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The morphology of the Luciąża River valley floor in the vicinity of the Rozprza medieval ring-fort in light of geophysical survey

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Abstract. Multidisciplinary research (including magnetic survey, earth resistance survey, geological mapping, detailed archaeological surface survey and geochemical prospection) was undertaken on an area of about 0.7–9.0 hectares (depending on the method) in the close surroundings of the medieval ring-fort relicts in central Poland. The geophysical studies of the vicinity of the Rozprza ring-fort were part of a multi-method complementary non-destructive archaeological survey. The ring-fort is situated in the Luciąża River (Vistula River basin) valley floor and the flood plain morphology is very important for the reconstruction of palaeoenvironmental conditions of settlement location. Results of aerial photographs and geophysical prospection allowed the discovery of traces of sub-fossil palaeomeanders of different sizes as well as relicts of archaeological features (system of ramparts and moats). It was possible due to the application of high resolution archaeo-geophysical surveys. Both natural structures and also anthropogenic features registered with geophysics have been verified by geological sounding. The surface geology structure of the close vicinity of the ring-fort has been recognised in detail and selected organic deposits of palaeochannel fills and overbank covers have been ^{14}C dated. The Rozprza ring-fort was situated in a defensive location on the surface of a sandy terrace remnant in the central part of a (partly) swampy valley floor. The accumulation of recorded fills of palaeochannels and moats covers the whole Holocene, as documented by ^{14}C data. It gives the possibility for future detailed palaeoenvironmental studies. The results of geophysical studies, due to their known precise location, allow the effective planning of further research activities, both archaeological and palaeoenvironmental.

Key words
valley floor,
geological mapping,
geophysical surveying,
Middle Ages,
central Poland

Introduction

The Rozprza ring-fort settlement complex functioned as a tribal centre from the second half of the 9th to the mid-10th century AD. Later in the 10th–13th century AD it played an important role in the Piast state as a centre of local administration. In the second half of the 13th century it was the seat of a castellan and in the 14th century it became a seat of a noble family (Chmielowska 1966, 1982). In the early Middle Ages Rozprza was one of the most important medieval strongholds in central Poland, next to Łęczyca, Sieradz and Spicymierz. The complex had been situated in the central part of the Luciąża River valley (Fig. 1). Relics of the defensive system of the ring-fort are badly preserved but still clearly visible in the field as earthworks. The present-day surface of the immediate vicinity of the site is flat and covered by meadows with a dense network of irrigation channels (Fig. 2). The artificial channel of the River Luciąża is situated approximately 200 m to the west of the ring-fort remnants.

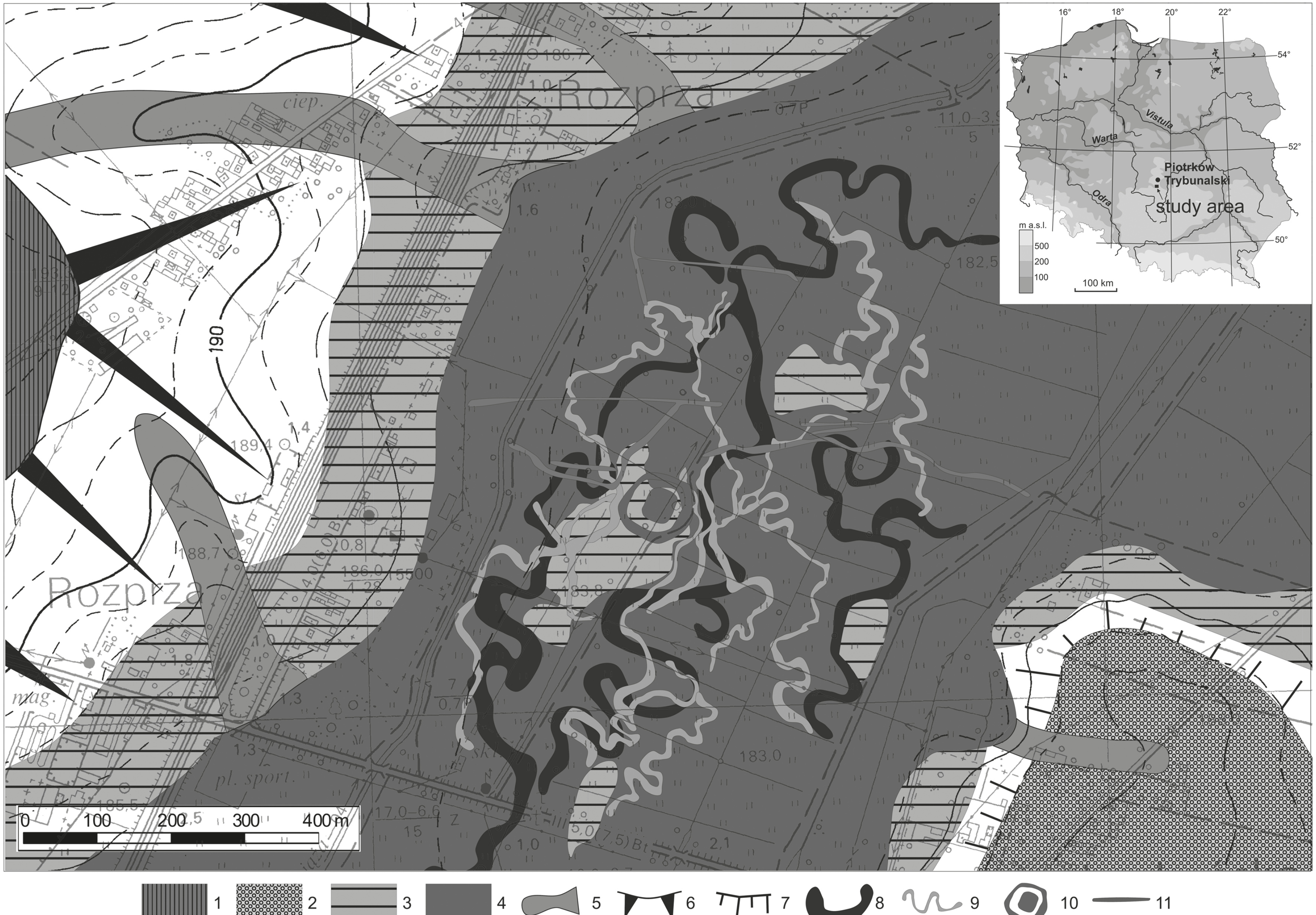

Fig. 1. Geomorphological map of the Rozprza ring-fort vicinity after Goździk (1982) and Wachecka-Kotkowska (2004a), modified: 1 – moraine plateau, 2 – glaciofluvial terrace, 3 – river terrace, 4 – valley floor, 5 – denudation valleys, 6 – long slopes, 7 – short slopes, 8 – large palaeomeanders (after aerial photos and partly after geophysical survey results), 9 – small palaeomeanders (after aerial photos and partly after geophysical survey results), 10 – location of the ring-fort, 11 – dykes, embankments and/or ways (after aerial photos)

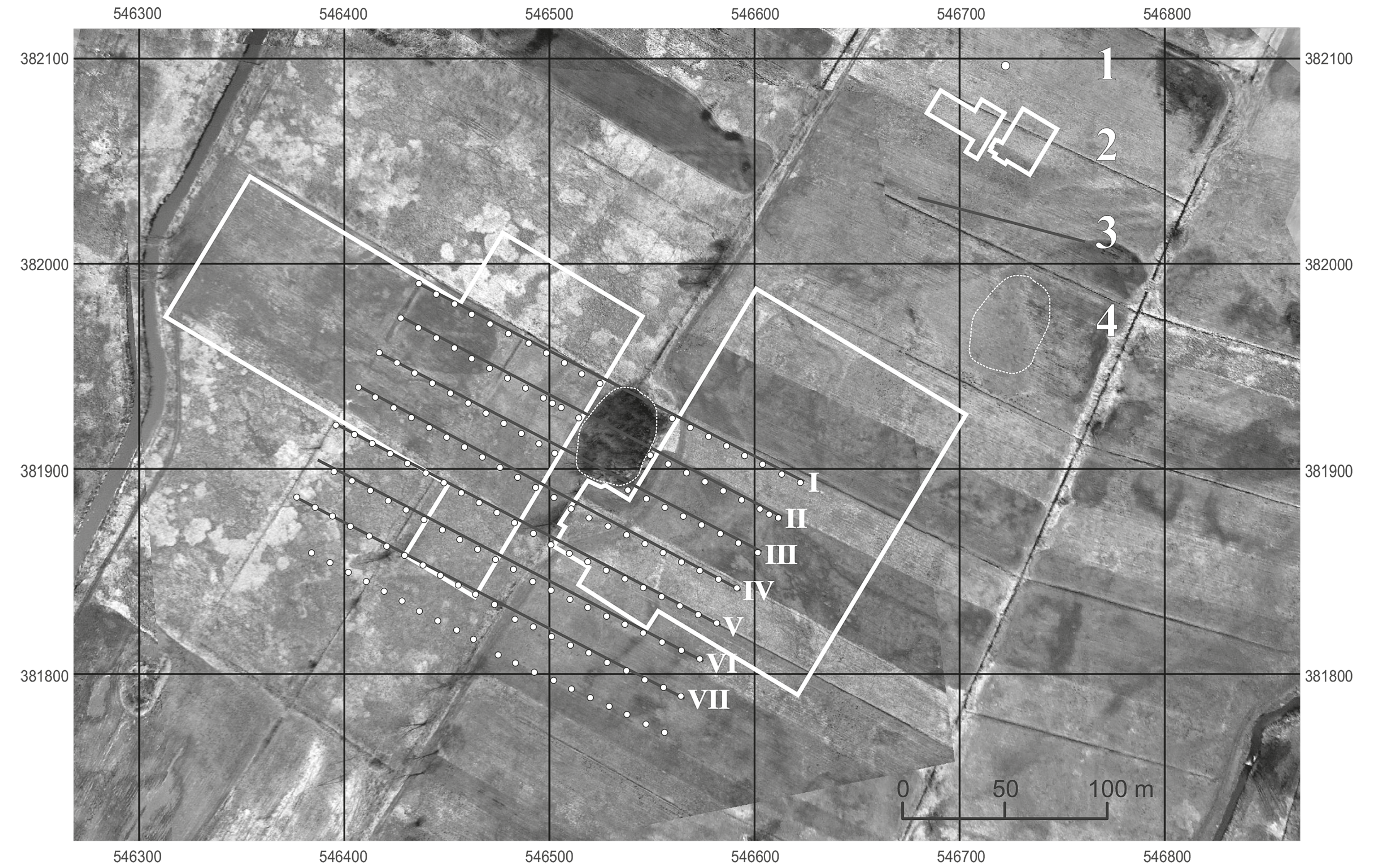

Fig. 2. Research area on aerial photography (Photo by W. Stępień, 2013): 1 – location of geological drillings, 2 – location of geophysical prospection area, 3 – geological cross-sections (see Fig. 5), 4 – location of the ring-fort remnants

In 2013 and 2014, a non-destructive survey of the area surrounding the ring-fort was carried out. The survey included analytical field walking, aerial photography, geochemical and geophysical (magnetic gradiometry and earth resistance) prospection along with geological mapping. The combined results shed new light by not only revealing new archaeological features but also showing previously unknown geomorphologic structures on the river valley floor.

Geomorphological research of the Luciąża River valley area was conducted by Goździk (1982) and Wachecka-Kotkowska (2004a, 2004b). Previous studies enhanced the general knowledge of the geological structure of the Luciąża River valley and recognition of the late Quaternary major stages in the evolution of the valley, but they did not include a detailed survey of the valley floor.

Results of geophysical surveys, large scale aerial photography and detailed geological mapping provided new data useful in reconstructing the river pattern of a small (ca. 2 ha) area and the artificial medieval moat system situated in the valley floor, which is a new approach in geological research. This detailed survey was supported by geochronometric determinations.

This area of central Poland lacks detailed palaeogeographical studies of river valleys in the Middle Ages (Twardy et al. 2014). Intense geomorphological and geoarchaeological research that took place in the mid-Ner River valley unfortunately revealed no evidence of sediments recording the medieval evolution of the valley environment (Kittel 2012). A clear geological record of medieval flooding dated back to the 11^{th}–12^{th} century AD is described in the Dobrzynka River valley (Kittel 2011).

Situation of the Site

The site (51˚18'07"N; 19˚40'04"E; 183 m a.s.l.) is situated in the middle sector of the Luciąża River valley, 12 km south from Piotrków Trybunalski and on the Piotrkowska Plain, after Kondracki (1998). Wachecka-Kotkowska (2004a) recognised three Weichselian river terraces (high terrace and low terrace) and one (highest) Wartanian glacifluvial terrace in the Luciąża River valley close to Rozprza. The western moraine plateau is formed by tills and the eastern by glacifluvial sands and gravels. The ring-fort occupies an area of the Plenivistulian residual terrace which probably adjoins the Late Weichselian low terrace and the Holocene floodplain (see also Goździk 1982). The valley floor is expanding in the Rozprza area. The morphology of the valley floor was obliterated by the deposition of modern overbank alluvium (see also Wachecka-Kotkowska 2004a, 2004b). Currently, the site occupies an area covered by meadows and fields in some places located between the main channel of the River Luciąża and the River Rajska (the secondary channel of the Luciąża R. system).

Methods and Approaches

As part of the non-destructive approach to the study of the ring-fort and its surroundings, a multitude of methods and activities were carried out including the commissioning of a contour plan of the settlement area covering about 7.2 hectares, a detailed archaeological surface survey of an area of about 8 hectares, geochemical (phosphate) analysis of an area of 1.5 hectares, a magnetometer survey of an area of 4 hectares, an earth resistance survey of an area of 0.7 hectares, and geological mapping of an area of 1.5 hectares. Two aerial prospection missions with the use of a plane and additionally with the use of a drone helicopter were carried out, resulting in a series of oblique and vertical aerial photographs of the settlement area. Selected images were georeferenced to obtain orthophotomaps of the site. All results have been integrated within a Geographic Information System (GIS).

Geophysical surveys were carried out with the use of the magnetic gradiometry (Fig. 3) and earth resistance methods (Fig. 4). Different geophysical methods allow the registration of different aspects of physical properties of the geological basement, such as magnetic susceptibility or conductivity. The specifications of the geophysical surveys (such as sampling rates, data collection strategy) aim at a comprehensive collection of data which will form the basis for a reliable interpretation of the acquired (magnetic field and soil resistance) measurements. This interpretation takes into account the analysis of contrasts between the natural background and visible disturbances – anomalies – and is most reliable in the case of large-scale surveys which fully encompass whole structures, making them easier to distinguish and analyse.

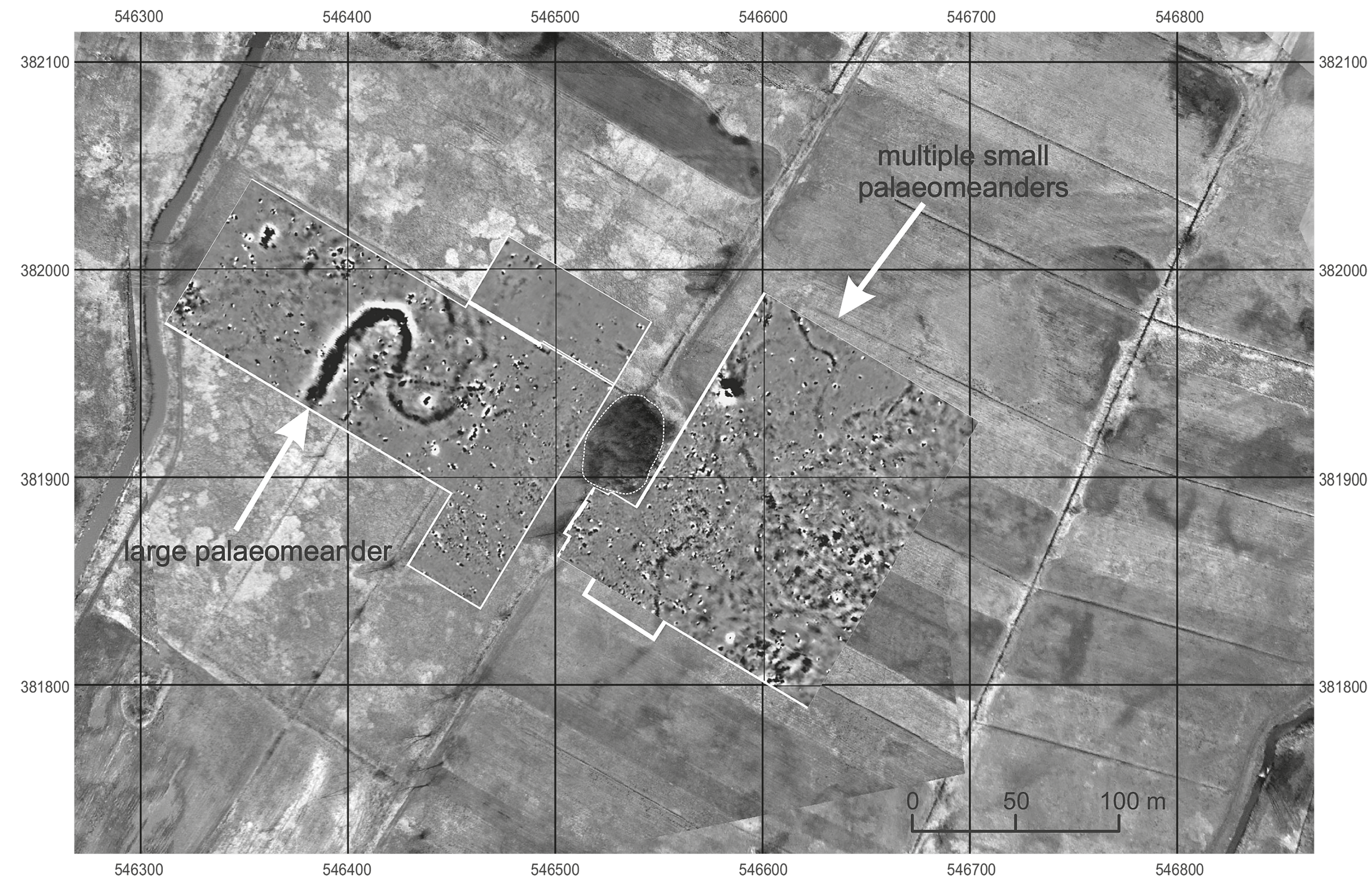

Fig. 3. Magnetic gradiometry survey results superimposed on an orthorectified aerial photograph with marked subsurface distribution of discovered structures (visualisation of magnetic gradiometry in grayscale, -3 to 3 nT, light to dark)

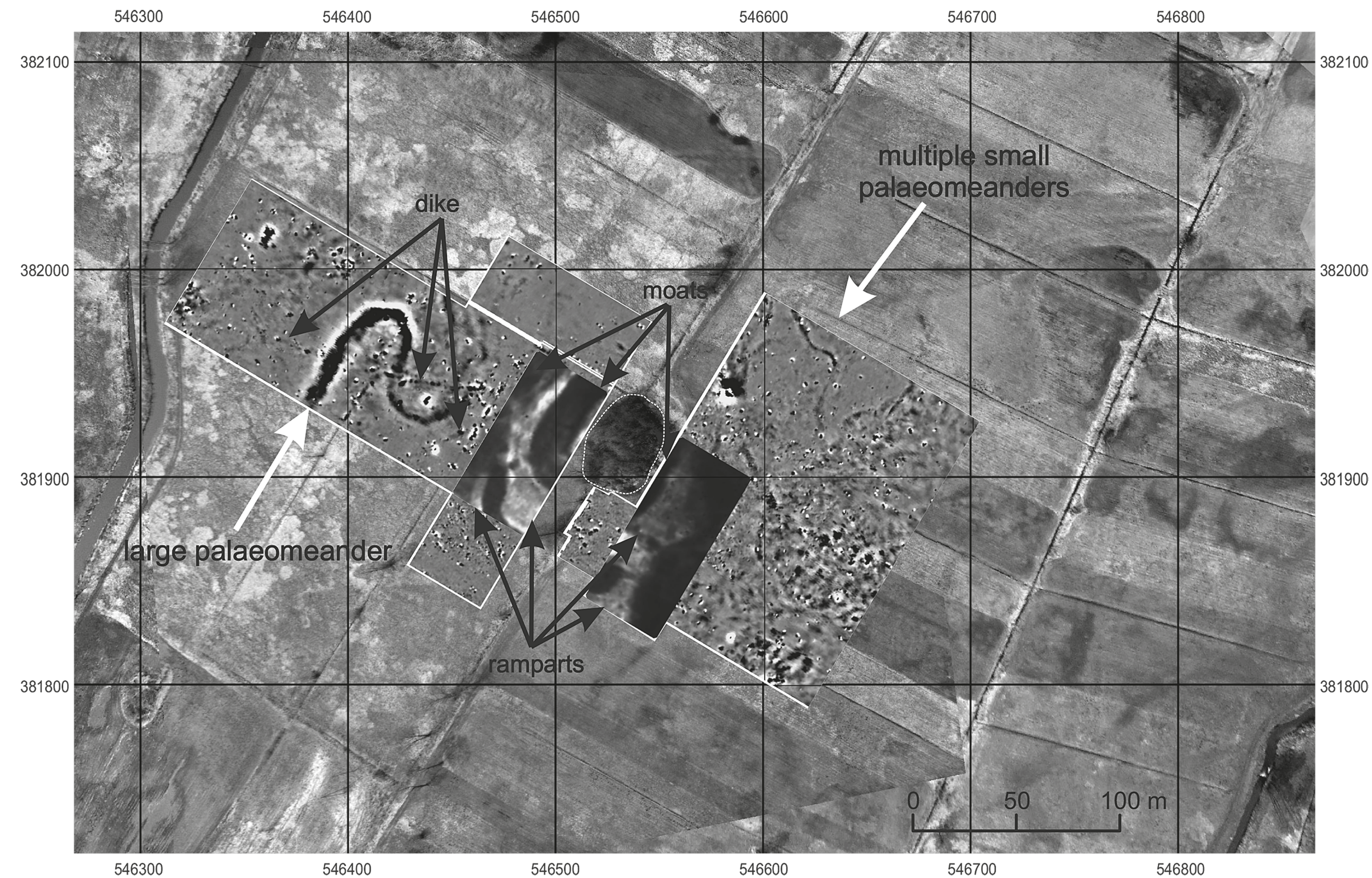

Fig. 4. Earth resistance survey results superimposed on an orthorectified aerial photograph with marked subsurface distribution of discovered natural and anthropogenic structures (visualisation of magnetic gradiometry in grayscale, -3 to 3 nT, light to dark; visualisation of earth resistance in grayscale, 20 - 300 Ohm/m, dark to light)

The study area of the geophysical survey was situated on both eastern and western sides of the ring-fort earthwork. A drainage channel in the centre of this area, along the remains of the ring-fort, severely impeded data collection. Initially, only the magnetic gradiometry survey was planned on an area of 4 ha. Based on recommendations from the English Heritage Geophysical Guidelines (David et al. 2008), the area adjacent to the ring-fort earthworks was also surveyed with the earth resistance method (0.7 ha). This was done in order to verify the effectiveness of the magnetic gradiometry, as it did not register the expected remains of the ring-fort defensive systems.

Magnetic gradiometry was carried out with the use of a Bartington Grad601-Dual system. Data were collected in a zig-zag pattern with a 0.5×0.25 m sampling. In total 326,000 such measurements were registered. The earth resistance survey applied an ADA-05 Elmes resistance meter setup in a 0.5 m Wenner array. Data were collected also in a zig-zag pattern with a 1×1 m sampling rate. In total 6,800 measurements were collected with this method. The acquired data were assembled and filtered with the use of geophysical software – Terrasurveyor (magnetic gradiometry) and Geoplot 3 (earth resistance).

Detailed geological survey was carried on the ring-fort settlement surroundings in order to recognise the surface geology of the area and geological structures recorded by aerial photographs and geophysical surveys. In total 166 drillings were performed using a hand auger (Eijkelkamp) at depths of 1.0 to 2.5 metres deployed in a 10×20 m grid. Seven 200-210 m long cross-sections were the result of these actions. Nine samples of organic materials collected from drillings have been dated by the radiocarbon method in the Laboratory of Radiocarbon Dating in Skała. For the calibration the OxCal v4.2 program has been used (Bronk Ramsey 2009), using atmospheric data from IntCal13 (Reimer et al. 2013).

All of the various field works were precisely located with the use of RTK GPS and Total Station instruments. These were used both for staking out study areas, as well as localising geological drillings, archaeological finds and collecting height data for the contour map. Geodetic, geophysical, geological and cartographic data derived from the field work were integrated into a GIS which was then used as a tool for multi-faceted interpretation of the newly acquired data.

Results

The study area is characterised by strong local variations of the magnetic field, which may be associated with the fluvial genesis of the area (Fig. 3). This manifests itself in the eastern part of the survey area in the form of narrow, linear, partly wavy, positive anomalies and zones of positive point and point dipolar magnetic anomalies. These are interpreted as a system of multiple narrow sub-fossil palaeomeanders. However, in the western part of the site a strong linear magnetic anomaly was captured, visible as an anomaly with a double arc shape continuing to the north and south. It is probably a trace of a large palaeomeander of the River Luciąża, which may be additionally supported by the existence of a terrain depression periodically covered with water (evidenced also on aerial photographs). The width of this form is about 10–15 m and the radius ca. 15 m.

Earth resistance prospection revealed the presence of a lowering of soil resistance on both sides of the ring-fort which was arranged concentrically around the ring-fort earthwork (Fig. 4). Low resistance values imply higher soil moisture, which is common for moat features, even ones that have been filled for a long time. Adjacent to this anomaly was a second, high resistance one which was barely visible on the magnetic data as a concentric zone of small amplitude dipolar anomalies. The shape and location of these anomalies strongly suggest that they are caused by hitherto not fully recognised exterior defensive systems which may be tied to one of the phases of the ring-fort's existence.

Another group of distinct anomalies was registered south of the ring-fort. Earth resistance prospection captured a high resistance structure. Its characteristic hemispherical outline (despite being revealed partially) allows an assumption that it may be a trace of a further defensive perimeter. In the western part of the study area, a narrow, linear anomaly intersecting the (above-mentioned) large palaeomeander was registered by the magnetic gradiometry survey. The same feature was clearly visible on multiple aerial images as a cropmark. Based on geological soundings (which revealed that the fill causing this anomaly contains wooden remains) and its spatial orientation towards the ring-fort's earthwork, it is interpreted as a possible bridge or causeway.

Based on the acquired geophysical data, the inner bailey was surrounded by two concentric ramparts and a moat system; an additional, second bailey surrounded by another wall and a moat was located to the south. Both are partly visible in terrain, on aerial photographs and earth resistance surveys and are also confirmed by geological coring (Fig. 5). The total area occupied by the fortification system spanned about 1.3 hectares, which fully corresponds to analogous timber castles from this period in Central Poland (Sikora 2007, 2009) and is larger than reconstructed in previous studies (Chmielowska 1966, 1982).

The geological survey confirmed the existence of moats with organic fill and partially inorganic deposits with rich remains of wood fragments that correspond to the various geophysical anomalies and to known features documented previously by Chmielowska (1966, 1982). The medieval age of the documented features is evidenced by radiocarbon data of the bottom part of the moat fill: 1080 ± 60 BP (MKL-2405); i.e. 895–1017 AD (prob. 68.2%), 774–1115 AD (prob. 95.4%) and 1040 ± 60 BP (MKL-2411); i.e. 897–1038 AD (prob. 68.2%), 783–1158 AD (prob. 95.4%) (Fig. 5, Table 1). They confirmed the possibility of the existence of a moat of the ring-fort system in the 9th century AD.

Another feature significant in advancing the spatial understanding of the Rozprza ring-fort was the large palaeomeander formed by the palaeochannel filled with organic deposits. This feature was registered by geophysical (magnetic gradiometer) and aerial prospection. The fill consisted of peat and gyttja and had a thickness up to 2.5 m containing also well preserved fragments of wood and hazelnut shells. Organic fill is overlain by channel alluvia of sands and gravels with organic admixtures. Radiocarbon data (10,200 ± 120 BP MKL-2408) from the bottom of the palaeochannel fill evidenced the channel cut-off in the Late Weichselian – Holocene transition. The oxbow basin was existing up to 6760 ± 80 (MKL-2407), i.e. 5732–5576 BC or 7681–7525 cal. BP and it was covered from ca. 4700 BC or 6700 cal. BP (5780 ± 80 BP, MKL-2406) with organic deposits of the flood basin. The cut-off of large palaeomeanders at the Younger Dryas – Holocene transition is documented for the Luciąża River valley (Wachecka-Kotkowska 2004a), the Pilica River valley (Szumański 1983), and other river valleys in the Łódź region (Turkowska 1990, 2006; Forysiak 2005; Kittel 2012) and in Poland (Starkel 1983, 2002; Starkel, Gębica 1995; Turkowska 1995; Kalicki 2006; Krupa 2013 et al.).

Another, yet smaller palaeomeander system was documented by the same techniques east of the ring-fort. In that area, channel alluvia with a depth up to 2 metres covered with overbank alluvia were recorded and with organic fills of palaeochannels in places. These small palaeomeanders with a depth up to 1 m are similarly filled with partly organic and inorganic deposits (above all peats and gyttja with remains of wood fragments). The bottom part of the gyttja filling of the sub-fossil palaeochannel is ^{14}C dated to 5790 ± 90 BP (MKL-2410), i.e. 4766–4532 BC or 6715–6481 cal. BP (prob. 68.2%). It means that an increase in fluvial processes ca. 6700–6500 cal. BP resulted in the cut-off of the river channel, but also in initiation of deposition of overbank alluvia in the flood basin in the area of the large palaeochannel situated west of the ring-fort. This phase could be situated on the AT3/AT4 boundary recognised by Starkel et al. (2013) as a humid period. Most probably in the 14th century AD (after 540 ± 60 BP, MKL-2409, 1318–1435 AD), the accumulation of silty-sandy overbank deposit cover was initiated in the valley floor of the Luciąża River valley in the Rozprza surroundings.

Some of the structures of narrow palaeomeanders recognised in the eastern part of the studied area may be interpreted as traces of overbank flow channels or may represent the remains of the multichannel river pattern shaped in the extension of the valley floor from the Little Ice Age.

The geological and geomorphological mapping of the Rozprza ring-fort surroundings confirmed the conclusions of Goździk (1982) about very reasonable conditions of location of the defensive settlement on the surface of the sandy Plenivistulian terrace remnant protected by swampy areas. However, our research allowed more detailed recognition of the morphology of the strict vicinity of the stronghold.

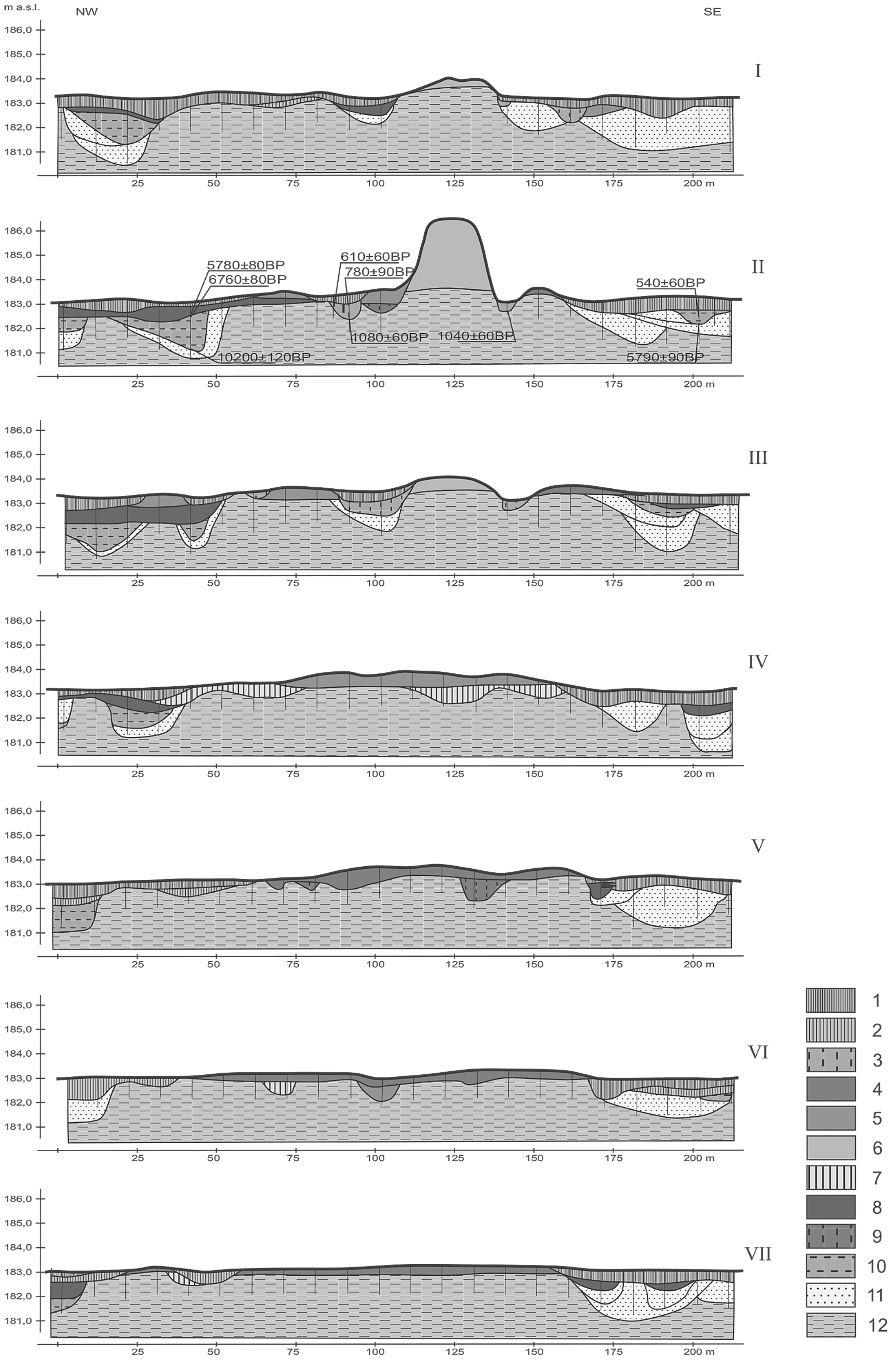

Fig. 5. Geological cross-sections of the Luciąża River valley floor in the ring-fort vicinity (location of cross-sections see Fig. 2): 1 – overbank sandy organic mud, 2 – overbank sands with laminations of organic mud, 3 – organic mud, peat and gyttja (moat fill), 4 – humic sands with organic mud (embankment and cultural layer), 5 – humic sands with charcoals (embankment), 6 – humic sands with charcoals (relicts of ring-fort rampart), 7 – overbank sands with organic mud, 8 – overbank organic mud and peat with plant macro-remains of flood basins, 9 – organic mud (moat fill), 10 – gyttja and peat (palaeochannel fill), 11 – sands with laminations of organic mud with plant macro-remains (channel alluvia), 12 – sands of Weichselian terrace

Table 1. Radiocarbon data of organic deposits from the valley floor in the vicinity of the Rozprza ring-fort

No.	Material (Fig. 5)	Depth [cm b.g.l.]	Age conv. BP	Laboratory code	Age cal. [BC/AD prob. 68.2%]	Age cal. [BC/AD prob. 95.4%]
1.	peat of moat fill (layer 3)	35–45	610±60	MKL-2412	1299–1399 AD	1281–1421 AD
2.	top of peat of moat fill (layer 3)	40–50	780±90	MKL-2404	1155–1297 AD	1035–1390 AD
3.	bottom of peat of moat fill (layer 3)	75–85	1080±60	MKL-2405	895–1017 AD	774–1115 AD
4.	bottom of organic mud of moat fill (layer 3)	35–45	1040±60	MKL-2411	897–1038 AD	783–1158 AD
5.	top of gyttja of palaeochannel fill (layer 10)	80–90	540±60	MKL-2409	1318–1435 AD	1296–1448 AD
6.	bottom of gyttja of palaeochannel fill (layer 10)	110–120	5790±90	MKL-2410	4766–4532 BC	4876–4450 BC
7.	bottom of overbank organic mud and peat of flood basins (layer 8)	65–73	5780±80	MKL-2406	4721–4538 BC	4826–4457 BC
8.	top of gyttja of palaeochannel fill (layer 10)	83–90	6760±80	MKL-2407	5732–5576 BC	5834–5527 BC
9.	bottom of gyttja of palaeochannel fill (layer 10)	180–190	10200±120	MKL-2408	10180–9667 BC	10441–9445 BC

Conclusions

The results of geophysical studies in 2013–2014 which were a part of a multi-method complementary non-destructive survey constitute a very important source of information regarding subsurface anthropogenic features as well as the diversity of the geological structures of the valley floor. They revealed the existence and spread of various morphological elements of the valley floor such as palaeochannels, flood basins, river terraces and river terrace remnants. Geophysical anomalies, due to their known precise location, allow also the effective planning of further research activities. Subsequent verification of anomalies by means of geological augering or geological test pitting combined with small-scale geoarchaeological excavations will allow the implementation of a time and cost-effective field methodology which will allow a comprehensive identification of the area's geoarchaeological resources.

The analysis of aerial photographs conducted for prospection purposes, and large-scale geophysical and geological surveys have shown moats and sub-fossil palaeochannels filled with organic deposits. It is necessary to identify the strict chronology of development of the recorded palaeomeander system with the use of geological methods including archaeological dating and palaeoecological research. The documented good state of preservation of biogenic sediments, reaching up to 2.5 m in thickness, with a number of well-preserved wood fragments (as well as hazelnuts) suggest that it will be possible to recognise in detail the evolution of the medieval environment in strict cooperation with archaeological excavations. A series of test trenches are planned, which should allow cross-sections of moat system fills to be obtained as well as those of palaeochannels west and east of the settlement for detailed palaeoenvironmental research.

Geophysical prospection (and non-destructive archaeology in general) during the past 25 years has become a household technique that vastly improves the cognitive abilities of archaeology. Most of the geophysical techniques used currently in archaeology have been adapted from traditional exploratory (shallow and deep) geophysics; however, due to the fact that many of the features that are sought by archaeologists are small (for instance 0.25 m cm wide), the methodology of archaeo-geophysical surveys has been vastly altered to suit these realities. One of the main changes is sampling: in order to effectively locate and correctly attribute various anomalies to archaeological features it is necessary to carry out systematic, high resolution measurements. As the Rozprza ring-fort case study proves, such approaches allow a similarly effective and precise discovery of natural structures. Undoubtedly the adaptation of archaeo-geophysical survey methodology could be a significant boost to the planning and analysing of geological, palaeoecological and palaeogeographical studies.

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