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Ground-penetrating radar survey and test pitting on Mädara hill fort

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INTRODUCTION

Mädara hill fort[1] (Reg. No. 11868[2]) on the lands of Mädara village at Pärnu County is situated on a steep-sloped riverside section of a larger NE–SW oriented sandy promontory (Fig. 1A). The promontory is bordered in the northwest by a small stream, in the south and southwest by the River Mädara and its southeastern side is separated from a swamp by rampart-like formations. A 1–1.5 m high man-made rampart sets the hill fort apart from the rest of the promontory (Tõnisson 2008, 270). The hill fort and its nearby surroundings are covered by coniferous forest and thin brushwood. The hill fort plateau amounts only to about 800 m^2 (approximately 40–45 × 25 metres), it is uneven and its edges slope downward. The site was first described by Jaan Jung (1898, 76), according to whom charcoal and burnt logs were found at the depth of 4 feet when digging the edge of the hill. Jung's test-pit was located in the southwestern part of the hill fort, where he also found a five-branched iron pin (Indreko 1925, 113). The small-scale excavations conducted on the hill fort by Artur Vassar in 1953 (Tõnisson 1966, 99) did not result in a report or a publication, but the few recovered sherds of handmade pottery (AI 4076; AI 4569; AM A 165) have enabled to date the hill fort to the second half of the I millennium and the beginning of the II millennium AD (e.g. Lõugas & Selirand 1977, 59, 242).

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[1] The site's former toponyms include *Kirikumägi* (Eng. Church Hill), *Linnamägi* (Eng. Town Hill) (Jung 1898, 76), and *Punamägi* (Eng. Red Hill) (Tõnisson 2008, 270).

[2] https://register.muinas.ee/public.php?menuID=monument&action=view&id=11868 (25.09.2018).

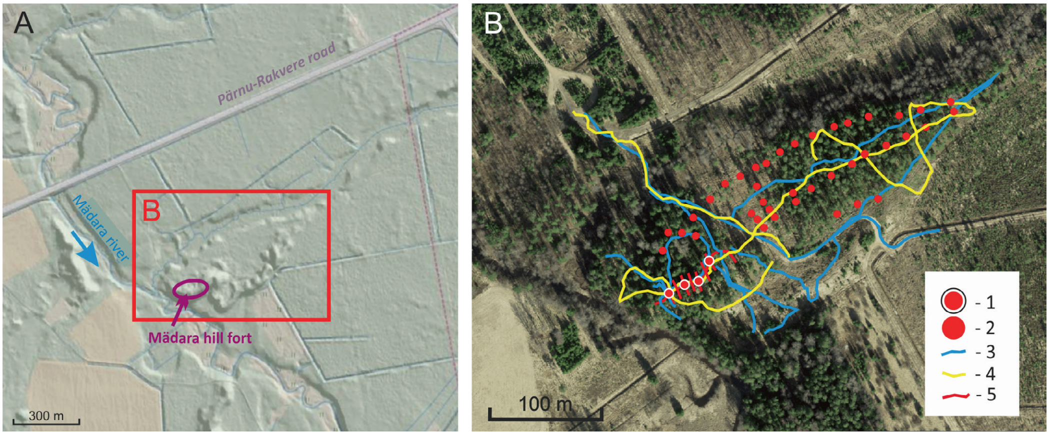

Fig. 1. *Location of Mädara hill fort (A) and plan of the ground-penetrating radar profiles and test pits (B). 1 – test pits on the hill fort, 2 – test pits around the hill fort, 3 – GPR profile of frequency 300 MHz, 4 – GPR profile of frequency 500 MHz, 5 – GPR profile of frequency 900 MHz.*
Jn 1. *Mädara linnuse asukoht (A) ning georadari profiilide ja prooviaukude plaan (B). 1 – prooviaugud linnusel, 2 – prooviaugud linnuse ümbruses, 3 – georadari profiil sagedusega 300 MHz, 4 – georadari profiil sagedusega 500 MHz, 5 – georadari profiil sagedusega 900 MHz.*
Relief map and orthophoto / Reljeefivarjutusega kaart ja ortofoto: Maa-amet
Mapping / Kaardistus: Alina Tšugai-Tsyrulnikova, Jüri Plado, Andres Kimber
Drawing / Teostus: Alina Tšugai-Tsyrulnikova, Andres Kimber

In May 2015, Aldur Vunk discovered pieces of charcoal in the profiles of a dirt road transecting the rampart-like formations some hundred metres to the northeast of the hill fort (Fig. 4). The charcoal pieces were located in sand, 7–10 cm below the turf and the samples were taken from the profile closer to the hill fort. Conventional radiocarbon dating determined the age of the charcoal to 2016±45 BP[3], when calibrated with 95.4% confidence, between 162 cal BC and 73 cal AD.[4] The difference between the radiocarbon result and the much later pottery-based date of the hill fort raised the question if the rampart-like formations could be part of an earlier hill fort, since during the Pre-Roman Iron Age several hill forts were established in Estonia (e.g. Lang 2007, 71–74, 81–82, fig. 28). The stone grave at Sepa farmstead in Kadjaste village (3.4 km from Mädara hill fort) confirms settlements in this area at that time (Vassar 1943, 194).

Therefore, small-scale fieldwork was conducted to determine if the sandy rampart-like formations northeast of the hill fort on the southeastern side of the promontory may also be man-made or modified, and whether there are any traces of an occupation layer in the region between the hill fort and the rampart-like formations (Fig. 1B). Since the information regarding the occupation layer on the hill fort was meagre and its date was based on few rather nondescript finds, some test pits were dug on the plateau as well. The aim was to determine the extent and intensity of the occupation layer and to find organic matter for radiocarbon dating to specify the use period of the hill fort.

METHODS

The fieldwork combined ground-penetrating radar survey with extensive test-pitting. GPR survey and test pitting were conducted in Mädara in autumn and winter 2017. The GPR survey

[3] SPb-2042.
[4] Calibrated using OxCal v4.3 (Bronk Ramsey 2017) and the IntCal13 atmospheric calibration curve (Reimer *et al.* 2013).

was performed with a Zond 12-e system of Radar System Inc., using frequencies of 300, 500 and 900 MHz. The radar antennae were pulled at walking speed and measurements were made at constant spacing equalled to 1 cm by an odometer wheel. The time ranged from 25 to 100 ns. For location tracking a portable global positioning system (GPS) navigator was used, connected to the radar. To convert time-scale to depth-scale, relative dielectric permittivity was found by hyperbolic fitting method. Data processing with Prism2 software included using (1) a band-pass filter to remove low-frequency induction effects; (2) a gain control to improve readability of deeper reflections; and (3) correction for topography. Topographic information was derived from the LiDAR data[5] of the Estonian Land Board.

Fig. 2. *Test pitting on the hill fort plateau.*
Jn. 2. *Prooviaukude kaevamine linnuse hoovialal.*
Photo / Foto: Aivar Kriiska

In all, 43 test pits were dug on the promontory (Figs 1B, 4A). 37 of them were located on the plain between the stream, the hill fort and the rampart-like formations. Two test pits (Fig. 4A, 38–39) were dug on the rampart-like formations, close to where the Pre-Roman Iron Age charcoal fragments were found. Three test pits (Fig. 4, LN1–3) were located on the hill fort plateau (Fig. 2) and one directly outside the man-made rampart (Fig. 4, LN4). Charcoal discovered from test pit LN3 was dated using conventional radiocarbon dating method in Radiocarbon Laboratory of the Herzen State Pedagogical University (St. Petersburg, Russia).

RESULTS AND DISCUSSION

The GPR profiles and test pits indicate that the rampart-like formations north-east of the hill fort are natural and the plain between the formations and the stream lacks an occupation layer. On the GPR profiles of the hill fort and its surroundings, three radar facies (RF) were identified based on the location depth and a characteristic pattern of reflections (Fig. 3). A reflection corresponding to groundwater level is sporadically visible at the absolute altitude of approximately 35 m a.s.l. Upper parts of some of the profiles present several hyperbolic reflections from tree roots. No reflections of an occupation layer were identified on the hill fort either, most

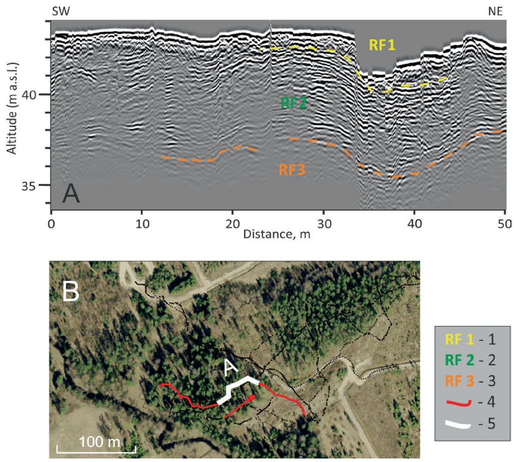

Fig. 3. *An example of the ground-penetrating radar image (A) and the location of the radar profile (B). 1 – aeolian sands, 2 – deposits of the Baltic Ice Lake, 3 – glacial till, 4 – GPR profile, 5 – section of the GPR profile (A).*
Jn 3. *Näide georadari kujutisest (A) ja profiilikujutise asukoht (B). 1 – luiteliivad, 2 – Balti jääpaisjärve setted, 3 – jääaegne moreen, 4 – georadari profiil, 5 – georadari profiili lõik (A).*
Mapping / Objektide kaardistus: Alina Tšugai-Tsyrulnikova, Jüri Plado

[5] Collected from an altitude of 2.4 km, with an areal coverage of ~0.45 points per m^2 (https://geoportaal.maaamet.ee/est/Andmed-ja-kaardid/Topograafilised-andmed/Korgusandmed/Aerolaserskaneerimise-korguspunktid-p499.html, 28.09.2018).

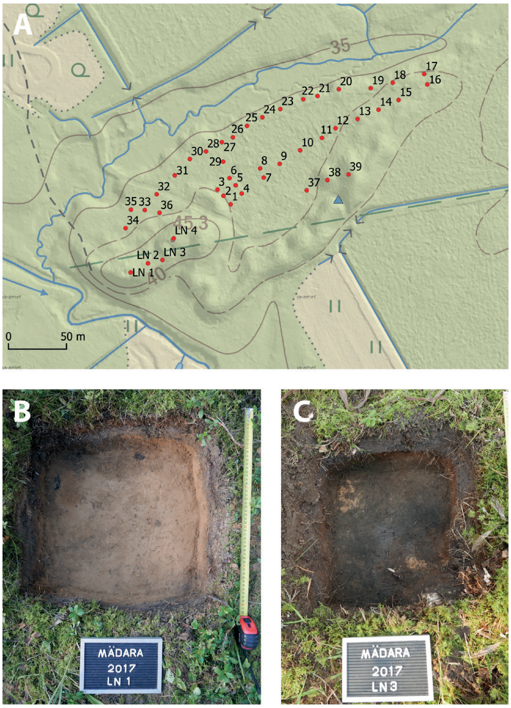

Fig. 4. *Location plan of test pits (A), and test pits LN1 (B) and LN3 (C) on the hill fort plateau. The blue triangle marks the location of charcoal collected by A. Vunk.*
Jn 4. *Prooviaukude asendiskeem (B) ning linnuse hoovialale kaevatud pooviauk LN1 (A) ja LN3 (C). Sinise kolmnurgaga on märgitud A. Vungi kogutud söe leiukoht.*
Relief map / Reljeefivarjutusega kaart: Maa-amet
Mapping / Kaardistus: Andres Kimber
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likely because the layer is thin and too shallow for GPR to identify.

The topmost radar facies (RF1) corresponds to aeolian sands that were distinguishable as fairly short subparallel reflections with limited lateral extent in the uppermost section of the profile. The facies occurs irregularly, as a layer in one place and as lenses in other. The thickness of the layer is mostly 1–2 m, sometimes up to 3 m. Beneath the aeolian deposits lies a layer of tightly compressed long horizontal parallel reflections (RF2) characteristic of lacustrine deposits, likely by the Baltic Ice Lake (see Rosentau *et al.* 2011). The thickness of RF2 is between 1–7 m, mostly 4–6 m. The transition between aeolian and Ice Lake deposits is mostly diffusive. At the bottom of the radar images, a strong reflection produced by the upper surface of glacial till (RF3) can be seen. Glacial till is a high-performance reflector for electromagnetic waves, inside the layer the wave diffuses and does not produce considerable reflections.

Glacial till relates most likely to one of the largest till plains in western Estonia that also partly reaches Kõrvemaa (Arold 2005, pl. II, 175, 296–297, 369; Kalda 2007, 23). The uppermost strata, the positive sand formations, are not unique in Mädara region. There are other long and narrow NE–SW aligned landforms in the area (Fig. 1A) which coincide with the alignment of the landforms deposited by the glacial recession, post-glacial rebound isobases, and the Baltic Ice Lake water level isobases (Rosentau *et al.* 2011, fig. 8.1, fig. 8.7a–c). This gives reason to believe that the rampart-like formations are Baltic Ice Lake coastal formations whose top surface has become dune-like.

The soil in the test pits dug in the plain between the rampart-like formations and the stream was fairly consistent: a 5–25 cm thick layer of turf and humus lay on top of aeolian sand. Only in a few test pits in the centre of the study area, a 2–10 cm thick layer of darker, charcoal-rich soil was discovered on top of the natural sand. Since no artefacts or other indications of human activity were found in this layer, it is likely a remnant of a wildfire. The test pits were 20–75 cm deep.

Traces of human activity were found only on the hill fort (Figs 2, 4). The occupation layer in the southwestern and central part of the hill fort (test pits LN1–2) was located directly beneath the approximately 10 cm thick layer of turf and humus. The occupation layer was 3–7 cm thick and consisted of slightly impure sand with remnants of charcoal and a few organic-rich darker spots (Fig. 4: A, B). The occupation layer in the northeastern part of the hill fort (test pit LN3) was up to 16 cm thick and consisted of two horizons. The upper 8 cm consisted of brown sand and the lower horizon was up to 8 cm thick and comprised of black charcoal-rich sand (Fig. 4 A and C). The charcoal-rich sand also contained disintegrated crystalline stones and was presumably a fire pit. Charcoal collected from the test pit was dated using the conventional ^{14}C dating method and the result was 1135±25 BP[6], with 95.4% confidence between 777–984 years cal AD when calibrated. The occupation layer was situated on top of aeolian sand deposits.

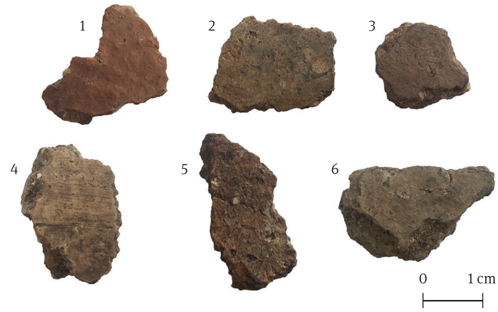

Fig. 5. *Sherds of hand-made pottery from test pit LN1 (1–2) and LN3 (3–6).*
Jn 5. *Käsitsikeraamika killud prooviaugust LN1 (1–2) ja LN3 (3–6).*
(PäMu 39321 A 2695)
Photo / Foto: Aivar Kriiska

The find assemblage collected from the test pits was modest. Two sherds were discovered in test pit LN1 (Fig. 5: 1–2). They come from two thin-walled bowls and measure 3.8 and 5.6 mm in thickness. 11 sherds were found in test pit LN3, one of them originating from a bowl with wall-thickness of 5 mm (Fig. 5: 3). The rest of the sherds come from two thick-walled bowls and measure 9.2 mm and 9.5 mm in thickness (Fig. 5: 4–6). All pottery fragments have smoothed inner and outer surfaces and consist of clay mixed with rock debris. As the sherds are small and lack clearly identifiable specific features, they cannot be dated more precisely than the second half of the Iron Age.

CONCLUSION

The GPR profiles and test pits demonstrated that the rampart-like formations around Mädara hill fort are natural, and the area inside the formations lacks an occupation layer. On the GPR profiles of the hill fort and its surroundings, three radar facies were identified based on the location depth and a characteristic pattern of reflections to which correspond aeolian sands (RF1), sediments of the Baltic Ice Lake (RF2), and glacial till (RF3).

Traces of human activity were found only on the already known hill fort. The occupation layer is relatively thin (3–16 cm), with its thicker part located near the rampart. Test pit LN3 was probably dug into a fire pit. The thin occupation layer indicates that the settlement on Mädara hill fort was short-lived, possibly originating from its use as a refuge fort (Jaanits *et al.* 1982, 266). Compared to the hill fort's previous rather broad date based on pottery typochronology, the ^{14}C result of the charcoal from the probable fire pit enables to date at least that part of the occupation layer to the Viking Age, to the 9th to 10th century.[7]

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[6] SPb-2530; see footnote 5 for data regarding calibration.
[7] With 87.7% confidence between 862–984 cal AD.

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GEORADARIUURINGUD JA PROOVIAUGUSTAMINE MÄDARA LINNUSEL

Aivar Kriiska, Alina Tšugai-Tsyrulnikova, Jüri Plado, Aldur Vunk, Andres Kimber ja Kristiina Paavel

Vaid u 800 m² suuruse õuealaga Mädara linnus asub Pärnumaal Mädara külas samanimelise jõe kaldal paikneva kirde-edela suunalise liivase neemiku jõepoolsel otsal (jn 1). Neemik piirneb loodest ojaga ning läänes ja lõunas Mädara jõega. Kagusse jäävast soost eraldavad seda vallitaolised liivast moodustised. Linnuse alal tegi Artur Vassar 1953. aastal väikesemahulisi proovikaevamisi, kogutud leidude järgi dateeriti muistis I aastatuhande teise poolde ja II aastatuhande algussajanditesse. 2015. aastal koguti linnusest kirdesse jäävat vallilaadset moodustist lõikava pinnastee profiilist vahetult mättakihi alt liivast söetükikesi (jn 4A). Konventsionaalne radiosüsiniku analüüs andis söe vanuseks 95,4% tõenäosusega 162 eKr kuni 73 pKr. Nii varane dateering oli intrigeeriv ning tõstatas küsimuse võimalikust varasemast linnusest. Selle oletuse kontrollimiseks võeti ette georadari uuringud ja prooviaugustamine (jn 1), et selgitada, kas linnusest kirdesse jäävate liivaste vallilaadsete moodustiste puhul võib olla midagi inimtekkelist või on need pelgalt looduslikud moodustised ja kas nendega piiratud tasasel alal esineb kultuurkihti. Kuivõrd kaitsealuse linnuse kultuurkihi kohta oli olemas vaid üldsõnaline teave, kaevati linnuseõuele kolm prooviauku (jn 1B, 2, 4), eesmärgiga selgitada kultuurkihi paiknemist ja intensiivsust ning leidmaks orgaanilist materjali linnuse radiosüsiniku meetodil dateerimiseks.

Georadari uuringud ja prooviaugud osutavad, et linnuse kõrval olevad vallilaadsed moodustised on looduslikud. Linnamäe ja selle ümbruse läbilõigetel tuvastati kolm radarfaatsiest vastavalt paiknemissügavusele ja iseloomulikule peegelduste mustrile (jn 3). Kõige peal paiknesid (1) eoolsed liivad (paksus valdavalt 1–2 m, kohati kuni 3 m), nende all (2) Balti jääpaisjärve setted (paksus 1–7 m, enamasti 4–6 m) ja viimaste all (3) jääaegne moreen.

Inimasustuse jälgi leiti ainult juba teadaolevalt linnuselt. Linnuseõue edela- ja keskosas (prooviaugud LN1–2) oli veidi üle 10 cm paksuse mätta- ja huumusekihi ning loodusliku liiva vahel õhuke, 3–10 cm paksune kultuurkiht (jn 4A–B). Linnust ülejäänud seljakust eraldava otsavalli lähistel (prooviauk LN3) oli kuni 15 cm paksuse mätta- ja huumusekihi all kuni 16 cm tüse kultuurkiht (jn 4C). Tules lagunenud kristalsete kivimite tükid osutavad võimalusele, et avati osa tuleasemest. Prooviaugust LN1 leiti kaks ja prooviaugust LN3 saadi 11 käsitsi vormitud savinõude kildu. Esindatud on nii peen- kui ka jämekeraamika (jn 5). Prooviaugust LN3 kogutud söest tehtud konventsionaalse radiosüsiniku analüüs andis vanuseks 95,4% tõenäosusega 777–984 aastat pKr (1135±25 BP; SPb-2530).