Non-invasive investigations of a Late Neolithic rondel at Gétye in western Hungary

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Introduction

This paper is an interim report on the initial findings of a research project designed to explore the prehistoric earthworks of Zala County in western Hungary. About thirty rondels and other complex structures of the Lengyel culture, seven of them in Zala County (Barna et al. 2016), are known from western Hungary (Transdanubia) to date. The present study focuses on the non-invasive and multidisciplinary investigation of one of these sites, the circular enclosure at Gétye-Gyomgyáló-lejtős. This site was discovered on an amateur aerial photo taken during an agricultural flight (Fig. 1).

The research project was designed and undertaken by a team made up of researchers from several Hungarian research institutes. Our research project focuses on the investigation of the earthworks, their location and setting in the landscape, their natural environment and their role in prehistoric settlement systems. Since we also consider the sky as an integral part of the natural environment, one of our goals is the analysis of how rondels are aligned in relation to the celestial bodies or phenomena. The authors of this paper have addressed the problems of the definition, designation, function, distribution, origin, and orientation of rondels in several studies (Barna/Pásztor 2011; Pásztor/Barna/Zotti 2014; Barna et al. 2015; Barna et al. 2016).

Rondels: History of research in Zala County

Since the discovery of the first Neolithic rondel in Hungary at Sé (Vas County) in the 1970s (Károlyi 1983–84), about thirty rondels and other complex structures of the Lengyel culture have been identified in western Hungary to date (Barna et al. 2016, Table 1; Bertók/Gáti 2011; 2014). The exact number of Late Neolithic rondels cannot be determined in the lack of exact dates. The Late Neolithic period in Transdanubia is spanned by the early and classical phase of the Lengyel culture (Kalicz 1988) according to the Hungarian terminology.

Seven circular earthworks of the Lengyel culture, whose majority are rondels, have been discovered at six sites in Zala County (Fig. 2.1–7), including the two enclosures at Sormás-Török-földek. Over one-half of the currently known sites lie in the Zalapáti Ridge micro-region.

These include a rondel with a single ditch (Gétye-Gyomgyáló-lejtős) and a triple rondel (Nagykanizsa-Palin, Anyagnyerőhely). Four double enclosures have been identified to date (Sormás-Török-földek I and II, Bezeréd-Teleki-dűlő II, and Balatonmagyaród-Hídvégpuszta). Field surveys were carried out on all of these sites. The exact ground plan of the assumed rondel at Becsehely-Gesztenyési-földek remains uncertain as it is only known from aerial photographs, while smaller or larger excavations have been conducted on the other sites (Sormás-Török-földek: Barna 2007; Barna/Pásztor 2011; Nagykanizsa-Palin, Anyagnyerőhely: Tokai 2008; Balatonmagyaród-Hídvégpuszta: Bánffy 1992; 1996). The sites at Bezeréd-Teleki-dűlő II and Gétye-Gyomgyáló-lejtős were also investigated by geomagnetic surveys.

Fig. 1 Amateur aerial photo of the rondel at Gétye-Gyomgyáló-lejtős.

History of research on the site

This site was discovered on an amateur aerial photo taken during an agricultural flight (Fig. 1) and then reported to the researchers of the Balaton Museum by an amateur collector. Our research team decided to gather as much information about the site as possible using non-invasive methods. First, in order to clarify the age of the site from surface finds, we conducted two field surveys in July and December 2011 before the geomagnetic survey, which was first undertaken in March 2012. The results of the first geomagnetic survey, which revealed approximately one-half of the rondel's ground plan, were published in a short preliminary report (Barna et al. 2012).

Another geomagnetic survey was carried out in November 2012 with the goal of mapping the entire ground plan of the rondel. This survey ended with partial success: although the previously missing part of the ground plan of the rondel could be measured and we obtained a clear outline of the enclosure, the GPS measurements of the height data were unsuccessful and, as a consequence, the digital elevation model of the site and the rondel could not be prepared. In order to remedy this situation, another survey was undertaken to repeat the measurements of the height data in September 2014. The pedological analysis was performed in August 2015. Two soil profiles were described in the field, while the chemical and physical properties of the soil samples collected from the profiles and from augerings at eight locations were further examined in a laboratory.

Geographical description of the site

The site of Gétye-Gyomgyáló-lejtős lies in Zala County, 13 km west of Keszthely. It is located on the northern part of the Zalaapáti Ridge, in the catchment of the Zala River. The site was selected for a geomagnetic survey based on several factors such as previously collected information (aerial and satellite photos), its geographical location and natural environment. The rondel is also clearly visible on an archive aerial photo taken for military purposes in the 1960s (Fig. 3).

The geomagnetic survey was undertaken in order to gather further data, first of all on the layout (ground plan) of the feature, which would help in clarifying the function of the en-

Fig. 2 The Late Neolithic rondels of Zala County: **1** Becsehely-Gesztenyési-földek; **2** Sormás-Török-földek; **3** Nagykanizsa-Palin, Anyagnyerő-hely; **4** Balatonmagyaród-Hídvég-puszta; **5** Gétye-Gyomgyáló-lejtős; **6** Ligetfalva-Gesztenyési-dűlő; **7** Bezeréd-Teleki-dűlő II.

closure identified on aerial and satellite photos.

The Gétye rondel lies in the Zala Hills of Zala County in western Hungary (latitude 46°45′4.65″N, longitude 17° 4′4.71″E). The area's topography is characterised by eroded valleys oriented towards north and south, its mean elevation is 171 m. The top and the slopes of the hills are eroded, the mean relief is 61 m^2/km. Yearly average precipitation is between 700 and 750 mm, the mean temperature is 10 °C. The geology of the area is characterised by young, Tertiary, clayey or sandy sediments (Pannonian deposition), Pleistocene loess deposited on the Cretaceous and Triassic rocks rich in calcium carbonate, and on metamorphic rocks from the Devonian and the Silurian period. The main land use type is arable farming, fruit trees and forests (Marosi/Somogyi 1990, 463).

The Zalaapáti Ridge is a 5–12-kilometre wide, weathered, flat-topped hill that runs lengthways from north to south between the

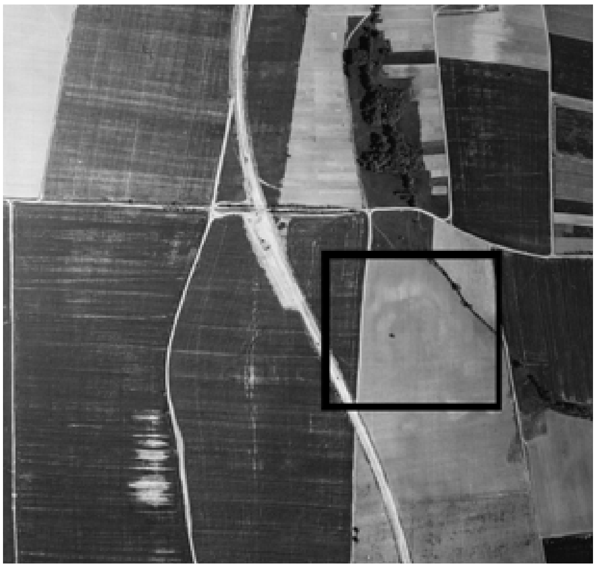

Fig. 3 Archive aerial photo taken for military purposes showing the surroundings of the site at Gétye-Gyomgyáló-lejtős, 14.05.1964.

Principális Channel and the lower course of the Zala River. Its surface is remarkably complex. This is the most extensive micro-region in the eastern Zala Hills. The typical soil type in the northern part of the Zalaapáti Ridge is Luvisol (IUSS Working Group WRB 2014) that evolved on loess slopes (Marosi/Somogyi 1990, 463).

The rondel at Gétye-Gyomgyáló-lejtős is located partly on the eastern slope of a north to south oriented hill and partly on a plateau whose height is *ca*. 170 m a.s.l. Owing to its location, its eastern side is distorted on account of the terrain where it was constructed, the result being an irregular oval ground plan instead of a regular circle. Here, on the eastern side of the hill, the slope descends steeply to the valley of the Csuhi Stream, which flows into the Zalaapáti Stream at a distance of *ca*. 500 metres south, south-east of the site. Similarly to all the streams flowing in the northern part of the Zalaapáti Ridge, the water of Zalaapáti Stream is collected by the Zala River.

Traces of an extensive Neolithic settlement were identified at Gétye-Káptalan út on the other side of the valley of the Csuhi Stream during a field survey in 2011. The site lies east of the rondel. The settlement, which had possibly been occupied during the rondel's active use, can perhaps be identified with this site, but this assumption still needs to be confirmed. The Neolithic site at Gétye-Káptalan út is bordered

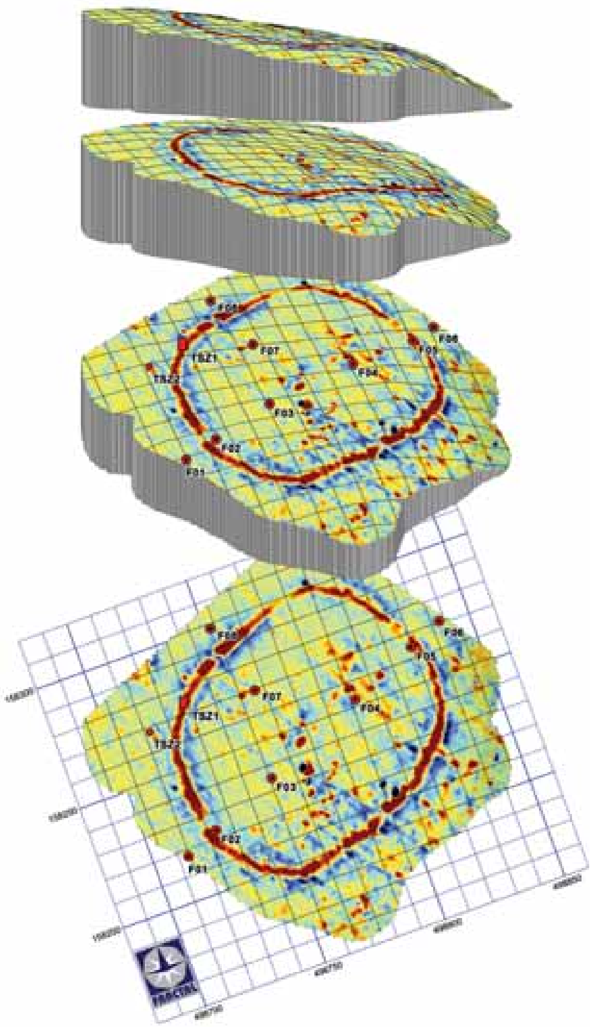

Fig. 4 The processed magnetic map of the rondel shown with a blue-yellow-red colour scale.

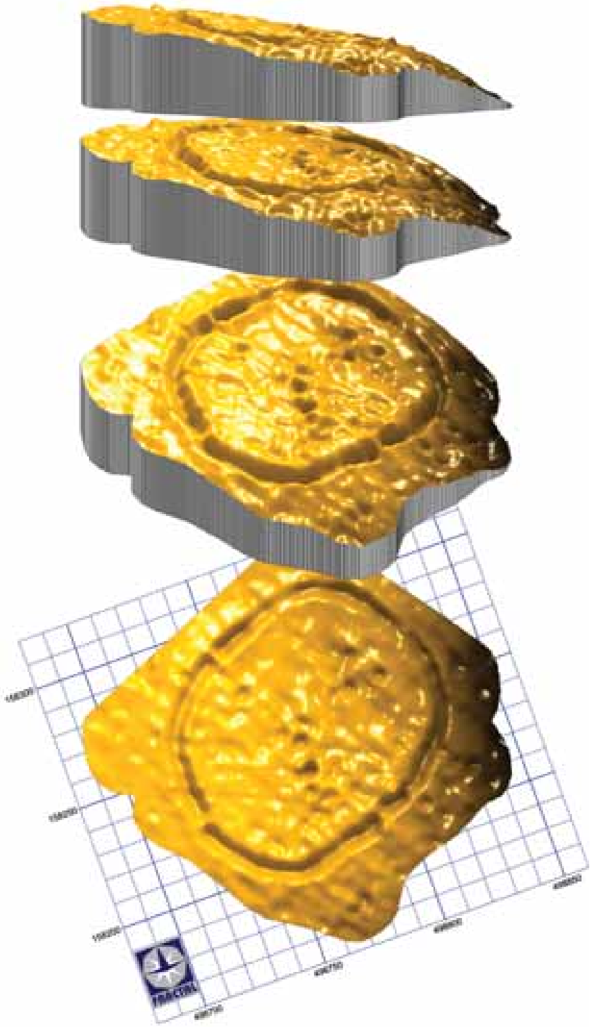

Fig. 5 The assumed source of magnetic anomalies shown on a map.

by the Csuhi Stream from the south and the west, and by the Zalaapáti Stream from the east. The southern end of the hill extends into the valleys of both streams like a peninsula. The hill top rises significantly above its surroundings and offers a splendid view and a strategically excellent position.

The rondel at Gétye-Gyomgyáló-lejtős: Orientation and location of the rondel

The Gétye rondel consists of a single, oval ditch (Figs 4–5) with a V-shaped cross-section as can be seen on the graphic representation depicting the magnetic anomalies as negative heights (Fig. 5). The four gates interrupting the ditch have their axes oriented 66°, 141°, 255°, and 333° of north, respectively. Its diameter is about 96 m x 115 m, making it a medium-sized rondel compared to the other ones. The low number of magnetic anomalies and the scatter and position of the Neolithic surface finds indicate a handful of settlement features both inside and outside the rondel. There were no recognisable trace of a palisade. The higher anomalies in the "gate" areas of the ditch – except at the eastern gate – are noteworthy because they perhaps indicate the remains of burnt wooden gate constructions or of charcoal and burnt daub remains from ritual activities.

The location of the Gétye rondel in the landscape can be regarded as typical. The selection of the rondel's location in the geographical surroundings was most likely principally determined by the choice of settlement locations. Also, additional functional considerations such

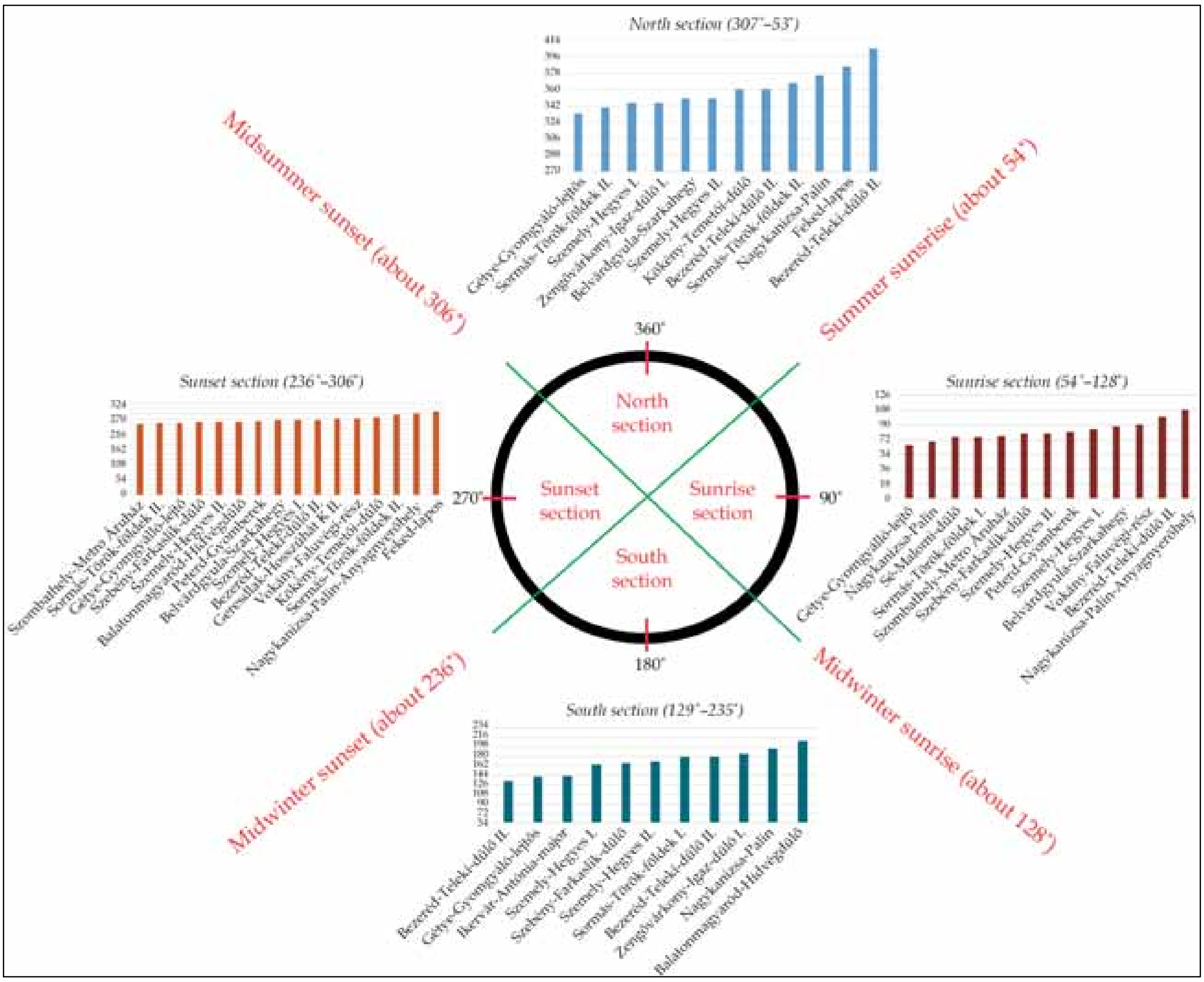

Fig. 6 The orientation values of the gates on the eastern side of circular enclosures (rondels) investigated in Transdanubia.

as the alignment or maintenance of the earthwork as well as various dimensions of beliefs such as the ones relating to the sun may also have played a role. It has been recently argued that topographic conditions and slope direction may also have influenced the location of the earthworks and the orientation of their gates (Zotti/Neubauer 2015; Pásztor/Barna/Zotti 2014). The orientation of the eastern "gates" of the rondels reflects a conscious and deliberate choice, which was no doubt motivated by the belief system (Pásztor/Barna/Roslund 2008).

The analysis of the alignments of nineteen sites for which data is currently available in Transdanubia (Barna et al. 2015) seems to support our previously published contention that the eastern gates were oriented toward the position of the rising sun on the horizon (Pásztor/Barna/Roslund 2008; Pásztor/Barna/Zotti 2014). The orientations of the gates on the eastern side of the rondels not only fall within the rising sun arc on the horizon, but they also fall within a narrow range (± 5% to due east) which reflects a common principle behind the architectural features and, possibly, shared foundation rites (Barna et al. 2015, Fig. 10) (Fig. 6). The clustering in the alignment data may indicate the strict and coherent adherence to this principle ruling alignment. At the same time, it seems to be irrelevant in terms of the chronological position of a particular site within the Lengyel culture since the same practice can be traced in different phases of this culture. A high degree of uniformity in the architectural design of rondels is attested among the ditch systems of the Lengyel culture in the western (Transdanubian) half of the Carpathian Basin, in south-western Slovakia and in eastern Austria (Zalai-Gaál

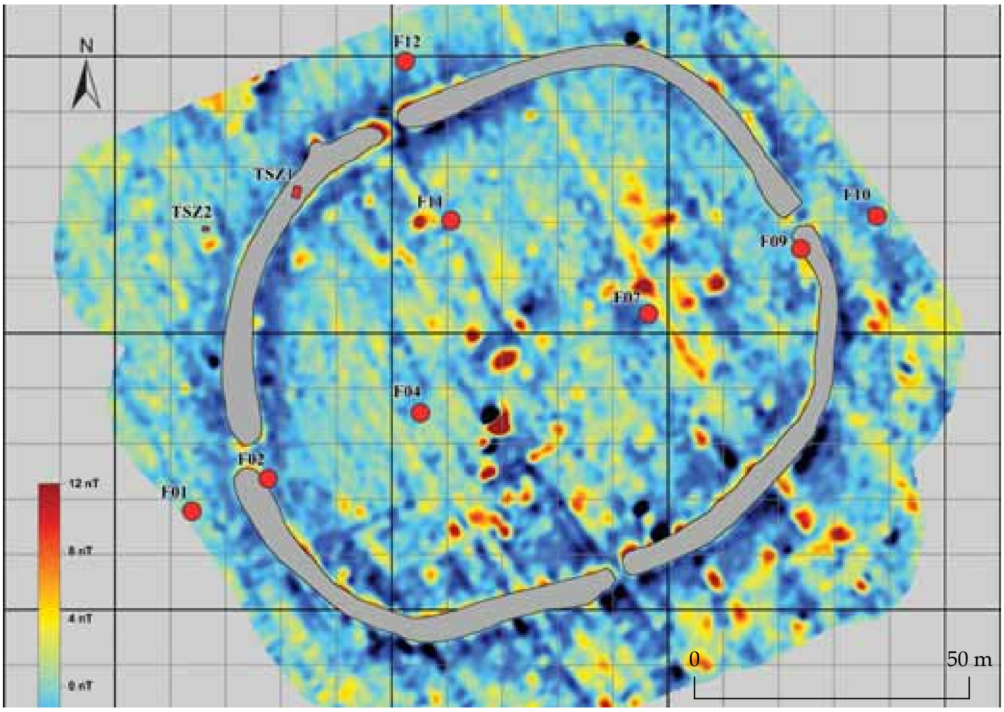

Fig. 7 The location of soil profiles (TSZ1 and TSZ2) and soil augering points (F01-F08) shown on the magnetometer plot.

1990, 20). Our assumption is that this uniformity can be demonstrated in the alignment of the eastern gates, in the principle of how to set the direction of these gates, as well as in how to construct the others, that is, in the materialised form of the very "concept of the rondel".

This principle and ideology was observed in the later phases of development in Transdanubia, which is part of the formation territory both of the Lengyel culture and of the rondels (Barna/Pásztor 2011). This principle in founder orientation also survived into later times, when the layout and structure of rondels had undergone considerable change and deformation.

From our detailed analysis of the alignment data of the Gétye rondel, we concluded that the relief conditions may have resulted not only in the distorted oval ground plan, but also in some bias of the direction set out during the alignment procedure. The extreme alignment data of the Gétye rondel can be clearly seen in Figure 6.

GIS measurements

We needed a field equipment capable of phase measurement for the high-precision GPS measurement. We used a Trimble 5800 receiver with the TSC2 survey controller version 12.22. There was no possibility to receive online refinement data during the terrain measurements.

During the post-processing of the GPS data gained from the kinematic terrain measurement, we used the data collected by the GNSS (Global Navigation Satellite System – GPS, GLONASS) Base Station of the Georgikon Faculty, University of Pannonia, Hungary. The optimal short base vectors (well under 30 km) were suitable for geodesic accuracy (cm). The GPS data exported to a RINEX (Receiver Independent Exchange Format) format were used with the help of the TBC (Trimble Business Center version 2.6) processing software to meet the base data.

We chose the EOV[1] (1972) Hungarian coordinate system for our data, which is officially and widely used in Hungary. The elevation cut and the frequency of procession of observation were, similarly to the terrain measurement settings, 10 degrees and 10 seconds. Vertical and horizontal accuracy requirements were set to the usual 0.1m + 1ppm and 0.2m + 1ppm (ppm – part per million). Thus, the processed vectors of several

[1] Egységes Országos Vetületi Rendszer = National Uniform Projection System.

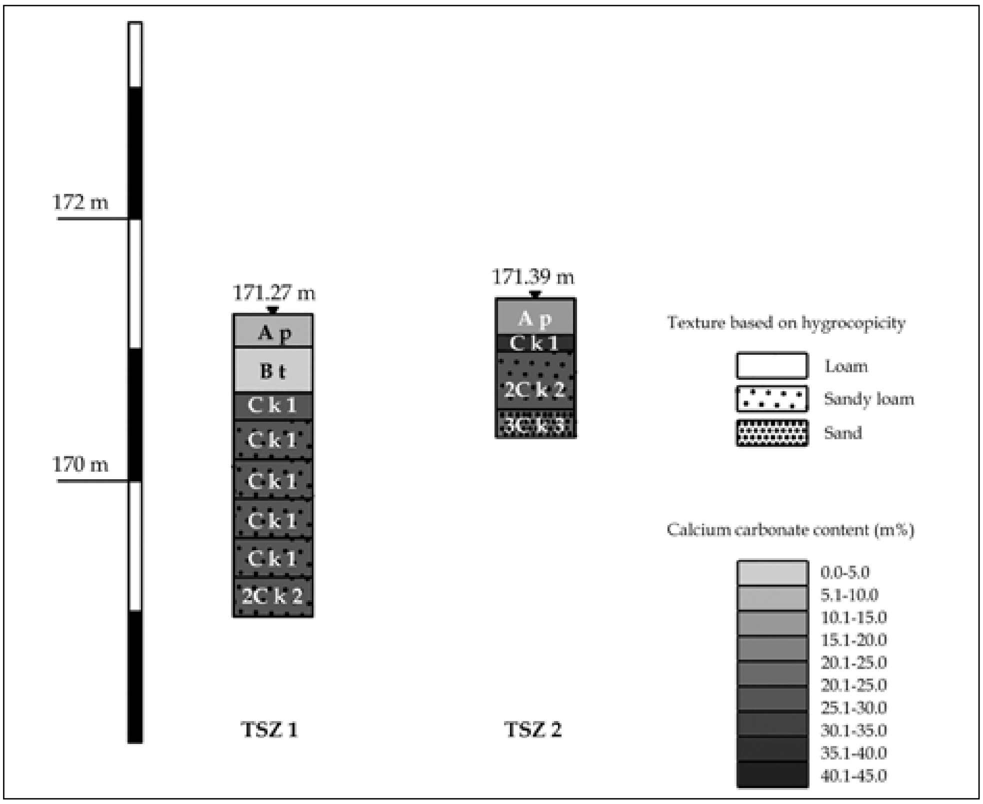

Fig. 8 Texture and calcium carbonate content of augered soil profiles (TSZ1 and TSZ2).

kinematic measurements were altogether 15849 in Gétye, Hungary.

Several problems had to be solved during the collection of the coordination information used for the magnetometer measurement. First, while performing the measurements, the tools had to be synchronised in time and space. Because of local circumstances, a continuous GPRS connection was not accessible (appropriate accuracy radio and satellite refinement was not possible), and thus only the post-processing of the GPS data could be applied. Measurements were carried out in three stages. Terrain positioning was used twice for the magnetometric measurements, and once for the validation and accuracy refinement of previously obtained data. The latter was necessary because of the uncertainty caused by the short initialisation time during the post-processing of the second set of measurements. These measurements ensured that we could work with a geodesic accuracy model.

Geophysical survey

The extent of the examined area was 180 m × 160 m. We took magnetic measurements on the points of a 0.5 m × 1.0 m grid. We collected over 30,000 magnetic data, from which we computed a map.

We used a GSM-19 (Overhauser) magnetometer by GEM Systems for measuring the magnetic induction in horizontal variometer arrangement. This involves a parallel data collecting with a moving magnetometer and a base magnetometer. The navigation was performed by the "GPS tracking" method. In this case, the two units (GPS and MAG) were at a constant distance from each other in order to minimise the magnetic disturbance of the GPS. The coordinates of each point were treated as data of sub-meter accuracy.

During the processing, we analysed the properties of the data in the field and frequency domain, and chose the optimal processing parameters. The following steps were performed during data processing: measurement noise reduction; base correction; dynamic compression; interpolation of the data; filtering of the magnetic maps; extrapolation of the data; calculation of the two-dimensional Fourier spectrum; calculation of the radial power spectra; low pass filtering of the data; direction dependent filter-

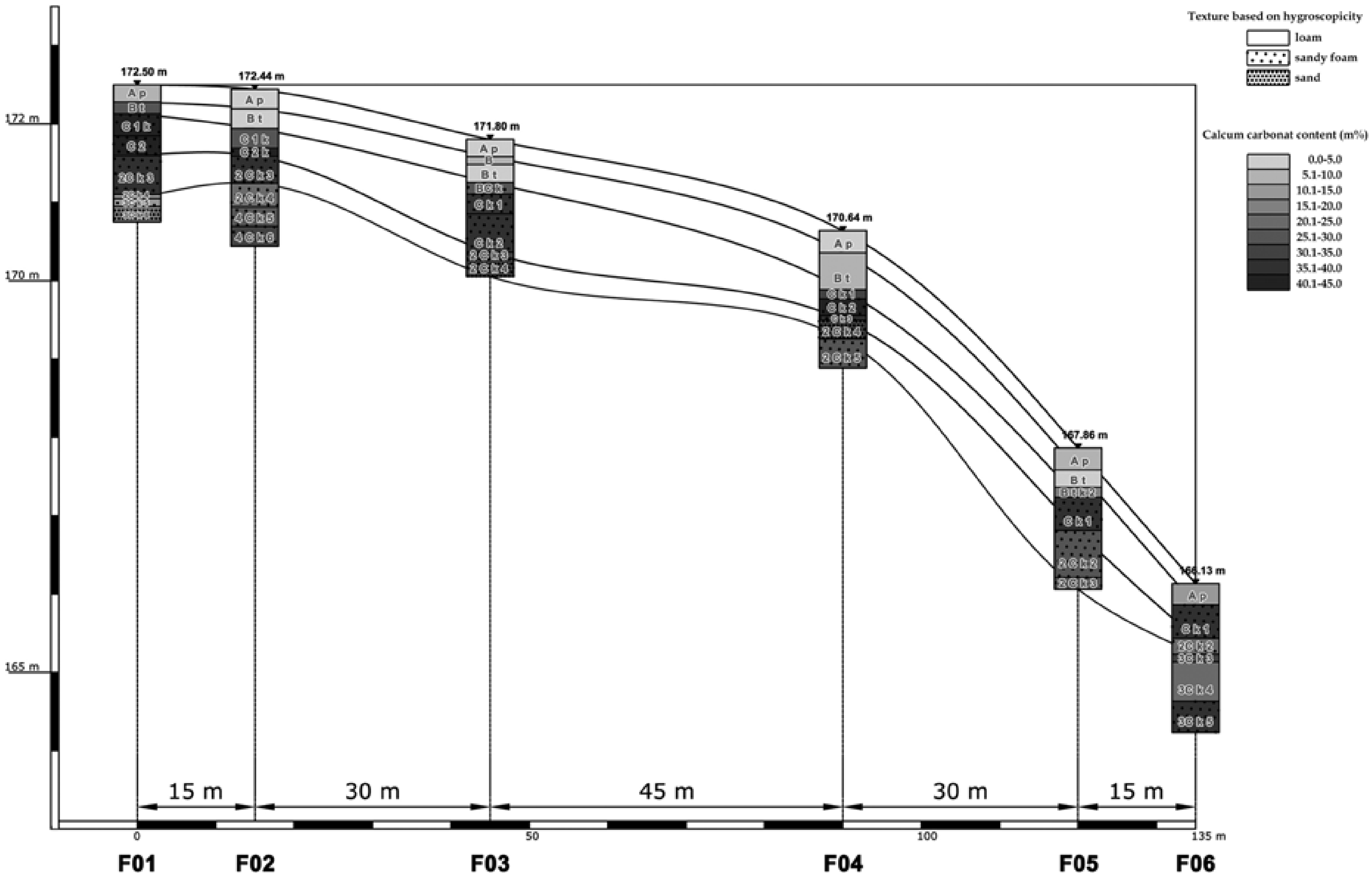

Fig. 9 Location, calcium carbonate content and texture of augered soil samples 5 m southwest from the centreline of the ditch's west and east gate (F01-F06).

Point ID	Horizon symbol	Depth (cm)	Colour	Plasticity according to Arany (m%)	Hygro-scopicity (m%)	Texture based on hygro-scopicity	Or-ganic carbon (m%)*	Or-ganic matter (m%)	$CaCO_3$ (m%)	PH_{H2O}	PH_{KCl}	Total P (mg/kg)
F01	A p	0-22	10YR 4/3	48	2.22	loam	1.00	1.73	5.43	7.64	7.28	1184
	B t	22-37	2.5Y 5/6	52	2.56	loam	0.79	1.36	26.75	7.67	7.3	1142
	C 1 k	37-65	2.5Y 6/6	58	1.68	sandy loam	NA	NA	40.76	7.84	7.59	634
	C 2	65-90	2.5Y 6/6	66	1.69	sandy loam	NA	NA	41.91	8.11	7.63	559
	2C k 3	90-140	2.5Y 6/4	72	1.92	sandy loam	NA	NA	37.18	8.24	7.67	539
	2C k 4	140-145	2.5Y 4/1	72	2.70	loam	NA	NA	10.35	8.18	7.5	678
	3C k 5	145-155	10YR 3/3	56	1.57	sandy loam	NA	NA	19.88	8.11	7.76	982
	3C k 6	155-175	10YR 4/3	46	0.85	sand	NA	NA	22.25	8.15	7.95	1645
F02	A p	0-25	10YR 4/3	46	2.22	loam	1.01	1.74	4.57	7.59	7.29	1297
	B t	25-50	10YR 4/4	48	2.84	loam	0.72	1.24	4.54	7.48	7.08	1006
	C 1 k	50-75	2.5Y 5/6	60	2.21	loam	NA	NA	29.74	7.91	7.45	669
	C 2 k	75-85	2.5Y 6/6	62	1.91	sandy loam	NA	NA	44.72	8.23	7.55	547
	2 C k 3	85-120	2.5Y 5/2	64	2.02	sandy loam	NA	NA	39.14	8.21	7.54	536
	3 C k 4	120-150	2.5Y 6/6	66	1.08	sandy loam	NA	NA	24.25	8.21	7.77	782
	4C k 5	150-175	2.5Y 6/8	54	1.16	sandy loam	NA	NA	30.63	8.15	7.82	592
	4C k 6	175-200	10YR 5/8	56	1.21	sandy loam	NA	NA	35.24	8.17	7.69	616
F03	A p	0-22	2.5Y 4/4	54	2.84	loam	1.22	2.10	4.69	7.52	7.2	1101
	B	22-32	10YR 3/6	56	2.99	loam	0.92	1.59	6.03	7.55	7.22	952
	B t	32-55	10YR 4/6	66	3.02	loam	0.52	0.90	2.79	7.7	7.25	973
	BC k	55-70	10YR 5/4	56	2.00	sandy loam	0.30	0.51	28.27	7.88	7.56	904
	C k 1	70-95	10YR 5/6	52	1.35	sandy loam	NA	NA	35.81	8.1	7.63	1175
	C k 2	95-144	10YR 6/6	62	1.65	sandy loam	NA	NA	35.01	8.27	7.61	541
	2 C k 3	144-152	2.5Y 5/6	54	1.52	sandy loam	NA	NA	25.42	8.11	7.62	1488
	2 C k 4	152-175	2.5Y 5/6	50	0.97	sand	NA	NA	25.16	8.21	7.78	750
F04	A p	0-28	10YR 3/3	48	2.21	loam	1.17	2.01	4.60	7.37	7.02	979
	B t	28-75	10YR 4/3	54	2.49	loam	0.57	0.98	5.65	7.48	7.2	1056
	C k 1	75-87	10YR 5/6	54	2.10	loam	NA	NA	34.81	7.64	7.47	1273
	C k 2	87-108	10YR 7/8	60	1.71	sandy loam	NA	NA	41.97	8.03	7.56	815
	C k 3	108-114	10YR 5/6	60	1.95	sandy loam	NA	NA	38.37	8.05	7.52	663
	2 C k 4	114-138	10YR 5/3	62	2.19	loam	NA	NA	33.60	8.09	7.49	506
	3 C k 5	138-175	10YR 5/8	62	1.91	sandy loam	NA	NA	29.19	8.18	7.58	613
F05	A p	0-28	10YR 3/3	54	2.36	loam	1.07	1.84	7.39	7.56	7.35	1068
	B t	28-50	10YR 3/4	56	2.45	loam	0.65	1.12	3.59	7.68	7.33	1113
	B t k 2	50-63	10YR 3/6	52	2.11	loam	0.28	0.48	18.16	7.97	7.55	1916
	C k 1	63-105	10YR 5/6	56	1.70	sandy loam	NA	NA	35.99	8.04	7.68	756
	2C k 2	105-165	10YR 4/6	60	1.91	sandy loam	NA	NA	25.08	8.14	7.65	465
	2C k 3	165-180	10YR 6/6	64	1.76	sandy loam	NA	NA	29.09	8.21	7.7	336
F06	A p	0-27	10YR 3/3	54	2.07	loam	1.00	1.72	13.88	7.63	7.41	531
	C k 1	27-70	10YR 5/6	56	1.84	sandy loam	NA	NA	35.18	7.97	7.58	379
	2C k 2	70-90	10YR 5/8	52	1.82	sandy loam	NA	NA	22.85	8.06	7.64	301
	3C k 3	90-100	10YR 6/6	58	2.58	loam	NA	NA	30.04	8.12	7.55	281

Table 1 (part 1) Physical and chemical properties of soil horizons collected for the analysis of the Gétye ditch.

Point ID	Horizon symbol	Depth (cm)	Colour	Plasticity according to Arany (m%)	Hygro-scopicity (m%)	Texture based on hygro-scopicity	Or-ganic carbon (m%)*	Or-ganic matter (m%)	$CaCO_3$ (m%)	PH_{H2O}	PH_{KCl}	Total P (mg/kg)
F06	3C k 4	100-150	2.5Y 6/6	58	2.29	loam	NA	NA	22.55	8.21	7.64	244
	3C k 5	150-190	2.5Y 5/4	70	1.97	sandy loam	NA	NA	35.69	8.19	7.73	376
F07	A p	0-25	2.5Y 3/2	52	2.47	loam	1.22	2.11	6.24	7.62	7.32	881
	B	25-30	10YR 3/3	50	2.43	loam	1.22	2.10	10.36	7.69	7.31	866
	C k 1	30-50	10YR 3/1	56	1.42	sandy loam	NA	NA	39.35	7.86	7.61	453
	2C k 2	50-95	10YR 3/6	48	0.71	sand	NA	NA	27.49	8.02	7.8	496
	2C k 3	95-120	10YR 5/6	46	0.81	sand	NA	NA	21.12	8.14	7.91	470
	3C k 4	120-150	2.5Y 5/6	72	1.79	sandy loam	NA	NA	36.10	8.14	7.7	663
F08	A p	0-22	10YR 3/4	52	2.26	loam	1.20	2.06	12.92	7.79	7.32	909
	B t	22-30	10YR 3/3	56	2.30	loam	1.07	1.85	14.95	7.67	7.39	866
	C k 1	30-45	10YR 5/6	60	1.84	sandy loam	NA	NA	34.90	7.76	7.53	350
	2C k 2	45-60	10YR 5/1	74	2.46	loam	NA	NA	33.54	8.02	7.44	232
	3C k 3	60-105	10YR 3/2	48	1.01	sand	NA	NA	24.37	8.13	7.79	915
	4C k 4	105-115	10YR 4/3	66	1.76	sandy loam	NA	NA	29.25	8.2	7.65	688
	4C k 5	115-145	10YR 4/4	66	1.67	sandy loam	NA	NA	24.69	7.99	7.56	439
TSZ1	A p	0-25	10YR 4/4	60	2.52	loam	0.82	1.41	6.21	7.68	7.61	792
	B t	25-60	10YR 3/4	60	2.71	loam	0.56	0.97	4.26	7.71	7.33	947
	C k 1	70-80	10YR 4/4	50	2.05	loam	NA	NA	26.50	8	7.65	643
	C k 1	100-110	10YR 4/6	50	1.78	sandy loam	NA	NA	26.79	8.13	7.72	1030
	C k 1	130-140	10YR 4/4	52	1.86	sandy loam	NA	NA	28.04	8.18	7.69	436
	C k 1	160-170	10YR 4/4	52	1.71	sandy loam	NA	NA	27.66	8.15	7.7	605
	C k 1	190-200	10YR 4/4	60	1.73	sandy loam	NA	NA	25.59	8.07	7.67	1004
	2C k 2	210-230	10YR 4/3	54	1.22	sandy loam	NA	NA	21.83	8.1	7.7	556
TSZ2	A p	0-28	10YR 3/4	50	2.45	loam	1.21	2.09	16.12	8.09	7.28	591
	C k 1	28-40	10YR 4/6	48	1.45	sandy loam	NA	NA	37.64	7.81	7.58	278
	2C k 2	40-85	10YR 4/4	50	1.37	sandy loam	NA	NA	34.91	8.08	7.59	674
	3C k 3	85-105	10YR 4/3	50	0.82	sand	NA	NA	21.45	8.19	7.69	410

Table 1 (part 2) Physical and chemical properties of soil horizons collected for the analysis of the Gétye ditch.

[a] Organic carbon content was analysed for topsoils and subsoils.

[b] Organic matter content was calculated assuming that it has 58% organic carbon content.

ing of the data; downward continuation of the data; reduction to the pole; optimum (Wiener) smoothing filtering; phase only map; coherence enhancement.

The processed magnetic map is shown by a blue-yellow-red colour scale (Fig. 4).

The second map shows the assumed source of the magnetic anomalies. In our view, the anomalies reflect the material of infilled pits or ditches (Fig. 5).

Pedological analysis

The aim of the pedological analysis was to confirm the findings of the archaeological research in terms of soil formation processes and to predict the probable depth of the prehistoric soil surface at the time the Gétye rondel was constructed.

The most characteristic soil type around Gétye is Luvisol (IUSS Working Group WRB 2014)

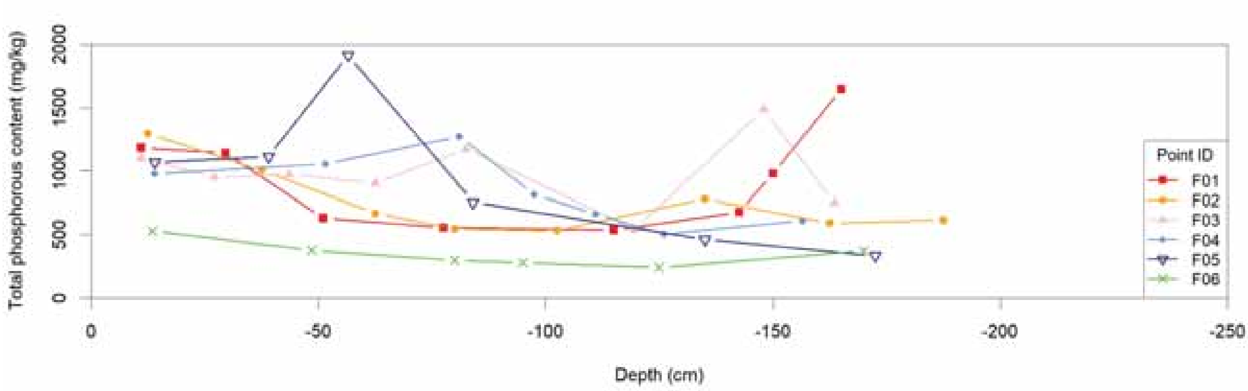

Fig. 10 Total phosphate content of soil samples inside and outside the Gétye rondel (F01–F06).

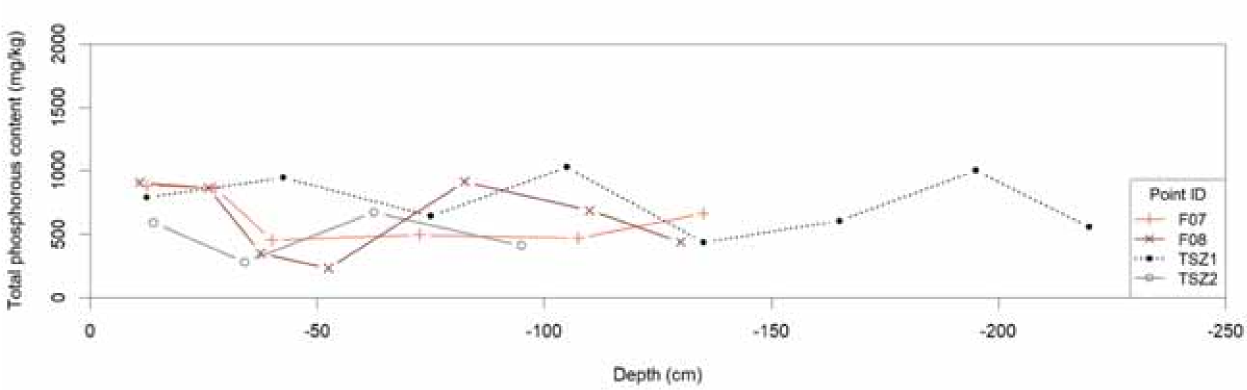

Fig. 11 Total phosphate content of soils samples inside and outside the Gétye rondel (F07–F08, TSZ1–TSZ2).

developed on loess parent material, which is eroded on the hillslope areas (Dövényi 2010).

We analysed two soil profiles and augered samples taken from eight points. We used the results of the magnetometer analysis when selecting the soil sampling locations (Barna et al. 2012). We analysed two soil profiles for confirming the presence of the infilled ditch. One was taken from the fill of the rondel's ditch (TSZ1), the other from a point outside the ditch (TSZ2), where the magnetometer analysis did not indicate any disturbances.

We also analysed the differences in soil development caused by the slope in order to understand where the prehistoric soil surface was at the time the rondel was constructed. We collected augered samples at eight points: six augerings were made 5 m south-west of the imaginary centreline between the rondel's western and eastern gate (F01–F06) and two were made along a line towards the north that was perpendicular to the imaginary centreline (F07 and F08) (Fig. 7).

The distribution of soil properties according to soil depth was analysed in R statistics (R Core Team 2013).

We described the soil profiles in the field. Soil horizons were also distinguished for the augered samples. In the case of F01-F08 and TSZ2, we collected samples from each soil horizons. In order to better understand the ditch's infilling, we sampled horizon C of the TSZ1 profile at every 30 cm with 10 cm depth interval.

We analysed the Munsell colour of wet samples, the soil texture based on hygroscopicity (MSZ-08-0205-1978) and plasticity (MSZ-21470-51-1983), organic carbon content (Tyurin 1931), calcium carbonate content (Nelson 1982), pH in water and potassium chloride in a 1:2.5 soil water/solution ratio (McLean 1982) and total phosphate content (modified Murphy/Riley 1962) in the laboratory after Pető et al. (2012; 2015).

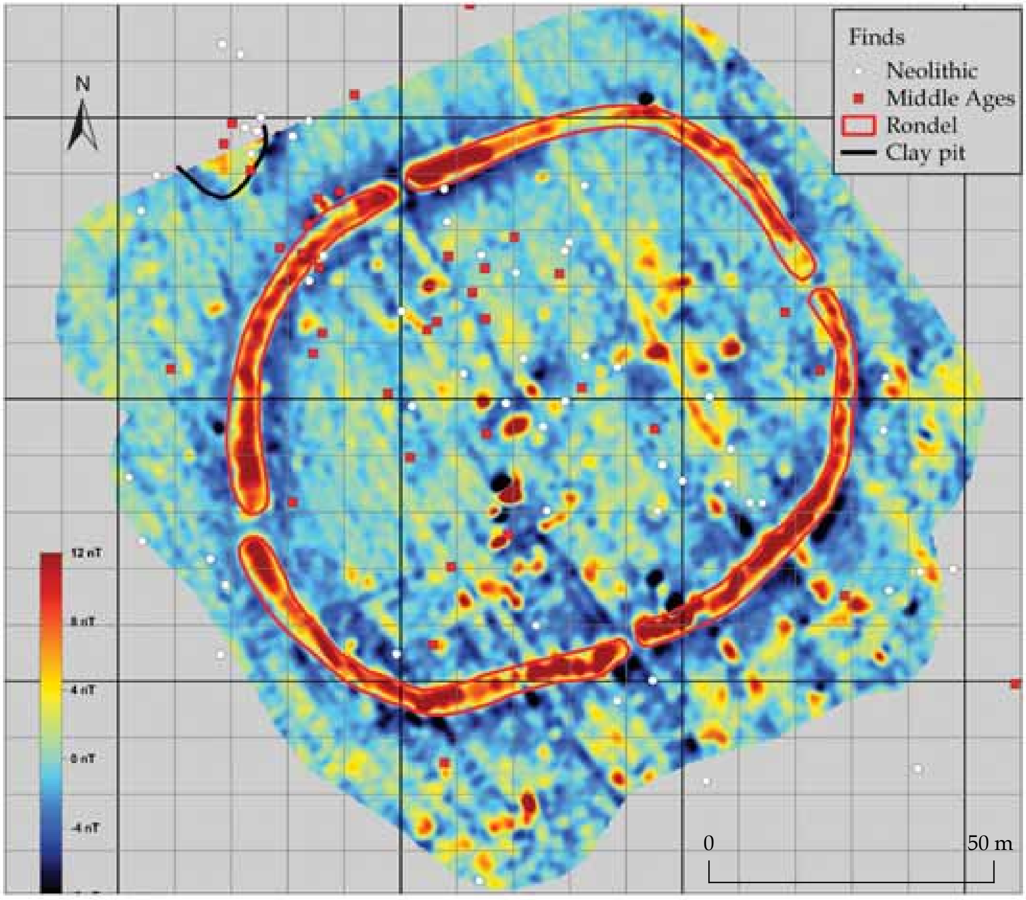

Fig. 12 Scatter and position of the Neolithic surface finds inside and outside the rondel.

Results of the pedological analyses

The depth of the soil – the depth of horizons A and B – changed due to the topography (Fig. 8; Table 1). Soil depth increased towards the east along the imaginary centreline between the ditch's western and eastern gate (F01-F05) (Fig. 9). We can assume that the soil profiles in which horizon C starts within 50 cm are eroded because the average depth of the non-eroded Luvisol varied between 50 and 100 cm in this area. Despite the high precipitation and lower evaporation rates that characterise this region, the presence of high amounts of calcium carbonate (4.6–16.1%) in the topsoil (Fig. 9) indicate that there was no eluviation of calcium carbonate, which is characteristic in this region. The lack of eluviation might have been caused by a decrease in the amount of water infiltrating the soil due to the relief, which increases the amount of runoff water. Another reason could be the continuous erosion of the soil surface.

The distribution of the calcium carbonate content in TSZ1 quite clearly differs from all the other points (F01-08 and TSZ2), confirming that this soil profile represents the fill of the rondel because the original horizonation with a different calcium carbonate content was more or less homogenised due to their mixing during the construction of the rondel and later on, during the infilling as well.

As a result of weak eluviation, we did not find any clay migration either. Some clay migration could only be noted in F01-F05 and TSZ1, reflected by the slight increase of hygroscopic values (Table 1).

The texture of the horizon of point F06 and its chemical properties such as calcium carbonate (Fig. 9) and phosphate content (Fig. 10) differ slightly from the other augered points (Table 1), which could be due to its greater proximity to the Csuhi Stream. At the F06 point, fluvial sediments had a dominant impact on soil profile development.

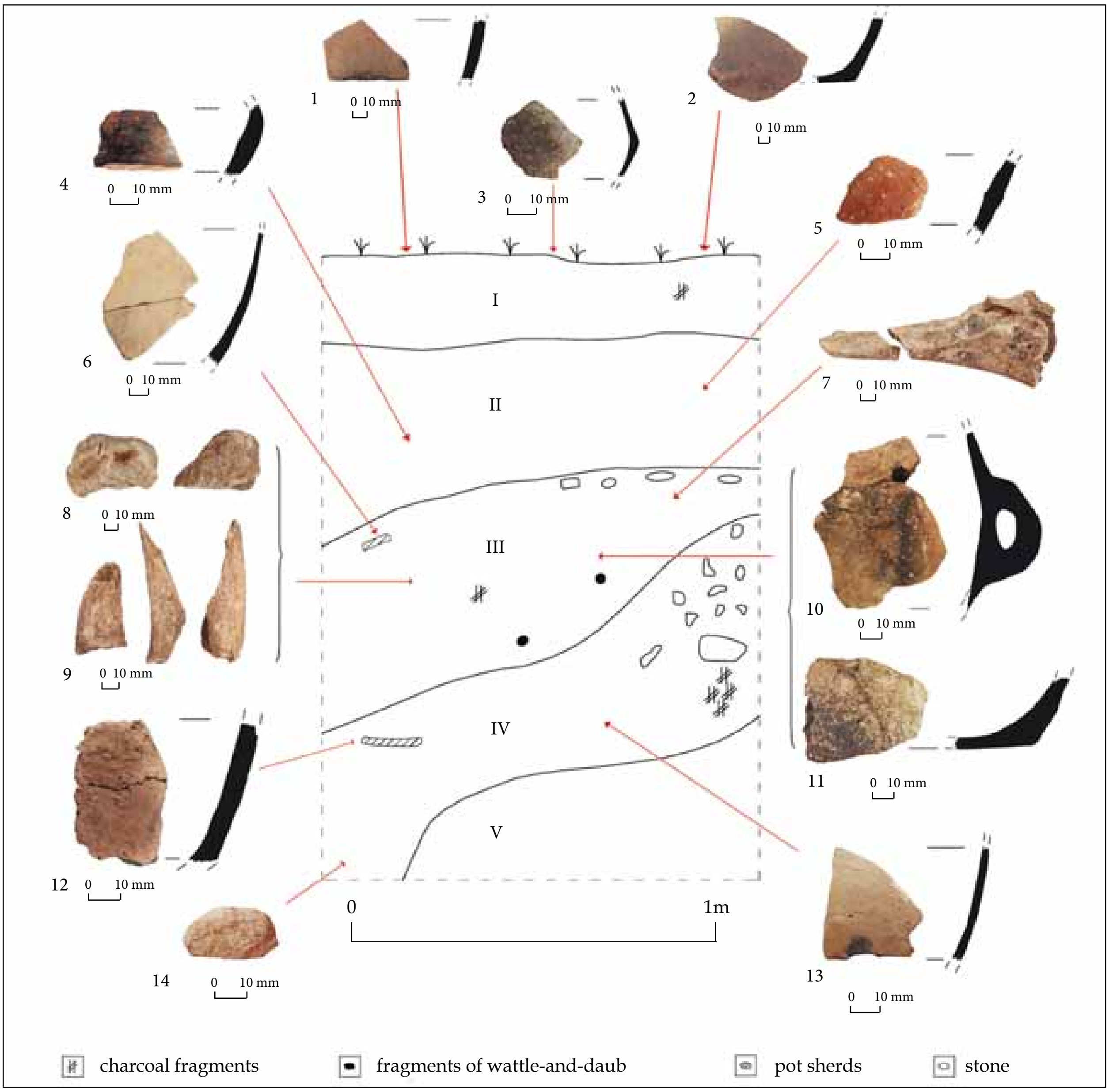

Fig. 13 Layers of the soil profile No 1 (TSZ1) and its finds.

The total P content of the Hungarian cultivated topsoils varies between 20 and 1400 mg/kg (Győry 1984); according to Füleky (1983), total P content is under 1000 mg/kg in most cases. Phosphate is not mobile in the soil (Troeh/Thompson 2005), and therefore the amount originating from fertilisation can increase soil P content up to 30 cm depth. It can be mechanically moved down into deeper layers if deep ploughing is applied, but in that case, P content is homogeneously increased in the entire cultivated layer, which is 60 cm deep at most. Among the analysed soil samples, total P content varied between 232 and 1916 mg/kg, its mean value was 752 mg/kg (Figs 10–11). Between 50 and 100 cm, total P content had a first peak in F03, F04, F05 and TSZ1. In the case of F01 and F03, there is a second peak at a depth of *ca.* 150 cm. Pető et al. (2010; 2012) found a total P content of 1105–1325 mg/kg in the paleosoils of the Lyukas-halom kurgan and of 1456–1941 mg/kg at the Győr–Ménfőcsanak-Szélesföldek archaeological site in the prehistoric soil surface layer, which might be of anthropogenic origin other than fertilisation.

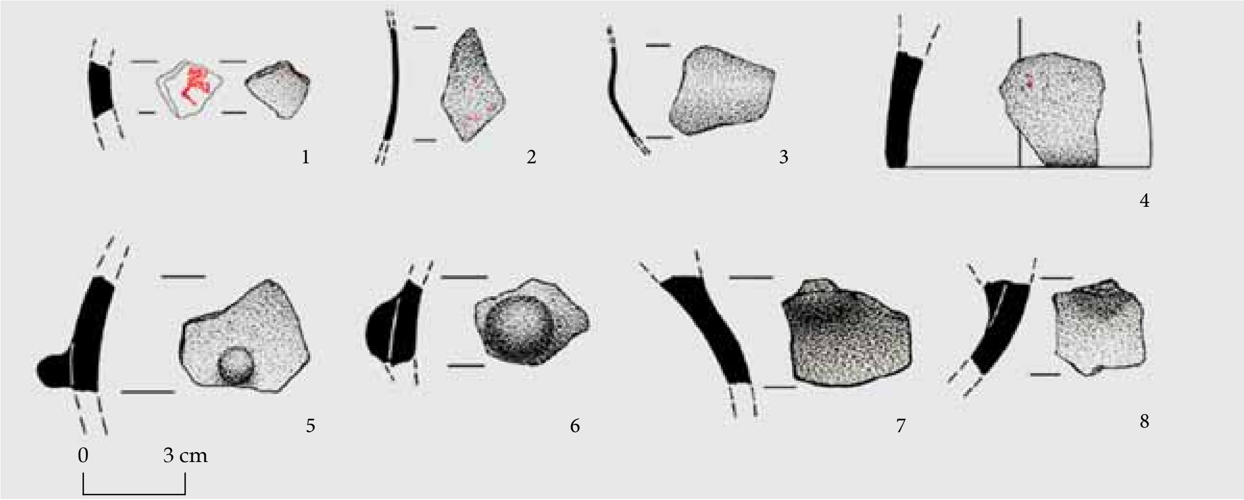

Fig. 14 Selection of the surface ceramic finds (**1–8**) collected during field surveys.

Conclusions drawn from the pedological analyses

The chemical soil analyses indicated a higher amount of total phosphate content in the horizons lying deeper than 60 cm, implying that this high amount of phosphate cannot be attributed to fertilisation, but to some other human impact. It seems likely that a high number of bones were deposited during the use of the ditch (Pető et al. 2012).

The distribution of calcium carbonate content and hygroscopicity values, and the joint depth of horizons A and B indicated that the pedological development of the two studied soil profiles – one outside the ditch, the other in the fill of the ditch – differed from each other, which is also underpinned by the augered samples. The analysis of soil properties confirmed that soil profile development in the ditch was influenced by human disturbance, which is consistent with the archaeological findings of Barna et al. (2012). The high amount of total P in deeper horizons inside the ditch can be attributed to human impact other than fertilisation (Pető et al. 2012) because phosphorus applied with fertilisation cannot be found deeper than the depth of cultivation – due to its low mobility – and the distribution of total P is variable in depth.

In this landscape, erosion plays a dominant role in soil formation and soil profile development. The soil depth, which varies due to the position of the soil on the slope, reflects the strength of erosion processes. Luvisols are the most characteristic soils in this area, with a depth of 50–100 cm down to horizon C if they are not eroded (Stefanovits et al. 1999). The soil forming processes – eluviation of calcium carbonate and clay migration – typical for this region cannot be observed in the analysed soil profiles. The lack of eluviation processes can be explained by the steep slope and the sparser vegetation cover in the non-vegetation period. A certain amount of rainfall, which would cause the eluviation of the soil – the downward movement of calcium carbonate and clay minerals – will not infiltrate into the soil, but flow away on the surface as runoff water, causing erosion on the slope. Thus, we can conclude that in the areas where horizon C begins at 30 cm, soils are eroded. Assuming a forest vegetation before the construction of the ditch, the probable soil surface lay roughly 20–70 cm higher than the present surface in those parts of the landscape where soil depth was the shallowest, namely the joint depth of horizons A and B.

Description and analysis of the find material

Ceramic finds

We repeatedly conducted field surveys on the site, in the course of which we recorded the position of the finds collected from the surface with a hand-held GPS. The accuracy range of 3–5 m did not enable the examination of possible correlations between the finds and the magnetic

Depth (cm)	Sample number	Species	Piece(s)	Name of bone	Name of bone part	Orientation	Physical length (mm)	Note
-65	4	cattle (*Bos taurus* L.)	1	ulna	fragment	left	150	The smaller bone fragment found beside the larger one came from the same bone, the fracture was not fresh (Fig. 13.7).
-60–75	5	snail	4				10, 16, 16, 20	
-60–75	5	snail (*Cepaea vindobonensis*)	1				>70	
-100–105	8	snail	1				18	
-105–110	10	cattle (*Bos taurus* L.)	1	radius	distalis epiphysis + diaphysis fragment	right	>70	Age: subadultus. Broken in several pieces (Fig. 13.8–9).
125 – 140	14	cattle (*Bos taurus* L.)		humerus	diaphysis fragment	right	27	Slightly weathered (Fig. 13.14).

Table 2 Animal bones and malacological remains collected from soil profile 1 in the ditch of the rondel at Gétye-Gyomgyáló-lejtős.

anomalies. An exception to this conclusion is a high anomaly in front of the northern entrance, which was also supported by a concentration of surface finds in the same spot, indicating probably a rather large clay extracting pit (Fig. 12).

We opened a trench (TSZ1) as part of our investigation, whose location was selected so that it would cut the rondel (Fig. 7). However, the goal was not a complete section of the rondel. We recovered a few finds (pottery, burnt daub fragments and animal bones) of the Lengyel culture (Fig. 13). The first find was recorded at a depth of 48 cm, the last at a depth of 150 cm. The pottery fragments were extremely worn, most were tempered with sand or, in a few cases, with crushed pebbles (Fig. 13.5, 8). Fragments of thick-walled vessels were more frequent, while thin-walled fine wares were fewer in number (Fig. 13.6, 13). Pottery forms ranged from smaller cups (Fig. 13.3) to a variety of bowls (Fig. 13.4, 6, 13) and pots (Fig. 13.8, 10–11). Judging from their fabric, the non-joining body and base fragments of a pot were found between 100–125 cm. One fragment has a wide loop handle. Their surface was covered with a light brown slip, which wore off in some spots (Fig. 13.10–11).

Noteworthy among the finds collected on the surface (Fig. 14) are the body fragment of a small, thin-walled biconical cup (Fig. 14.3), the fragment of a low, hollow pedestal (Fig. 14.4) and a few knob-decorated pottery sherds.

Vessels were decorated with appliqué knobs and painted patterns. Knobs were most often of the medium-sized or large round variety (Fig. 14.5–6). Red earth pigments were used for painting the vessels after they had been fired. Because the vessels were not fired for a second time, only traces of the one-time red-painted designs survived on the vessel surface (Fig. 13.4; 14.2, 4) or vessel interiors (Fig. 14.1), from which the original ornamental motifs cannot be reconstructed.

The finds from Gétye do not include pieces typical for the late phase of the Lengyel culture and thus the site can be dated to the classical (perhaps the early classical) Lengyel phase. A closer dating would only be possible after a more large-scale excavation.

Animal bones and malacological remains

Animal remains – three bones and six molluscs – were recovered from a depth of 65–110 cm

Tool types	Raw material types												
	10	13	14	15	21	50	51	59	909	922	945	949	total
B1		1											1
B2	1												1
B2w				1									1
B4					1						1		2
B4f	1												1
B5			1										1
B7/9										1			1
B8	1								1				2
csi.						1							1
csi9							1						1
fen.												1	1
fest								4					4
total	3	1	1	1	1	1	1	4	1	1	1	1	17

Table 3 Type/Raw material matrix of the Gétye-Gyomgyáló-lejtős lithic assemblage.

and 125–140 cm from the ditch in Trench I (TSZ1) at the Gétye-Gyomgyáló-lejtős site (Table 2). The bones all came from the same species, namely cattle *(Bos taurus* L.). One of these was a radius distal epiphysis and the diaphysis broken into several fragments. The second was an ulna fragment, broken in two joining fragments, although the breaks were not fresh. The third was a small fragment of a humerus. The radius was found at a depth of 105–110 cm, the cubitus at 65 cm, while the humerus at 125–140 cm. The radius and the ulna do not come from the same side, but they may come from the same animal judging from their size. Both represent the less meaty parts of the leg, whose lower portion has very little meat. The animal – assuming that the remains represent the same creature – was slaughtered at a relatively young age, when it was *ca.* 3–4 years old. Cattle was the most frequent domestic species in the Late Neolithic and the Copper Age (Bartosiewicz 2006, 103).

Lithic finds

The number of lithics from the Gétye-Gyomláló site is very modest: ten pieces come from a known context and seven were collected during the field survey (Table 3). These are listed below:

Feature[2] 20/1: **B8** blade-like chip, **10** Úrkút-Eplény-type dark yellow radiolarite, 14 x 12 x 4 mm.

Feature 36/2: **B4** chip, **21** blue (Croatian?) radiolarite, 17x 23 x 4 mm; **B4f** pointed chip, **10** Úrkút-Eplény-type yellow radiolarite with porcelanite, 22 x 14 x 3 mm

Feature 44/1: **fest**,[3] brick-coloured lump of mineral pigment, **59** fine sandstone with ochre (?), 37 x 39 x 15 mm; **fest**, white lump of mineral pigment, **59** calcareous fine sandstone (?), 45 x 30 x 27 mm; **fest**, white lump of mineral pigment, **59** calcareous fine sandstone (?) 50 x 30 x 24 mm; **fest**, white lump of mineral pigment, **59** calcareous fine sandstone (?), 27 x 23 x 14 mm; **csi9**,[4] fragment of a polisher, **51** medium fine sandstone, reddish-grey, 53 x 44 x 17 mm; **csi.**, raw material block for a polisher (?), **50** fine grain sandstone, light yellowish-white, 54 x 50 x 40 mm; **fen.**,[5] honing stone, **949** greenschist (?), 74 x 25 x 13 mm.

Stray finds:

B1 core, **13** reddish-brown Transdanubian radiolarite, burnt(?), with porcelanite phase, 40 x 45 x 45 mm.

B2 core remnant with burin edge, **10** Úrkút-Eplény-type dark yellow radiolarite with white cortex, 35 x 33 x 15 mm (Fig. 15.2).

B2w micro-core remnant, **15** brownish-orange Transdanubian radiolarite, 20 x 16 x 14 mm (Fig. 15.3).

B4 proximal fragment of a chip, **945** grey hornstone, Balaton Uplands (?), light grey with remnants of the embedding rock, 23 x 12 x 9 mm.

2 The numbering of the features refers to the GPS coordinates of the findspots of the finds as measured during the field survey.

3 fest: abbreviation of "*festék*" (pigment).

4 csi: abbreviation of "*csiszoló*" (polisher).

5 fen: abbreviation of *"fenőkő"* (honing stone).

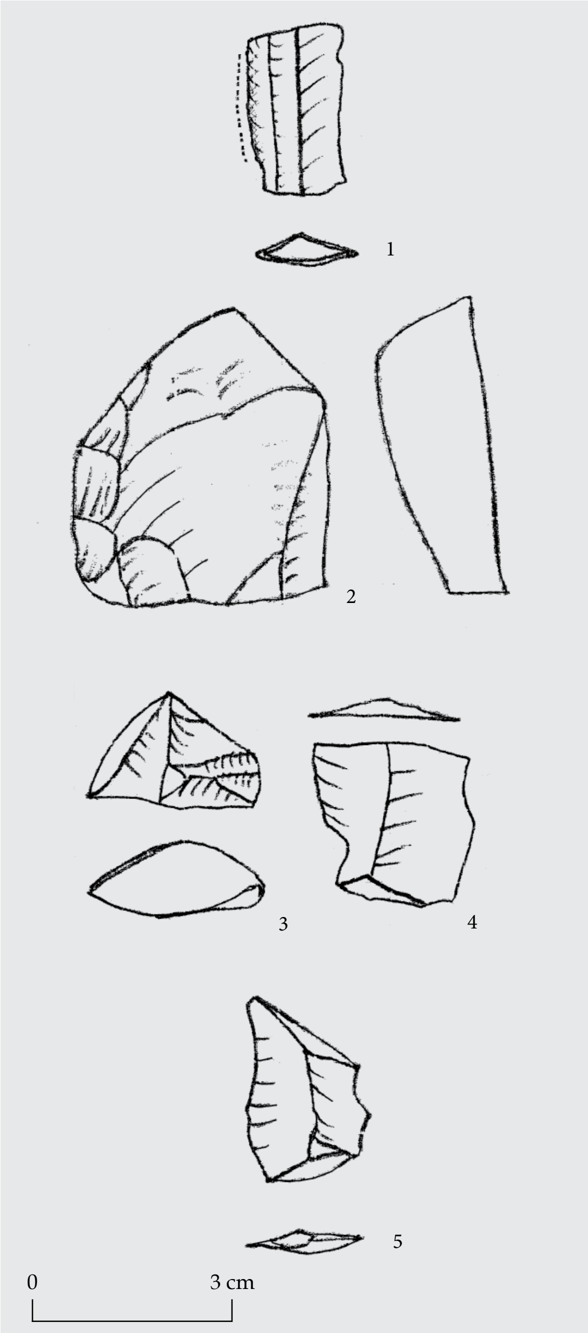

Fig. 15 Stone artefacts from Gétye.

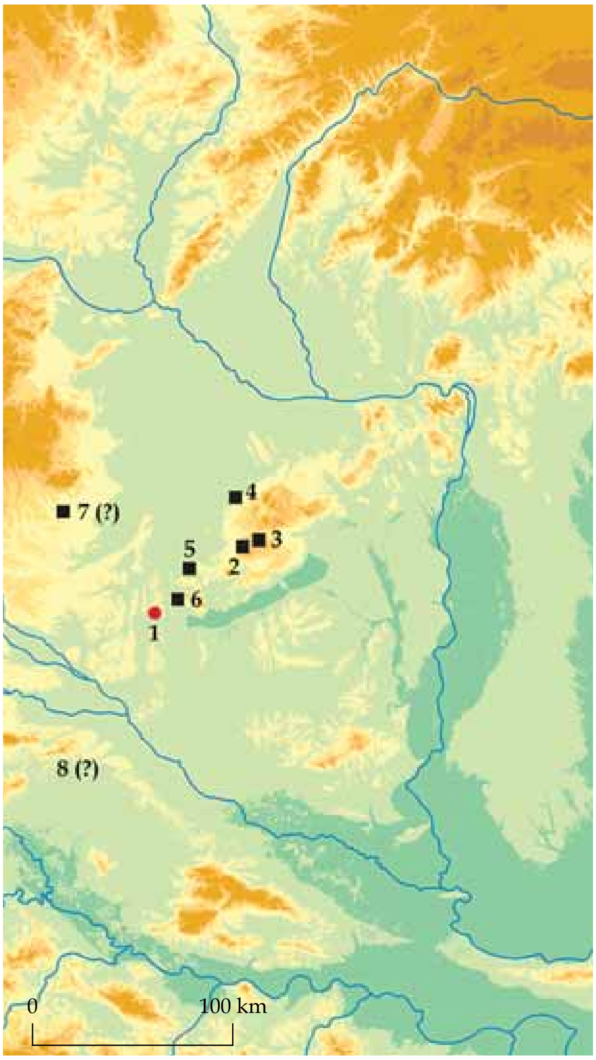

Fig. 16 Contacts of the Gétye site on the basis of lithic raw materials. Key: **1** Gétye; **2** Úrkút-Eplény type radiolarite; **3** Other Transdanubian radiolarites; **4** Tevel flint; **5** Sümeg silex; **6** Rezi hornstone; **7** Greenschist; **8** Croatian (?) radiolarite.

B5 blade with sickle polish, **14** Sümeg-type grey chert with porcelanite or calcareous phase, 23 x 13 x 6 mm (Fig. 15.1).

B7/9 proximal fragment of a blade-like flake, **922** Tevel flint (?) grey 20 x 22 x 3 mm (Fig. 15.4).

B8 blade-like chip, trapeze form, **909** Szentgál-type radiolarite (?), flesh colour with porcelanite phase 23 x 17 x 4 mm (Fig. 15.5).

The type and raw material distribution of the small assemblage is summarised in Table 3. The categories are summarised by codes, highlighted bold in the text above (see Biró 1998, Tables 6 and 7).

The assemblage is too small for drawing any far-reaching conclusions, and the forms observed are not really culturally significant. The most elaborate piece is a blade with sickle polish (Fig. 15.1); no retouched artefacts were encountered so far. Most of the chipped stone artefacts are technological pieces such as cores (Fig. 15.2–3) and chips (Fig. 15.5). An important assemblage of stone artefacts of the "other utensils" category was found in Feature 44/1, namely lumps of (white and reddish) pigment and polishers that may also be related to the preparation and use of pigments.

The significance of raw material utilisation is more telling; it reflects the basic direction of contacts despite the low number of finds. The most numerous items are mineral pigments (4) and Úrkút-Eplény-type yellow radiolarite (3). The latter raw material type is specifically characteristic for the Sopot and early Lengyel lithic assemblages of Transdanubia (Baláca: Palágyi/Biró/Regenye 1989; Ajka: Biró 1998; Sormás: Barna/Bíró 2009). The other elements are represented by one item each and reflect contacts with western Transdanubia (Transdanubian radiolarites, Tevel flint, Sümeg chert and Triassic hornstone from the Balaton Uplands). Elements of probably southern origin can be observed as well: bluish-grey radiolarite which is common in Croatia (although its source is not known as yet). One interesting question is the red radiolarite of flesh colour, which was identified as probably coming from the Szentgál deposits, but this shade of red is seemingly more typical for Bosnian radiolarites (Halamić/Šošić-Klindžić 2009; Biró et al. 2009). There is no reliable method for distinguishing the two source regions as yet, and we therefore have to leave this question open.

The contact regions of Gétye, based on the current evidence, is summarised in Figure 16. Taking all data into consideration, the assemblage is very small, of a low degree of elaboration, comprising mainly technological types and reflecting western Transdanubian and southern (perhaps Croatian) contacts. The overall nature of the lithic assemblage may change with further research.

Summary and evaluation of the data

The results of the magnetic survey and the Late Neolithic finds collected on the surface confirmed the presence of a rondel of the Late Neolithic Lengyel culture at Gétye. The associated settlement can presumably be identified with the neighbouring site at Gétye-Káptalan út.

The basic ground plan of the circular enclosure has already been clarified. Based on the clear, recognisable layout, our opinion is that the enclosure discovered at Gétye is a genuine Lengyel-type rondel. The rondel itself is a simple, oval structure with four accesses. Its size is *ca.* 96 m x 115 m, making this monument a medium-sized enclosure. The ditch probably has a V-shaped cross-section, as shown by the model representing the magnetic inductive data as negative heights. The deviation from the regular circular design can be explained with the terrain conditions since the inclination of the site's eastern slope is quite steep, with an elevation difference of about 4 m.

The four entrances of the rondel at Gétye can be clearly identified on the ground plan. Their orientations measured clockwise from the north prove that the eastern entrance faces a point on the horizon that lies between the summer and winter solstice sunrises. Therefore, we may say that this monument also conforms to the most significant architectural principle of Lengyel rondels in Transdanubia, namely that the rising sun possibly played significant role in the foundation ritual (Pásztor/Barna/Roslund 2008, Pásztor/Barna/Zotti 2014).

Based on the pedological analysis of the site, the prehistoric surface level at the time of the ditch's construction probably lay 20–70 cm higher in the eroded areas and 0–30 cm higher in areas with less erosion. The high total phosphate content of the deeper horizons reflects human impact other than fertilisation. An especially high phosphate content (1916 mg/kg) was observed near the ditch's eastern entrance.

Animal bone fragments, all of them originating from cattle (*Bos taurus* L.), were recovered in considerably good condition from depths between 60–75 cm and 105–110 cm.

The lithic assemblage collected at the site is very small, of a low degree of elaboration, comprising mainly technological types and reflecting western Transdanubian and southern (perhaps Croatian) contacts.

We plan to continue the investigation of the site in the future. One of our goals is to sample the ditch more systematically with larger density in order to analyse the vertical and horizontal distribution of the total phosphate content. This information can contribute to a better understanding of the use of the ditch of the Neolithic rondel.

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Summary

This paper offers a preliminary report on the non-invasive investigation of an archaeological site at Gétye in western Hungary. The geophysical survey and several field surveys confirmed our previous assumption on the presence of a Late Neolithic circular enclosure, known as rondels. The ground plan of the enclosure is outlined clearly. The rondel has a simple oval ground plan with four accesses (or entrances). It is made up of a single ditch with a V-shaped cross-section. The axes of the four entrances are oriented 66°, 141°, 255°, and 333° of north, respectively. The pottery and stone artefacts, red painted sherds among them, collected on the site date the rondel to the Late Neolithic, to the classical phase of the Lengyel culture. Soil samples from soil profiles and augerings were collected and analysed. Soil forming processes and possible human impact were studied based on field descriptions and laboratory analyses. The top depth of Horizon C, the soil texture and the calcium carbonate content indicated that erosion, which is characteristic in this region, had a major impact on soil development. The extremely high phosphate content of the deeper soil horizons confirms the anthropogenic impact inside the rondel. The distribution of soil texture and calcium carbonate content along soil depth varies with soil depth in the case of the soil profile and augered samples from outside the ditch. In contrast, the calcium carbonate content and texture of the soil profile within the ditch do not change markedly between 60 and 190 cm, confirming the previous presence of the rondel and its later infilling from a pedological view, in line with the archaeological findings.

Zusammenfassung

Zerstörungsfreie Untersuchungen einer spätneolithischen Kreisgrabenanlage in Gétye, Westungarn

Der Aufsatz ist ein vorläufiger Bericht über die Ergebnisse der zerstörungsfreien Analyse des archäologischen Fundortes Gétye in Westungarn. Die geophysikalischen Messungen und einige Feldbegehungen bestätigen die vorherige Annahme, dass hier eine spätneolithische Kreisgrabenanlage (Rondell) bestand. Der ovale Grundriss der Kreisgrabenanlage ist klar zu erkennen. Die Anlage besteht aus einem V-förmigen Spitzgraben, der durch vier Öffnungen unterbrochen wird. Die Achsen der vier Öffnungen (Tore) weichen folgendermaßen von der Nordrichtung (= 0°) ab: 66° – 141° – 255° – 333°. Die Keramik- und Steinfunde, darunter rot bemalte Scherben, die am Fundort gesammelt wurden, datieren in das Spätneolithikum, und zwar in die klassische Phase der Lengyel-Kultur.

Zum Zwecke der Bestimmung der Bodenbildungsprozesse und der möglichen menschlichen Einwirkungen wurden vor Ort und im Labor Bodenuntersuchungen durchgeführt. Dazu wurden Erdbodenproben durch Bohrungen aus den prospektierten Flächen gewonnen. Die Tiefe der Schicht C, die Bodentextur und die Verteilung der Kalkablagerungen in der Tiefe zeigen, dass die Erosion, die für das Gebiet charakteristisch ist, eine wesentliche Rolle im Prozess der Bodenbildung gespielt hat. Der auffallend hohe Phosphorgehalt der tieferen Bodenschichten innerhalb der Kreisgrabenanlage weist auf menschliche Einwirkung hin. Die Bodentextur und die Verteilung der Kalkablagerungen außerhalb der Kreisgrabenanlage ändern sich abhängig von der jeweiligen Tiefe der Proben. Im Gegensatz dazu zeigen Proben innerhalb des Grabens, die aus einer Tiefe von 60 bis 190 cm stammen, dass diese beiden Bodeneigenschaften hier keine spezifischen Abweichungen aufweisen. Dies belegt eine vorausgehende Errichtung der Kreisgrabenanlage und deren spätere Verfüllung, was auch die archäologischen Funde bestätigen.