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Ground-penetrating radar investigation of an underwater settlement site at Koorküla Valgjärv

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INTRODUCTION

Koorküla Valgjärv is located in southern Estonia, in Valga County, and is known for its pile-dwelling settlement. The remains of prehistoric structures lie near the centre of the lake, situated on an underwater ridge that extends from the tip of a broad peninsula on the western shore and curves toward the southern part of the lake.

Previous investigations have discovered wooden piles and other construction remnants on the lakebed, indicating that the site was once used for erecting buildings and habitation. Koorküla Valgjärv is among Estonia's earliest studied settlement sites, with the first reported investigations allegedly taking place as early as 1640. According to historical accounts, the local manor owner, Wolf Heinrich von Anrep, employed divers to retrieve household items from the lake bottom (Hupel 1782, 331–332). In the centuries that followed, the site was subject to brief observations and scholarly debates regarding the origin of the remains. Scientific confirmation of a prehistoric lake settlement was finally achieved through archaeological investigations conducted by Jüri Selirand in 1958 (Selirand 1960; Roio 2003). Three distinct occupation periods have been identified: the Neolithic (3300–3200 BC), the Pre-Roman Iron Age (4th–2nd century BC), and the Pre-Viking/Viking Age (6th–9th century AD) (Roio 2006; Roio 2007; Virtanen 2012).

Koorküla Valgjärv remains unique in Estonia as the only lake where the remains of structures are clearly visible on the lakebed (Fig. 1). Nevertheless, the full extent of the pile dwellings and the thickness and composition of the cultural layer are still not well understood.

The objective of this study was to use ground-penetrating radar (GPR) to map the spatial extent of the prehistoric structures and estimate the thickness of the cultural layer in Valgjärv. GPR offers a non-invasive method for surveying underwater features and contributes to our understanding of the site's stratification and archaeological potential of the lake's cultural deposits, as well as aiding in planning future archaeological excavations.

Fig. 1. *The remains of pile structures on the lakebed are visually well identifiable. The hatched area indicates the extent of the settlement site.*
Jn 1. *Vaiehitiste jäänused järve põhjas on visuaalselt hästi tuvastatavad. Viirutatud ala tähistab asulakoha ulatust. Map / Kaart: Orthophoto by the Land and Spatial Development Board / Maa- ja Ruumiameti ortofoto, photo / foto: Maili Roio*

METHODS

Fieldwork at Koorküla Valgjärv was carried out on 31 January 2024, using a Zond-12e ground-penetrating radar (RADAR Systems Inc.; www.radsys.lv). At the time of the survey, the lake was covered by 20–25 cm of ice. The survey was conducted using shielded antennas operating at a frequency of 300 MHz. Measurement positions were tracked using a GPS unit and a measuring wheel integrated with the radar system. The time window – defined as the duration from the emission of the electromagnetic pulse to the end of signal recording – was set to 500 ns. To convert signal travel-time to depth, a wave velocity of 3.33 cm/ns was used, corresponding to the speed of electromagnetic waves in water. A velocity of 4.29 cm/ns was applied to estimate the thickness of the cultural layer. A 500 ns time window thus corresponds to an approximate penetration depth of 7.5 m.

The survey area was mapped using a grid of intersecting profiles (Fig. 2), with data collected at 2 cm intervals along the profiles. Initial measurement data were processed using Prism2 software (version 2.70.05) to improve the clarity of the radar cross-sections and support interpretation. During processing, signal strength at greater depths was amplified, and both low-frequency instrumental noise and high-frequency noise – caused by irregularities in the ice surface (frozen fishermen tracks) – were filtered out.

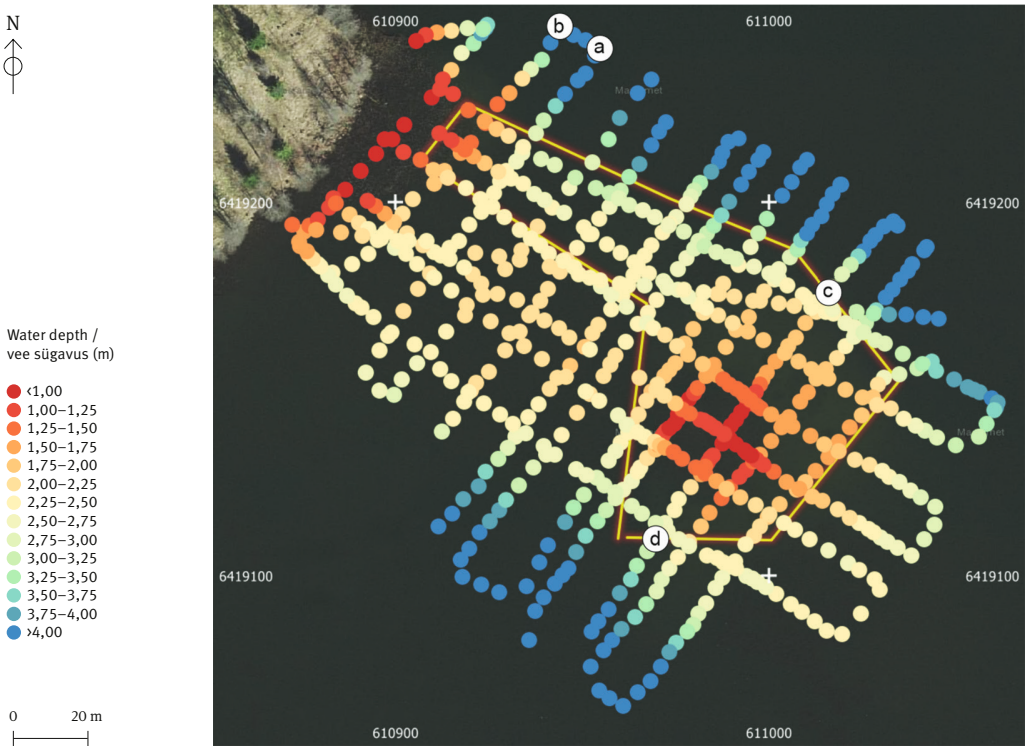

Fig. 2. *Sub-bottom topography of a portion of Valgjärv, measured from the lake ice on 31 January 2024. The yellow line indicates the area of interest as originally defined. Letters correspond to locations shown in Fig. 3.*
Jn 2. *Valgjärve põhja reljeef, mõõdetud järvejäält 31. jaanuaril 2024. Kollane joon tähistab algselt määratletud huvipakkuvat ala. Tähed viitavad läbilõigetele, mis on näidatud joonisel 3.*
Map / Kaart: Orthophoto by the Land and Spatial Development Board / Maa- ja Ruumiameti ortofoto, drawing / joonis: Jüri Plado

RESULTS

The upper portions of the radar profiles display a series of parallel, horizontal reflections caused by signal reflections and multiple echoes at the ice-water interface (Fig. 3A). High-frequency (~250 MHz) hyperbolic reflections appear, originating from footpaths compressed into melting snow (a thaw occurred prior to the fieldwork, and measurements were conducted under mild freezing conditions) and from holes cut into the ice for fishing. No reflections were detected from the water column itself. All these observed patterns – both the hyperbolic reflections from the ice surface and the faint horizontal lines within the ice and water column – are interpreted as noise.

The lakebed is identifiable in the radar profiles (Fig. 3), suggesting low salinity and predominantly rain-fed water. It consists mainly of mineral substrate, partially covered by lake sediments, presumably mud. These sediment types differ in reflection signal strengths: mineral soil generates stronger reflections than the overlying lake sediments. The fine sediments have accumulated in the deeper depressions of the lake and extend between the archaeologically significant underwater ridge and the shoreline.

In the surveyed area, the lakebed generally lies at a depth of 2–3 m, although in the southeastern part of the survey area, less than one metre of water and ice covers the crest of the

underwater hill (Fig. 3B). Within this hill, radar images revealed a strong, nearly horizontal reflection located 1.5–2 m below the ice surface (yellow dotted line in Fig. 3B). The precise nature of this reflection may be clarified with drilling. The distance between the lakebed and the strong reflection – possibly indicating a cultural layer – reaches 90 cm on the hill's western side.

Several hyperbolic reflections originating from the topmost soil were recorded (Fig. 4), likely caused by larger objects such as stones over 20 cm in size, recently submerged metal items, or potential archaeological features. These reflections become less frequent toward the edges and beyond the study area, suggesting that at least some are of archaeological origin. This interpretation is further supported by the fact that the natural soil in the region is predominantly fine-grained and devoid of large rocks.

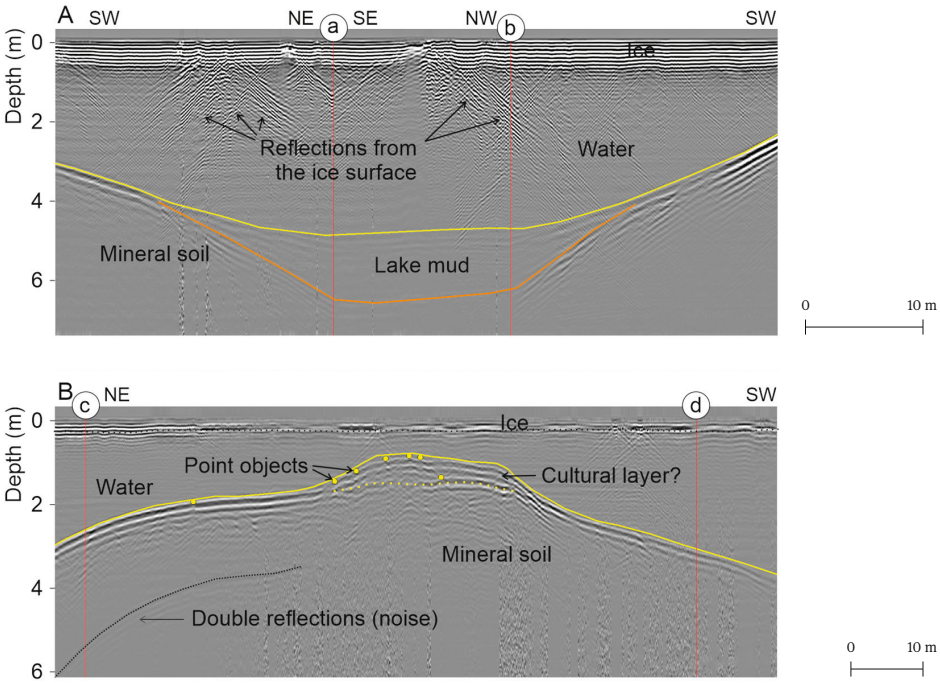

Fig. 3. *Two radar images illustrating key features observed in the study area. Image A originates from the northwestern part of the survey area; points a and b mark turning points along the profile. Image B was recorded over the underwater crest; a yellow dotted line marks the base of a possible cultural layer mixed with lake mud; points c and d indicate the boundaries of the area of interest.*

Jn 3. *Kaks radaripilti, mis illustreerivad uuringuala peamiseid nähtuseid. Pilt A pärineb uuringuala loodenurgast; punktid a ja b tähistavad profiili pöördepunkte. Pilt B illustreerib veealust künnist, millel on kollase punktiirjoonega märgitud järvesetetega segunenud võimaliku kultuurkihi lamav pind; punktid c ja d tähistavad huvipakkuva ala piire.*

Drawing / Joonis: Jüri Plado

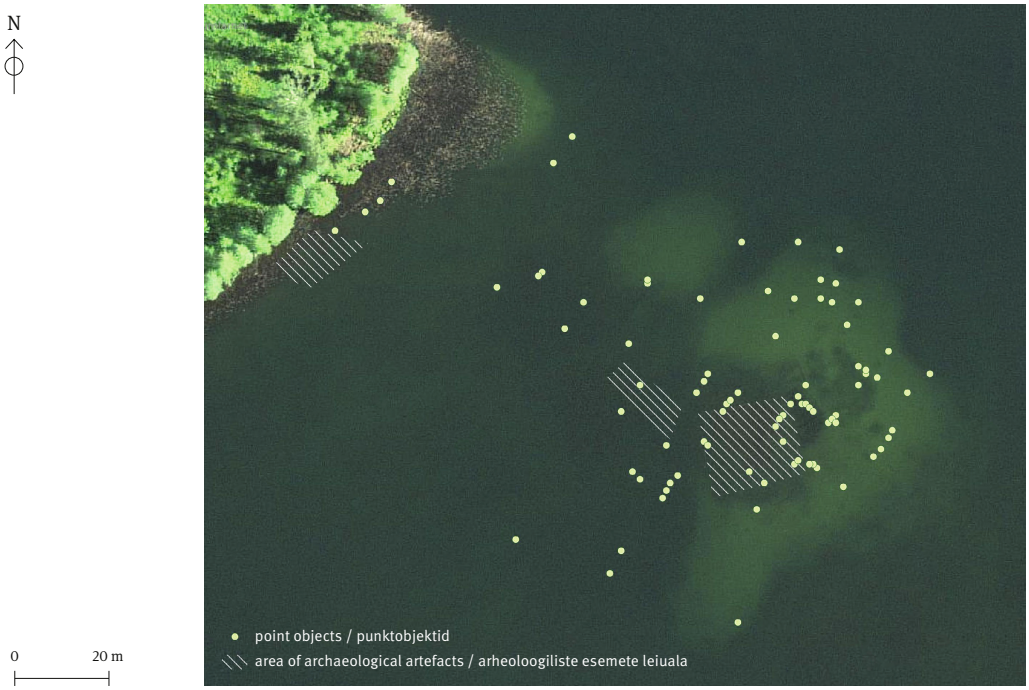

Fig. 4. *Location of point objects – potentially including archaeological features – producing hyperbolic reflections in the radar images. The locations of the artefacts discovered during previous archaeological investigations are approximate.*

Jn 4. *Punktobjektide – sealhulgas võimalike arheoloogiliste objektide – asukohad, mis põhjustasid radaripiltides hüperboolseid peegeldusi. Eelnevatel arheoloogilistel uuringutel leitud esemete leiualad on ligikaudsed.*

Map / Kaart: Orthophoto by the Land and Spatial Development Board / Maa- ja Ruumiameti ortofoto, drawing / joonis: Maili Roio

DISCUSSION

On the underwater ridge near the peninsula on the western shore of Koorküla Valgjärv, water depths range from 2 to 4 m. Submerged wooden log remains have been discovered in the section where the ridge turns southward. In this area, where the construction remains are clearly visible on the lakebed, the water is only 1–2 m deep (Fig. 5). These remains have primarily been linked to Pre-Viking and Viking Age settlement and form a roughly SW–NE oriented rectangular area. During archaeologist Jüri Selirand's investigations, this area was estimated to cover about 737 m² (Selirand 1958).

Based on Selirand's studies, the logs are most densely concentrated in the centre of the rectangle, where 74 relatively intact conifer logs were counted. Numerous smaller log fragments were also found embedded in the lakebed mud. The logs measure up to 9 m in length and up to 30 cm in diameter. Among them, obliquely embedded pillars up to 20 cm in diameter and smaller stakes were found in the mud, with axe-sharpened lower ends. Several large and small stones were found between the logs.

At the narrower NE end of the log-covered area, a circular pile of fire-altered stones – about 1 m in diameter and composed of stones roughly the size of a human head – was found, likely representing the remains of a hearth (Selirand 1960, 271). In some places, logs appeared to continue beneath others in the mud. In a test pit measuring 80 × 80 cm, an additional log was

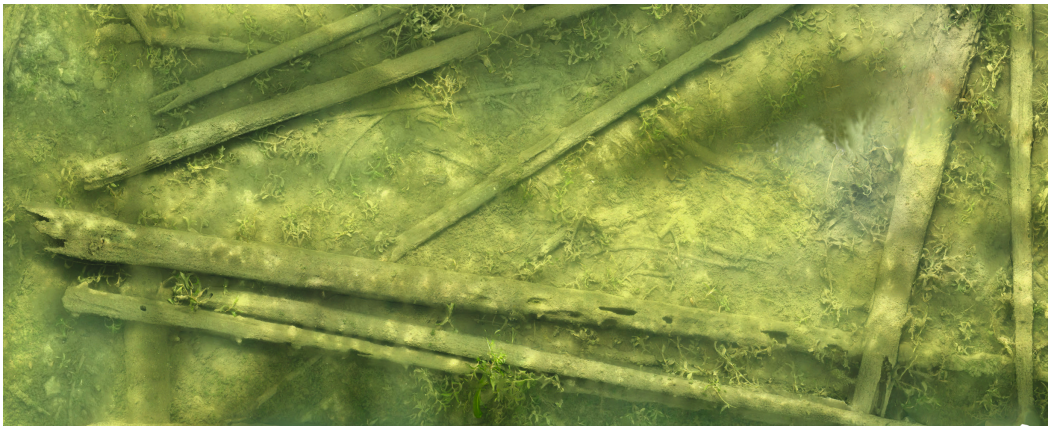

Fig. 5. *The remains of the pile dwelling are covered with vegetation and a thin layer of sediment.*
Jn 5. *Vaiehitise jäänused on kaetud taimestiku ja õhukese settekihiga.*
Photo / Foto: Maili Roio

encountered at a depth of 20 cm; at 60 cm, stones, moss, spruce branches, and needles were found (Selirand 1958, 8). However, archaeologist Kalle Virtanen later (2012) reported a cultural layer thickness of only 2 cm and observed no continuation of logs in the lower sediments.

About 40 m NE of the core area of the construction remains, another group of stakes was found, scattered across an area of approximately 25 × 25 m and extending to the north and east of the core remains. The stakes protruded only 10–20 cm above the lakebed mud. Numerous fist-sized stones were also noted in the same area. According to Vello Mäss (1991), this feature may represent a palisade, though he also suggested the stakes might belong to the oldest structural phase of the construction. Later radiocarbon studies (Virtanen 2012) dated this group of stakes to the Neolithic period, ruling out any association with Pre-Viking or Viking Age defensive structures.

Additionally, two parallel rows of posts have been identified extending from the lake's western shore to the NW corner of the construction remains, interpreted as bridge remains. The rows are about 1.5 m apart, with individual posts set 4–5 m from each other. The posts range from 15 to 30 cm in diameter, while the stakes measure 10–15 cm. Split boards and beams were found between the post rows, with stone fill beneath them (Selirand 1990, 3). The GPR survey revealed anomalies extending beyond the previously identified bridge structure, suggesting a broader distribution of subsurface features.

The GPR results indicate that potential construction remains presumably extend across a significantly larger area – approximately 16,000 m². The thickness of the possible archaeological cultural layer may reach up to one metre; however, its exact character can only be determined by underwater excavations. J. Selirand's detailed test pit descriptions suggest that the cultural layer mainly consists of construction remains. In contrast, K. Virtanen reported a much thinner layer, only 1–2 cm thick, raising questions about the excavation depth and the criteria used to define cultural material.

Archaeological finds from the site have been relatively limited compared to similar lake settlements. This may be due to the fact that items have reportedly been retrieved from the lake since the 17th century (Roio 2007). Unfortunately, these earlier recoveries are documented only in oral tradition and sparse written notes. To resolve questions regarding the extent

and use of remains from different periods, broader and more systematic investigations are required. The GPR survey provided evidence that, in some areas, structural remains are preserved within the lake sediments – rendering them invisible or difficult to detect by visual inspection alone.

SUMMARY

Koorküla Valgjärv in southern Estonia is a unique underwater archaeological site where the remains of prehistoric pile-dwellings are clearly visible. The study area is located on an underwater ridge near a peninsula on the lake's western shore, where archaeological excavations and finds indicate multiple periods of settlement, ranging from the end of the Neolithic through the Viking Age. Although reports of structural remains at the lake bottom date back to the 17th century, scientific confirmation was first provided by Jüri Selirand's investigations in 1958.

The goal of the 2024 ground-penetrating radar (GPR) survey was to non-invasively map the extent of the prehistoric structures and estimate the thickness of the cultural layer. The survey was carried out from the lake ice using 300 MHz shielded antennas. Results indicate that the lakebed in the study area lies mostly at a depth of 2–3 metres, whereas the top of the underwater hill is covered by less than one metre of water. At the underwater hill, a strong horizontal reflection was detected, which may indicate the base of a cultural layer up to 90 cm thick. In addition, isolated hyperbolic anomalies were observed, likely representing large stones or possible archaeological features.

Previously documented remains form a rectangular area where at least 74 logs, numerous log fragments, and axe-sharpened stakes have been found. A possible hearth structure and rows of posts extending from the shore to the NW corner of the construction area were also identified. Some finds, including stake clusters outside the core area of the construction remains, likely date from the Neolithic period, suggesting long-term settlement or repeated occupation of the site. While parts of the remains are visible in some areas of the lakebed, other potential structures appear to be buried beneath sediments.

The GPR results reveal that the potential archaeological area is significantly larger – exceeding 16,000 m² – and partially concealed by lake sediments, highlighting the need for further underwater archaeological excavations. The study also calls attention to inconsistencies in previous descriptions, underlining the need for a more detailed understanding of the nature and stratigraphy of the cultural layer. Given that artefacts have reportedly been retrieved from the lake since the 17th century, some archaeological material may have already been lost. Nevertheless, Koorküla Valgjärv remains an exceptional site with considerable potential for future archaeological research.

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KOORKÜLA VALGJÄRVE VEEALUSE ASULAKOHA GEORADARI UURING

Maili Roio, Jüri Plado ja Argo Jõeleht

Lõuna-Eestis asuv Koorküla Valgjärv on ainulaadne veealuse arheoloogilise pärandi paik, kus muinasaegsete vaiehitiste jäänused on visuaalselt hästi jälgitavad. Uuringuala paikneb järve läänekalda poolsaare läheduses veealusel seljandikul, kus varasemad arheoloogilised kaevamised ja leiud viitavad mitmele asustusperioodile alates neoliitikumi lõpust kuni viikingiajani. Esimesed teated ehitisjäänustest järve põhjas pärinevad juba 17. sajandist, ent teaduslik kinnitus nende olemasolule ja päritolule saadi 1958. aastal Jüri Seliranna uuringutega.

2024. aastal korraldatud georadariuuringu eesmärk oli kaardistada muinasaegse ehitise ulatust ning hinnata kultuurkihi paksust. Uuring viidi läbi järvejäält, kasutades 300 MHz sagedusega varjestatud antenne. Tulemused näitavad, et järvepõhi on uuringualal valdavalt 2–3 meetri sügavusel, kuid künka tipul katab seda vähem kui meeter vett. Künka tipul tuvastati tugev horisontaalne peegeldus, mis võib viidata järvesetetega segunenud kultuurkihi (kuni 90 cm paksune) lamavale pinnale. Samuti leiti hüperboolseid anomaaliaid, mis viitavad suurematele kividele või võimalikele arheoloogilistele objektidele.

Varem dokumenteeritud ehitised moodustavad ristkülikukujulise ala, kus leiti vähemalt 74 palki, hulgaliselt palgijäänuseid ning kirvega teritatud vaiu. Leiti ka võimalik koldestruktuur ja postiridasid, mis ulatuvad kaldalt ehitusala loodenurgani. Mõned leiud, sh vaiakogumid ehitusjäänuste tuumikalast eemal, pärinevad tõenäoliselt neoliitikumist, viidates pikaajalisele asustusele või korduvkasutusele. Kuigi visuaalselt on jäänused hästi jälgitavad, jääb osa potentsiaalseid ehitisi järvesetete alla varjatuks. Georadariuuring kinnitab, et võimalik arheoloogiline ala on ulatuslikum (üle 16 000 m²) ja osaliselt nähtamatu, mis suurendab vajadust täiendavate allveearheoloogiliste kaevamiste järele. Samuti rõhutab uuring vajadust kultuurkihi olemuse ja kihistumise põhjalikumaks määratlemiseks, kuna varasemad kirjeldused on kohati vastuolulised. Arvestades ajaloolist esemete väljatoomist järvest juba alates 17. sajandist, on võimalik, et osa arheoloogilisest materjalist on kaduma läinud. Siiski pakub Valgjärv märkimisväärset uurimispotentsiaali.