* from meadows and grasslands. Few species could grow in different forest stands, for instance, *Galium sylvaticum* in oak–hornbeam forests, *Silene nutans* in lighted oak forests and *G. aparine* and *Melandrium rubrum* in river-side forests. Soil preferences of herbaceous plant species defined by ecological numbers (Zarzycki et al. 2002) indicate that fresh (moisture index W 3), fertile (trophy index Tr 4) and neutral (acidity index R 4) soils were mainly taken under cultivation (Fig. 10).

The analysis of ecological demands demonstrates a certain difference between the assemblages of trees and herbs: (1) more herbaceous species preferred fresh (W 3) and dry (W2)

Table 5 Charred plant remains from profile RP WW

[illegible]

w—wood charcoal, *r*—rhizome, *st*—fruit stone, *c*—grain, *s*—seed, *f*—fruit, *b*—leaf, *sc*—scale, *scl*—sclerotium, *tub*—tuber, *veg*—vegetative, *mi*—mineralised

Table 6 Charred plant remains from profile RPM

[illegible]

Table 7 Charred plant remains from profile RP M2

Trees and shrubs													
Depth, cm	Volume, dm ³	Layer (S.U.)	<i>Quercus</i> sp.	<i>Pinus sylvestris</i>	<i>Picea abies/Larix</i> sp.	<i>Alnus</i> sp.	<i>Betula</i> sp.	<i>Fraxinus excelsior</i>	<i>Carpinus betulus</i>	<i>Fagus sylvatica</i>	<i>Acer</i> sp.	<i>Populus</i> sp.	<i>Corylus avellana</i>
10–15	0.42	273	w 27	w 4	w 7	w 11	w 3	w 3	w	w	w	w	w
15–20	0.35	273	17	5	32	27		6					
20–25	0.35	273	22	18	42	16	3	8			9		
25–30	0.25	273	26	6	21	14	4	3	1				1
30–35	0.4	273	103	19	29	10					5		
35–40	0.3	273/274	33	4	8	4	3		1	1		4	
40–45	0.32	274	251	8	17		3						
45–50	0.32	274	15	2		11							
50–55	0.25	274/275	10	1									
55–60	0.22	275	8										
60–65	0.3	275	1	3	1								
65–70	0.24	275	2		2	1							
70–75	0.24	275/PLV	2	4									

Trees and shrubs													
Depth, cm	<i>Cornus sanguinea</i>	Indeterminata	<i>Corylus avellana</i>	<i>Picea excelsa</i>	Cereals		Herbs (weeds, ruderals, grassland plants)						
					<i>Panicum miliaceum</i>	<i>Cerealia</i>	<i>Galium spurium</i>	<i>Polygonum lapathifolium</i>	<i>Polygonum persicaria</i>	<i>Chenopodium album</i>	<i>Galium sylvaticum</i>	<i>Chenopodium ficifolium</i>	
10–15	w 2	w	f	1	c		c	f	f	s	f	s	
15–20		13		1	9		3						
20–25		20			6		2		1				
25–30		28			3		9					1	
30–35		14	1		3		2		1				
35–40		20			4		1				1		
40–45		6								1			
45–50		29						1					
50–55		6			1								
55–60		3											
60–65		2											
65–70													
70–75		1											

Table 7 (continued)

Depth, cm	Herbs (weeds, ruderals, grassland plants)				Ecologically undetermined				
	<i>Fallopia convolvulus</i>	<i>Cerastium caespitosum</i>	<i>Rumex acetosa</i>	<i>Veronica officinalis</i>	Poaceae	<i>Chenopodium</i> sp.	<i>Polygonum</i> sp.	<i>Galium</i> sp.	<i>Veronica</i> sp.
10–15	f	s	f	f	c	s	f	f	f
15–20	1	1	7	1		1			1
20–25									
25–30								1	
30–35						1	1		
35–40									
40–45					2				
45–50									
50–55									
55–60									
60–65									
65–70									
70–75									

w—wood charcoal, r—rhizome, st—fruit stone, c—grain, s—seed, f—fruit, b—bark, l—leaf, sc—scale, scl—sclerotium, tub—tuber, veg—vegetative, mi—mineralised

Table 8 Charred plant remains from profile RP RM

				Trees and shrubs										Cereals									
Depth, cm	Volume, dm ³	Layer (S.U.)	Correlation with S.U. in profile RP WW	<i>Picea abies/ Larix sp.</i>	<i>Pinus sylvestris</i>	<i>Quercus</i> sp.	<i>Alnus</i> sp.	<i>Betula</i> sp.	<i>Carpinus betulus</i>	<i>Fraxinus excelsior</i>	Indeterminata	<i>Panicum miliaceum</i>	<i>Triticum aestivum</i> s.l.	<i>Triticum dicoccon/ spelta</i>	<i>Triticum sp.</i>	<i>Secale cereale</i>	<i>Cerealia indet.</i>						
0–5	0.3	W.1		w	w	w	w	w	w	w	w	c	c	c	c	c	c						
5–10	0.35	W.1			2						5	1	1				2						
10–15	0.35	W.1		2	2	1			1		12	3		3		1							
15–20	0.3	W.1		4	1	4			1		6	2			1								
20–25	0.35	W.2 (163)	273B	3	3	1					9	2											
25–30	0.2	W.2 (163)	273B	5	5						10	3					1						
30–35	0.2	W.2/3 (163/164)	273B/274	3	7	3	4				16	3					1						
35–40	0.2	W.3 (164)	274	2	2		2	1		1	7	3	1				1						
40–45	0.2	W.3 (164)	274	2	5						6	1	1				1						
45–50	0.3	W.3 (164)	274																				
50–55	0.2	W.4 (165)	275	2	2						3												
55–60	0.2	W.4 (165)	275			1			4		2												
60–65	0.3	W.4 (165)	275			3	1				3	1											
65–70	0.25	W.4 (165)	275	1	1						1												
70–75	0.2	W.4 (165) bottom	275																				
75–80	0.3	W.5	PLV	2																			

Herbs (weeds, ruderals, grassland plants)										Ecologically undetermined			
Depth, cm	<i>Agrostemma githago?</i>	<i>Galium boreale</i> cf.	<i>Plantago media</i>	<i>Rumex acetosella</i> agg.	<i>Melandrium rubrum</i>	<i>Setaria</i> sp.	Poaceae	Indeterminata	Indeterminata				
0–5	s	f	s	f	s	c	c	s/f	veg				
5–10						1							
10–15					1			1					
15–20					1								
20–25			1					1					
25–30					1		1						
30–35							1	7					
35–40		1						2	1				
40–45	1			1				1					
45–50													
50–55													
55–60													
60–65													
65–70													
70–75													
75–80													

w—wood charcoal, r—rhizome, st—fruit stone, c—grain, s—seed, f—fruit, b—bark, l—leaf, sc—scale, scl—sclerotium, tub—tuber, veg—vegetative, mi—mineralised

Table 9 Charred plant remains from sample RP T1

Profile RP T1		Trees and shrubs								Cultivated plants		
Volume, dm ³	Layer (S.U.)	<i>Picea/Larix</i>	<i>Pinus sylvestris</i>	<i>Quercus</i> sp.	<i>Betula</i> sp.	<i>Fraxinus excelsior</i>	<i>Populus</i> sp.	Indeterminata	<i>Sambucus nigra</i> , nch	<i>Panicum miliaceum</i>	<i>Pisum</i> sp.	Indeterminata
		w	w	w	w	w	w	w	st	c	s	s/f
0.8	270	13	11	5	2	1	2	5	1	3	1	3

w—wood charcoal, r—rhizome, st—fruit stone, c—grain, s—seed, f—fruit, b—bark, l—leaf, sc—scale, scl—sclerotium, tub—tuber, veg—vegetative, mi—mineralised

soils while more arborescent species grew on fresh (W 3) and moist (W 4) soils; (2) more herbs preferred soils which are rich in nutrients (Tr 4), while many woody species grew on moderately poor (Tr 3) and rich soils (Tr 4); (3) herbs preferred neutral soils (R 4), while woody species grew on neutral (R 4) and moderately acidic (R 3) soils (Fig. 10). This indicates some predictable process of taking richer and drier soils under cultivation, which were located in areas safe from spring and summer floods.

The recovered plant material offers some suggestions about plant gathering. The rich and diversified set of wood charcoals indicates the collection of wood (mainly for fuel) in the vicinity of the settlement. Forests and forest edges were also the source of edible fruits represented by hazel nuts *Corylus avellana* and fruit stones of raspberry *Rubus idaeus* and elder *Sambucus nigra*. Among the herbaceous plants, there are several species which were collected in the past (e.g. *Chenopodium* and *Polygonum* species), but their sporadic

Table 10 Semiquantitative contents of different types of microbiomorphs

Sample no.	Object	Depth, cm	Non-siliceous vegetable indicators ¹ Detritus	Non-vegetable siliceous indicator types ¹ Diatoms	Plant silica ¹ Phytolith	Note
1	T1	Top	+++	Single, broken	+++	Aboreal large detritus predominant, soil fungi. All particles are charred
2		Bottom	+++	Single, broken	++	
3	T2	Top	+++	—	+	
4		Bottom	+++	—	+++	Charcoal particles of grasses and trees. All particles are charred
5	T3	Top	+++	—	+++	
6		Bottom	+++	Single, broken	+++	
7	WW 273	A 5	+++	—	+++	
8		A 10	+++	Single, unbroken	+++	
9		A 15	+++	Single, unbroken	+++	
10		A 20	+++	—	+++	
11		AB 25	+++	—	+++	
12		B 30	+++	Single, broken and unbroken	+++	
13		B 35	+++	—	+++	
14		B 40	+++	—	+++	
15		B 45	+++	—	+++	
16		B 50	+++	Single, unbroken	+++	
17		B 55	+++	—	+++	
18	273B/274	60	+++	Single, broken	+++	All particles are charred
19	274	65	++	—	+++	
20	274	70	++	—	++	
21	275	75	+	—	+	
22	275	80	++	—	+	
23	275	85	+	—	+	

¹ +++ (many): over 100 units; ++ (middle): 40–100 units; + (little): 5–40 units; ± (single): 1–4 units; (absent): —

Table 11 Silica microbionorms (unit/%) and distribution of phytolith forms (%)

Sample	Total	Diatoms	Phytolith total	Phytolith distribution								
				Herbs	a ¹	b ¹	c ¹	d ¹	e ¹	i ¹	Reed	Mosses
1	107/100	3/3	104/97	35	8	8	15	4	2	—	4	24
2	85/100	1/1	84/99	51	7	6	19	—	1	—	6	10
3	36/100	—	36/100	67	8	3	8	—	—	—	—	14
4	294/100	—	294/100	39	3	5	32	3	—	—	7	11
5	309/100	—	309/100	36	1	1	38	7	1	—	2	14
6	196/100	1/* ²	195/100	46	2	1	26	6	5	—	2	12
7	198/100	—	198/100	36	2	3	44	5	2	—	2	6
8	265/100	1/*	265/100	24	1	5	51	7	1	—	3	8
9	352/100	1/*	351/100	30	1	5	39	8	4	—	4	9
10	392/100	—	392/100	34	3	4	38	—	1	—	2	18
11	228/100	—	228/100	35	2	2	38	—	—	—	—	23
12	350/100	2/1	349/99	32	5	3	37	—	—	—	—	23
13	311/100	—	311/100	37	4	4	29	—	—	—	—	26
14	464/100	—	464/100	39	3	6	20	3	1	—	—	28
15	436/100	—	436/100	39	3	8	24	1	1	—	—	24
16	455/100	3/1	452/99	36	2	7	24	2	3	—	—	26
17	236/100	—	236/100	39	2	8	22	2	—	—	—	27
18	461/100	1/*	460/100	37	3	8	23	2	*	—	—	27
19	104/100	—	104/100	42	17	4	25	6	—	—	3	3
20	66/100	—	66/100	45	12	6	20	2	—	2	8	5
21	46/100	—	46/100	33	11	13	28	11	—	2	2	—
22	27/100	—	27/100	51	15	7	19	—	—	—	4	4
23	20/100	—	20/100	70	15	10	—	—	—	—	—	5

¹ a: indicator types of coniferous species; b: trichomes of grasses of forest habitats; c: trichomes of grasses of meadow-type habitats; d: indicator forms of grasses of steppeland habitats; e: dendritic forms—indicator of cultural cereals; i: trichomes of grasses of ruderal habitats

² * particles of less than 1%

Fig. 10 Indicators of the most typical habitat conditions of plants found at Rozprza after Zarzycki et al. (2002) for layers (S.U.) 273, 273B and 273A in profiles RP WW, RP M and RB M2. For each category, the absolute number of taxa is given

Fig. 11 Percentage numbers of cereal species in profiles RP WW and RP M

occurrence in the material from Rozprza provides no direct evidence for their use.

The Rozprza Dark Earth layer—a man-made soil?

The documented geological and geochemical traits of stratigraphic unit 273B, recognised as the deep black (“Dark Earth”) buried soil, differ strongly from those of underlying deposits of brownish buried soil (S.U. 275) developed in the top of the Pleni-Weichselian alluvium on the river terrace remnant and deluvial sands (S.U. 274). It is a result of (at least partly) artificial origin of the earthwork of the deep black deposits, as an effect of human intentional deposition of organic rich sediments on the terrace surface. Intentional anthropogenic accumulation of organic matter on cultivated soils was discussed for an early medieval motte in Belgium by Gebhardt and Langohr (1999). A rich admixture of artefacts (potsherds, burned stones) and ecofacts (animal bones, plant macroremains, charcoal) clearly indicate a soil made by man (Anthrosol) (Pluskowski et al. 2014; Mazurek et al. 2016). Furthermore, the enriched total P and $\delta^{15}\text{N}$ values of profile RP M2 are typical for soils which were manured or contained excrements (Glaser and Birk 2012; Simpson et al. 1997). This is also clearly visible in the reference soil (RP GE) which is currently used for agriculture and obviously manured. Due to the exposed location of profile RP M2 and the presence of a

cover offered by the medieval rampart, modern agricultural cultivation can be excluded. In comparison to this, the properties of profile RP M2 suggest strong similarities with the “Nordic Dark Earth” (NDE) phenomenon known from the Slavic settlement reference site in Brünkendorf in Lower Saxony. The term NDE for medieval settlements (and especially in the Brünkendorf study) was defined on the basis of a comparison with the Amazonian Dark Earth. The Slavic black soil bears a strong similarity to the most fertile man-made soils in the world, that is, the Amazonian Dark Earth (=Terra Preta) (Wiedner et al. 2015). For instance, $\delta^{15}\text{N}$ values of the NDE at Brünkendorf were similarly enriched (up to +7.1‰) to the $\delta^{15}\text{N}$ values of the Rozprza Anthrosol (Table 4). SOM stocks of RP M2 are 173.5 Mg ha⁻¹ and even exceed the NDE stocks (121 Mg ha⁻¹) by 43%. The same can be said for the total P stock of the Rozprza Anthrosol which is five times higher as compared with the NDE (5.3 vs. 27.8 Mg ha⁻¹ at Rozprza). However, it will be necessary to carry out further analyses, such as micromorphology combined with molecular marker for soil organic matter inputs, e.g. derived from faecal or charcoal.

In sum, the increased soil organic carbon stocks in profile RP M2 indicate high amounts of organic input materials, which is inherent with the $\delta^{15}\text{N}$ and total P values. However, neither P nor $\delta^{15}\text{N}$ can be used as a direct marker for faeces or other SOM inputs indicating its sources, e.g. such as burned residues, organic waste or metabolic by-products, e.g. from faecal matter. Thus, more specific biomarkers such as sterols, bile acids and benzenepolycarboxylic acids (black carbon) are indispensable in order to identify the sources of organic soil inputs and to draw any conclusions regarding a possible similar soil origin as the NDE (Wiedner et al. 2015).

Except the Brünkendorf site, the “Nordic Dark Earth” phenomenon is also known from southern Scandinavia. The most famous example is Svarta Jorden (which means Black Earth) from Birka, where this phenomenon became eponymous for the site (Ambrosiani 2013). Micromorphological analysis revealed evidence for coproliths and high amounts of charcoal (Håkansson 1997). “Dark Earth” is also reported from excavations in later medieval towns, such as Brussels. It was interpreted there as a sign of pre-urban pastures and urban agricultural activity and gardening (Devos et al. 2009, 2013). The origin of the thick humus horizon of “Dark Earth” which has recently been discussed for Wrocław (SW Poland) has been identified as resulting from triple- and double-depth digging (Rigosol) of the soil used for gardens and orchards in the Late Middle Ages and the Modern Period (Krupski et al. 2017).

Based on the results of archaeobotanical research, we can hypothesise that at Rozprza organic matter which accumulated on the terrace surface was collected from different landscapes. These were varied forest, meadow and water habitats. This reflects the economic activity of the settlers during the Early

Middle Ages, who used diverse types of the surrounding environment. An effective deposition of sediments which were rich in organic material (including manure), and which were subsequently mixed with clay, charcoal, burned stones, bones and potsherds, resulted in accumulation of thick artificial fertile topsoil on the sandy surface (see also Sokołowski et al. 2008). It could be important that due to poor natural conditions of the terrace remnant in the valley floor, these deep black highly fertile soils were very useful for agricultural development.

The process of the ring-fort's rampart construction

The process of the ring-fort's rampart development can be reconstructed on the basis of the stratigraphy and chronology of identified stratigraphic units (Fig. 12). The surface on the eve of construction was the top of layer 273B (defined as the early medieval “Dark Earth”). At the very beginning (between the second half of the eleventh or the beginning of the twelfth and the end of the thirteenth century AD), sod bricks collected from the original surface were perhaps removed and deposited nearby. A small embankment was erected (S.U. 273A) from the material of the existing “Dark Earth” (S.U. 273B) layer. It could serve as a marker for the builders defining the course of the planned fortification. Then the core of the rampart was created (S.U. 272) with the use of mixed material from layers 273B, 274 and 275 lying closest to the surface. They were probably re-deposited from the simultaneously dug moat. After the removal of layers 273B, 274 and 275, the builders reached yellow sands of the Plen-Weichselian residual terrace (PLV). Using this material, they erected the top and outer layer of the rampart. Then, it was covered with previously prepared sod bricks.

The use of sod bricks in the construction of early medieval defensive ramparts, as well as other buildings in Polish territory, has not been reported by archaeologists so far. Such building techniques were usually connected with areas not rich in timber. In Scandinavia, sod or turf bricks were commonly used as building material in Denmark, some regions of Norway, Faeroe Islands, Iceland and Greenland. This phenomenon is seen as an environmental adaptation in areas poor in timber (Urbańczyk 1999, 2004). However, turf was mostly used for wall construction of houses and even churches, and it is known that in some cases, it was also used for defensive architecture. For example, it was applied as building material for the construction of the

Fig. 12 The process of the ring-fort's rampart construction: 1. Existence of the tenth–eleventh century AD garden/agricultural “Dark Earth” soil. 2. Removing of sod, construction of the rampart's core using the “Dark Earth” soil. 3. Construction of the upper part of the rampart with the use of mixed material from the “Dark Earth” soil, the early medieval cultural layer and the sandy substrate of the terrace remnant. 4. Development of the sandy embankment of the rampart with the use of terrace remnant sands and sod brick faces of the rampart, building of a hypothetical upper timber construction

motte-type castle of Ulfsborg near Ribe, built in 1147/1148 AD (Søvsø 2014). In northwestern Germany, sod bricks were commonly used for the construction of the ramparts of Saxonian fortifications from the ninth to eleventh century AD, despite the fact that other materials, such as sand, clay or timber, were also regularly used (Lemm 2013). In general, there was a significant variety of building techniques for fortifications in the Saxonian territory. On the other hand, these techniques differed from those used in the nearby Slavic lands (Brandt and Schneeweiss 2017). Slavic strongholds of the ninth/tenth centuries were usually sophisticated timber constructions with additional use of sand, clay and stones. The use of sod bricks was very rare and is mostly known from North-West Slavic territories in the area of today's east Germany. Examples for additional use of sod bricks in Slavic ramparts are offered by the stronghold of Scharstorf (Schleswig-Holstein, Germany; cf. Struve 1975) or Burg A of the Mecklenburg stronghold (Mecklenburg-Vorpommern, Germany; Donat 1984). It is striking that the different building traditions go hand in hand with different agricultural economic systems. Thus, in a generalised perspective, the use of sod bricks as building material seems to be common in regions with extensive agriculture by sod plugging, manuring and pasture of sheep, goat and cattle, while extensive timber constructions seem to be restricted to regions with small fields and wood pasture (Schneeweiss, 2019).

The use of sod bricks in the Rozprza ring-fort differs from the way they were used in house and defensive architecture of North Germany and Scandinavia. In these areas, turf was used to create wide, multi-layered wall-like structures. At Rozprza, the builders wanted to cover only the face of the rampart with a single layer of sod bricks in order to protect it against erosion. The use of sod bricks resulted probably from the necessity of fast rampart construction or it was due to the lack of suitable and sufficient quantity of wood material. However, the sandy embankment was unstable and several layers of slope deposits both in the outer and inner side of the construction were identified. This also suggests that an additional structure initially existed on the top of the embankment. It could be constructed as timber boxes or rather wicker baskets filled with sand and covered with clay. After the decomposition or destruction of the wicker construction, the sandy, clay and partly sod bricks were re-deposited by slope wash processes and mass movements. In this way, partly humic sandy deluvial covers (S.U. 269, 267, 261, 338, 336, 337, 310 and 309) with solids of humic sands (268, 263) and clay (262, 333) were deposited (Figs. 4 and 5; Table 3). These processes can be dated back to the period from the end of the thirteenth century to ca. 1330 AD (i.e. to the construction of the motte).

Most probably, ca. 1330 AD, the new owners of the stronghold initiated the next phase of construction works. The whole embankment was covered with sands and clayey sands to form a mound that was a platform to build a timber manor house or a keep. The material came from the levelling of part

of earlier structures as well as from the extension of the moat. At the foot of the mound, a timber construction was created, consisting of a double vertical palisade and horizontal beams. It strengthened the internal slope of the moat, which was extended to the width of even 21 m wide. It completely destroyed any remains of the earlier moat. The manor house built on the top of the mound was probably in the shape of a tower. Re-deposited layers of clay, carbonates, stones, humic sands and wooden remains suggest that the building was of timber frame construction with wattle and daub walls.

Conclusion

New research demonstrates that the area was occupied by open settlement from the second half of the tenth century. The earlier ring-fort was established there in the period between the eleventh and thirteenth century as a local administration and military center of the Piast Monarchy. From the fourteenth to fifteenth century, the stronghold in the form of motte-and-bailey functioned as a seat of a noble family (Sikora et al. 2018; Kittel et al. 2018a, b).

Pieces of charcoal of trees and shrubs are probably remnants of wood gathered for fuel in forest stands growing on dry (e.g. pine, spruce, oak), fresh (oak, hornbeam, lime, maple) and moist (alder, ash) lands in the surroundings of the settlement. The local agriculture was based on cultivation of bread wheat, rye and millet, possibly also oat. The list of field weeds suggests that summer crops were cultivated and tilling methods characteristic for root crops or gardens were used in the Early Middle Ages.

The differences in dating of charred plant macroremains and potsherds can suggest some use of earlier soil (cultural layer). We cannot exclude that some cultivated plots of early medieval origin were located in the area where the Rozprza stronghold was built a few centuries later. The presence of earlier charred remains could be explained by manuring plots with a cultural layer of early medieval origin which contained remains of ashes from fireplaces and other household activities. In such ashes, potsherds would be few in number or strongly fragmented.

It is conceivable that the “Dark Earth” soil and the sod bricks, respectively, from Rozprza indirectly reflect not only different environments (wood vs. open landscape) but also different economic systems with differing impacts on the local natural environment. However, the use of sod bricks at Rozprza, which is far away from the traditional “sod brick territory”, is until now unique in Poland and should be explained. The “Dark Earth” soil, in contrast, could be an evidence of a type of economy which was typical at least for the northern Slavic territory until the eleventh century (cf. Wiedner et al. 2015).

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