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Optical dating and archaeological survey of an inland dune along the Lower Scheldt valley at "Warandeduinen-Speelbos"(Wetteren, East Flanders, BE)

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1. Introduction

As part of a research project about the role of rivers during the Late Glacial recolonization of NW Europe (Pincé, 2020), a sand dune at the "Warandeduinen-Speelbos" in the municipality of Wetteren (province of East Flanders, Belgium) has been studied. A first aim was to determine the chronological framework for sediment deposition and accumulation through Optically Stimulated Luminescence (OSL) dating. The second aim was to investigate the potential of the dune for the presence of (sealed) prehistoric sites through archaeological augering and a test pit survey. The first OSL ages and results of the archaeological survey are presented here.

2. Site

The site comprises the eastern sand dune of the "Warandeduinen-Speelbos" in Wetteren and is part of an inland dune system along the Scheldt valley. The study area is located at the southern edge of the Flemish Valley, bordering the Scheldt – Dendre interfluvium (De Moor, 1963; De Moor & Pissart, 1992; De Moor *et al.*, 1999; Fig. 1). The top of the dune consists of heath- and grassland while the slopes are wooded. Historical maps from the 18th and 19th century (Villaret, Ferraris & Vandermaelen maps), however, indicate that the dune was completely forested (coppice) in that time. In the remaining part of the "Warandeduinen-Speelbos" also heathland and arable land occurred. Nowadays, still

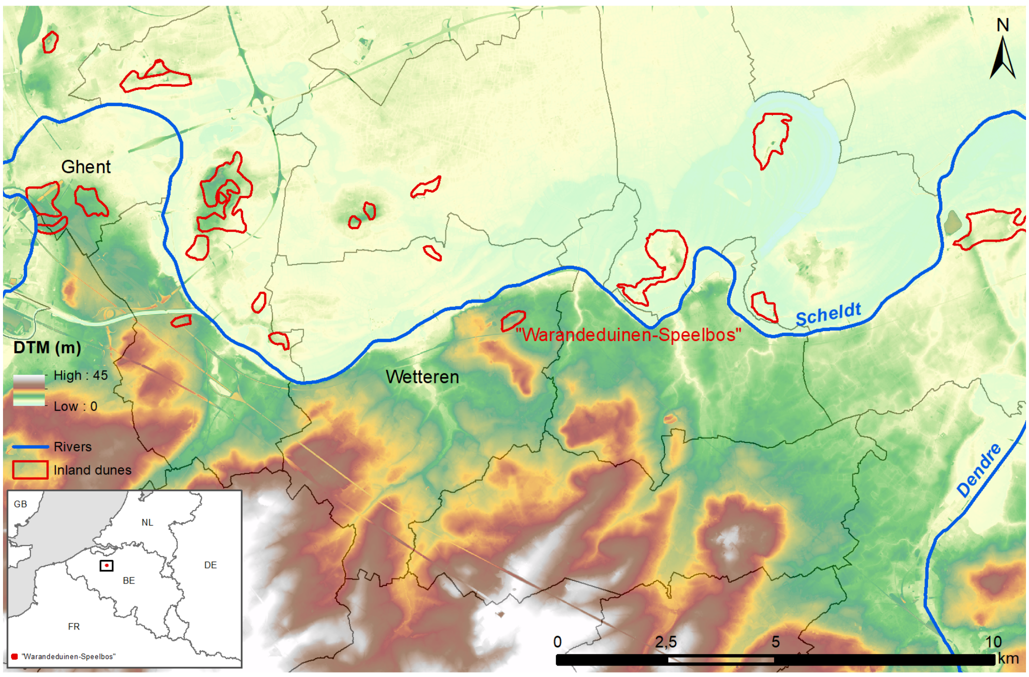

Fig. 1 – DEM with visualization of the study area, the inland dunes along the Scheldt, the municipality of Wetteren and the city of Ghent (AGIV 2014, 2016b; Bogemans, 2005)

some coppice stoves of beech and oak of over 400 years old are present at the site (AGIV 2010a, 2010b, 2016a; Agentschap Natuur en Bos, s.d.).

Human activities in the 20th century have heavily disturbed the dune morphology. From the 1950s to 1970, sand was exploited for construction works and from the 1970s onwards it became a motocross terrain. In 2001, however, the "Warandeduinen-Speelbos" was recognized as a Flemish nature reserve and became property of the Agency 'Nature and Forest' (Agentschap Natuur en Bos, s.d.).

3. Material and methods

3.1. OSL sampling pit

In spring 2020, several hand borings were made to determine the stratigraphy of the dune and identify the optimal place for a sampling pit. A pit of 300 cm deep was subsequently made along the northwestern slope of the dune. Samples for OSL dating were taken in a vertical sequence, starting at a depth of 45 cm and with intervals of more or less 20 cm. These samples were collected by hammering opaque PVC cylinders in the eastern profile wall. For each sample about 0.75 to 1 kg of surrounding sediment was additionally taken for dose rate determination. Furthermore, three sediment samples spread across the dune at 155 cm, 230 and 290 cm were collected to evaluate the time-averaged moisture content.

A total of thirteen OSL samples were assembled of which three have been processed so far: one that was taken in the upper part of the dune (70 cm, GLL-205026), one in the central part (175 cm, GLL205021) and one near the base of the exposure (270 cm, GLL205016) (Fig. 2).

3.2. OSL dating

The samples for luminescence analyses were prepared in line with widely adopted protocols for extracting quartz grains of the 125-180 µm fraction (HCl, H_2O_2, wet and dry sieving, HF). The purity of the quartz extracts was tested by measuring their

Fig. 2 – Picture (left) of the complete sampling pit and close-ups (center and right) of the two profiles in the sampling pit. The analyzed OSL samples are marked with white circles and their corresponding GLL-code.

sensitivity to stimulation with infrared light (OSL IR depletion ratio; Duller, 2003). The sensitivity to infrared stimulation was defined as significant if this ratio deviated more than 10 % from unity; none of the samples or aliquots had to be rejected on this basis. For measurement, the quartz grains were fixed on the inner 8 mm (small aliquots) of stainless steel discs with a thickness of 0.5 mm and a diameter of 9.7 mm, using an aerosol of silicone oil as adhesive. The luminescence measurements were made using an automated Risø TL/OSL reader equipped with blue (λ_{max} = 470 nm) and infrared (λ_{max} = 870 nm) light emitting diodes. All luminescence emissions were detected through a 7.5 mm thick Hoya U-340 UV filter. Details on the measurement apparatus can be found in Bøtter-Jensen *et al.* (2003). The equivalent dose (D_e) was determined using the single-aliquot regenerative-dose (SAR) protocol (Murray & Wintle, 2000, 2003). A preheat of 10 s at 220°C and a cut heat to 200°C were adopted. Stimulation with the blue diodes was for 38.5 s at 125°C. All calculations used the initial 0.31 s of the decay curve, minus a background evaluated from the following 0.77 s of stimulation. Each measurement of the response to the test dose was followed by a stimulation with the blue diodes for 38.5 s at 280°C to minimize recuperation (Murray & Wintle, 2003). A dose recovery test (Murray & Wintle, 2003) was used to assess the performance of the laboratory measurement procedure. In this test, natural aliquots were bleached for two times 250 s using the blue diodes at room temperature, separated by a 10.000 s pause; they were then given a known laboratory dose equal to the estimated natural dose and measured using the SAR protocol as outlined in the above.

The sediment that was collected for dose rate determination was dried at 110°C (until constant weight), pulverized and homogenized. A subsample of this material was then cast in wax to prevent radon loss and to provide a well-defined and reproducible counting geometry (Murray *et al.*, 1987; De Corte *et al.*, 2006). The samples were stored for at least one month before being measured on top of a low-level extended energy-range HPGe gamma-ray spectrometer. The specific radionuclide activities were converted to dose rates using the data tabulated by Adamiec & Aitken (1998). A factor of 0.9 (± 5 % relative uncertainty) was adopted to correct the external beta dose rates for the effects of attenuation and etching (Mejdahl, 1979). The external beta and gamma dose rates were corrected for the effect of moisture following the procedure outlined in Aitken (1985). We assumed that samples GLL-205021 and -26 were, on average, saturated for 20 % of the burial period and retained their present-day water content for 80 % of the time; for sample -16, this ratio was 40/60. An internal dose rate in quartz grains of 0.013 ± 0.003 Gy ka^{-1} was adopted (Vandenberghe *et al.*, 2008). The contribution of cosmic radiation was calculated following Prescott and Hutton (1994).

3.3. Archaeological augering and test pit for prehistoric artefact sites

For the detection and assessment of possible (sealed) prehistoric artefact sites a two-step gridding approach was applied in the summer of 2021.

In the first stage (in Dutch "verkennend archeologisch booronderzoek" = VAB), a total of 128 hand borings were executed within a staggered (isosceles triangular) grid of 10 x 12 m, using a manual Edelman core head of 12 cm (Fig. 3). The depth of the hand borings varied from 1.6 to 6 m, with an average depth of 4 m. In contrast to standard archaeological augering (Crombé & Verhegge, 2015), sediment samples were collected over the full depth of the dune in artificial levels of 50 cm to enable the discovery of possible Late Glacial sites at different levels within the river dunes. The importance of the latter was recently demonstrated at the site of Oudenaarde (Crombé *et al.*, 2018). However, in case a covered soil was present or a disturbed layer could be identified, a new sediment sample was taken starting from the top of this soil or at the end of the disturbed layer. This way, artefacts from colluvial or mixed layers could be differentiated from artefacts located in undisturbed sediments. The sediment samples collected this way were wet sieved through 1 x 1 mm meshes to increase the discovery probability, after which all archaeological indicators (e.g. lithic artefacts, carbonized plant remains, ceramics) were selected from the dried residues.

The second archaeological augering survey (in Dutch "waarderend archeologisch booronderzoek" = WAB) was performed in a closer staggered grid of 5 x 6 m around the positive borings yielding lithic artefacts or charred botanical remains to further evaluate the detected archaeological site(s) (Fig. 5). These hand borings were executed in two concentric circles around the positive borings, amounting to a total of 87 additional hand borings. The depth of these borings was based on the level at which the artefact or charred seed in the positive boring was found. Similar to the first augering survey, sediment samples were taken every 50 cm unless a covered soil was present or a disturbed layer could be identified. It must be kept in mind, however, that the negative boreholes of the initial augering survey do not necessarily represent negative locations in reality.

Based on the findings in borehole 126 during the first augering survey, a test pit of 1 x 1 m was made at this location to search for more (diagnostic) artefacts (Fig. 4). This test pit was subdivided in squares of 0.25 m^2 and sediment samples of each square were taken at vertical intervals of 5 cm up to 150 cm depth. The squares were named A, B, C and D in a clockwise direction, starting in the NE-corner of the pit.

4. Results

4.1. Stratigraphy and dune morphology

The studied dune consists of a homogeneous, aeolian deposition of moderately well sorted fine sand with a yellowish beige colour. However, in the upper part of the sediments along the slopes of the dune, extensive bioturbation took place creating a humic horizon with greyish brown color. This bioturbated layer was furthermore often mixed with recent anthropogenic material such as brick fragments, glass and coal. Underneath this, a covered soil could be determined in several borings along the slopes of the dune. At the top of the dune, however, no soil development was detected (A-C or C profiles) (Fig. 3). These observations suggest a stable, warm period with vegetation that allowed soil development to take place at some point during dune formation. Erosion from the upper part of the dune subsequently occurred, depositing the material down on the slopes of the dune, and hence covering the undisturbed sediments. As a result, the dune is less high and steep nowadays. Causes of these erosion processes are at least partially related to past anthropogenic activities such as sand exploitation and the use of the terrain for recreational purposes (e.g. motocross).

The maximal height of the remaining dune is ca. 18 m TAW (Belgian ordnance level). Based on field observations, the base of the dune was determined between ca. 11.3 and 11.9 m TAW, implying that up to 6 m of the dune has been preserved.

At the base of the dune a palaeosol could be identified in at least two hand borings at an elevation of 11.82 and 11.88 m TAW. The palaeosol has a light (brown) greyish colour with humic spots and varies between 5 to 20 cm in thickness. Several other borings, mainly along the western part of the dune, also showed a possible palaeosol at a level between 11.34 and 11.94 m TAW (Fig. 3). In the lower part of the dune and in the underlying sediments, redox effects were visible.

The studied sand dune is deposited on top of (light) sandy loam to sandy sediments, which has been described as Weichselian fluvioperiglacial deposits in this environment

(De Moor, 1963; De Moor & Walschot, 1979; De Moor *et al.*, 1999). However, based on the field observations, the attribution to coversand deposits of reworked fluvioperiglacial sediments cannot be excluded.

4.2. OSL ages

A sufficient amount of pure sand-sized quartz could be extracted from each sample. All samples exhibited satisfactory luminescence characteristics in terms of brightness (clearly distinguishable from the background), OSL decay (dominated by the fast component), recycling ratios (overall average ± 1 standard error: 0.98 ± 0.01), recuperation (0.4 ± 0.2 % of the sensitivity corrected natural OSL signal), and dose recovery (1.03 ± 0.03).

The analytical data and calculated OSL ages are summarized in Tab. 1. Uncertainties on the OSL ages were calculated as outlined by Aitken (1985), with systematic sources of uncertainty as in Vandenberghe (2004) and Vandenberghe *et al.* (2004). The OSL ages of the two lowest samples (at 175 cm and 270 cm depth) indicate dune formation during the Late Glacial. In case more OSL samples from this vertical sequence would be analysed, higher resolution dating would be possible. The upper OSL age (70 cm depth), on the other hand, shows a Holocene age. Based on field observations, this seems to be related to the colluvial nature of the sediment at this level, which was deposited on top of the undisturbed Late Glacial sediment in which a soil had been formed (Fig. 2). In case the sediment was indeed bleached completely during erosion and colluvium deposition, its depositional age is estimated at 460 ± 40 years before analysis (2021). However, if bleaching would have been insufficient, the aforementioned value could be an overestimation of the true depositional age. Moreover, the age could also be an underestimation in case of postdepositional reworking.

The resulting OSL ages are in accordance with the obtained dates of the dunes in Aard (Bogemans & Vandenberghe, 2011) and Oudenaarde (Crombé *et al.*, 2018) and improve the chronological framework of the inland dune system and the changing aeolian landscape along the Scheldt river in NW Belgium during the Late Glacial. It further indicates a potential for sealed Late Glacial (Final Palaeolithic sites) of which the possible presence has been investigated in this study by archaeological augering and test pit survey.

4.3. Prehistoric finds

The first augering survey (10 x 12 m) yielded eight lithic artefacts and one charred hazelnut. The lithic artefacts comprised four chips, three flake fragments and one complete blade (Tab. 2). Two of the positive borings were situated along the northeastern slope of the dune and two other on the southwestern slope. The negative area between the clusters in the southwestern part may be related to the intensive sand exploitation that occurred during the second part of the 20th century. Additionally, four possible chips were identified in the sieved sediment samples (Fig. 3).

GLL-code	*Field code*	*^{40}K (Bq kg^{-1})*	*^{234}Th (Bq kg^{-1})*	*^{226}Ra (Bq kg^{-1})*	*^{210}Pb (Bq kg^{-1})*	*^{232}Th (Bq kg^{-1})*	*w.c. (%)*	*Total dose rate (Gy ka^{-1})*	*D_e (Gy)*	*Age (ka)*	*σ_r (%)*	*σ_s (%)*	*σ_{tot} (%)*
205026	WEWA-PR01-OSL L1 (70 cm)	235 ± 3	8 ± 1	9.8 ± 0.4	6 ± 1	8.8 ± 0.2	12 ± 3	1.11 ± 0.02	0.51 ± 0.02	0.46 ± 0.04	3.8	8.6	9.4
205021	WEWA-PR01-OSL G1(175 cm)	261 ± 4	9 ± 1	9.2 ± 0.4	9 ± 1	8.5 ± 0.2	12 ± 3	1.18 ± 0.02	16.0 ± 0.4	13.5 ± 1.2	2.8	8.8	9.2
205016	WEWA-PR01-OSL B1 (270 cm)	278 ± 2	11 ± 1	11.8 ± 0.4	10 ± 2	11.1 ± 0.2	12 ± 3	1.27 ± 0.03	15.7 ± 0.3	12.4 ± 1.0	2.9	7.5	8.1

Tab. 1 – Specific radionuclide activities used for dose rate evaluation, estimates of past moisture content (F*W), calculated dose rates, D_e's, optical ages (± total uncertainty), and random (σ_r), systematic (σ_s) and total uncertainties (σ_{tot}). The total dose rate includes the contribution from internal radioactivity and cosmic radiation. The uncertainties mentioned with the dosimetry and D_e data are random; all uncertainties represent 1 sigma.

The current incomplete aeolian sequence at the top of the dune and the colluvial, disturbed and bioturbated layers on the slopes cause difficulties in the determination of different archaeological layers. However, three lithic artefacts were found in or below a covered soil suggesting undisturbed material of which the depths could be compared. The artefacts of hand boring 117 were found in the Ab or B horizon of the covered soil and the second lithic artefact in the underlying C horizon. Although this may indicate two archaeological levels, some vertical migration of these small artefacts is possible and the exact location of the chips in the sediment samples of 118-150 cm and 150-200 cm depth

Boring	*Sample nr*	*Top boring (TAW)*	*Depth artefact (cm)*	*Lithic artefacts / charred seeds*	*Soil development*	In situ
VAB29	M325	16.76 m	400-450	Chip	No soil development	*In situ*
VAB33	M329	17.40 m	100-150	Flake fragment	No soil development	Probably *in situ*
VAB112	M703	15.23 m	112-150	Chip	Soil development underneath colluvium	*In situ*
VAB117	M911	14.13 m	118-150	Chip	Soil development underneath colluvium	*In situ*
VAB117	M912	14.13 m	150-200	Chip	Soil development underneath colluvium	*In situ*
VAB124	M922	13.54 m	50-100	Large distal flake fragment	No soil development	Not *in situ*
VAB124	M922	13.54 m	50-100	Small distal flake fragment	No soil development	Not *in situ*
VAB126	M716	13.72 m	105	Blade	No soil development	*In situ*
VAB127	M457	13.51 m	100-110	Charred hazelnut	No soil development	Unclear

Tab. 2 – Overview of the augered lithic artefacts (phase 1, VAB), their depth and location in colluvium/mixed layers or undisturbed (*in situ*) sediment, the absolute elevation (TAW) of the boreholes and presence of soil development per positive boring.

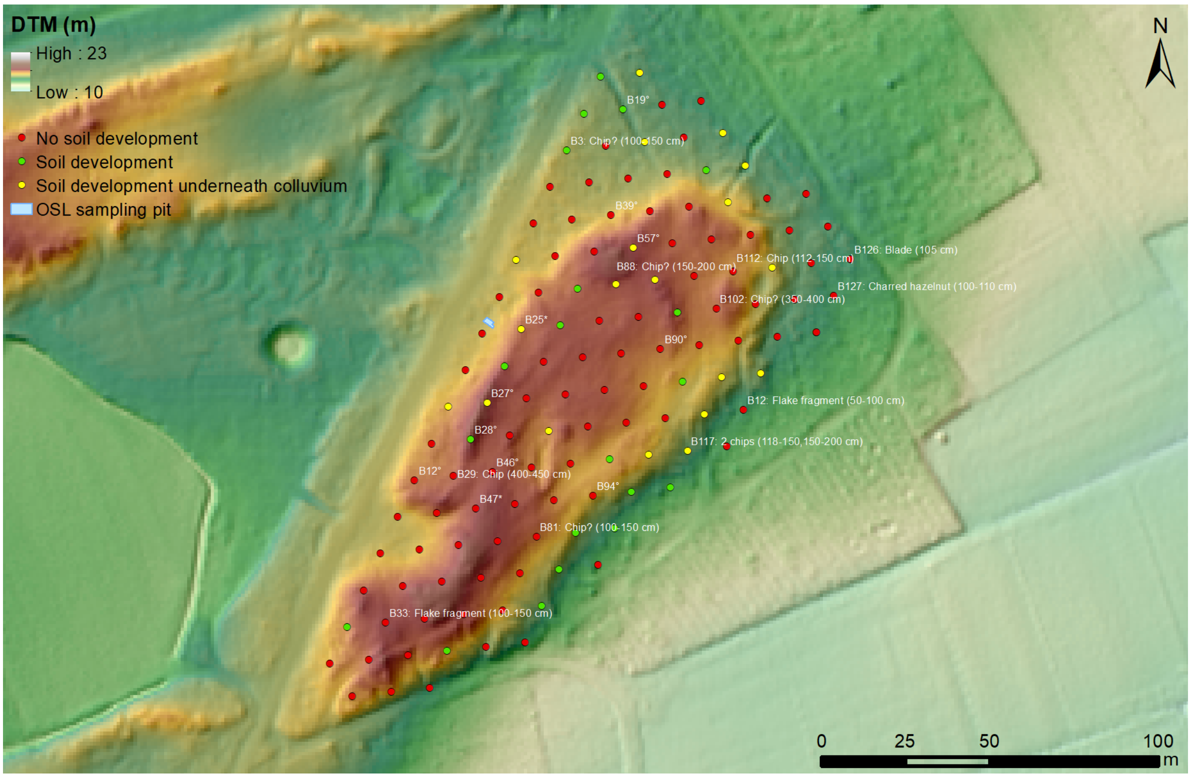

Fig. 3 – DEM with visualization of the possible soil development in the borings (colours of boreholes), overview of the found (possible) lithic artefacts and their depth inside these borings, the presence of a palaeosol (* = palaeosol, ° = possible palaeosol) and the location of the OSL sampling pit (AGIV, 2014, 2019).

might be closely located to each other. Furthermore, the depth of the chip of boring 112 from the top of the covered A horizon coincides partially with the depth of both sediment samples with chips from hand boring 117. This being said, no archaeological levels could be differentiated with certainty.

The blade found in hand boring 126 was located in the upper part of a homogeneous C horizon (from 100 cm depth onwards). It was discovered at a depth of 105 cm and can probably be attributed to the Neolithic (Fig. 4). The proximal part was absent and the blade was slightly damaged on the side due to contact with the corehead.

The test pit and second archaeological augering survey (5 x 6 m) concentrated around the positive borings from the first survey and yielded 17 lithic artefacts comprising 8 chips of which two are burnt, three flake fragments, one retouched flake fragment, one bladelet fragment, one complete bladelet, one striking platform rejuvenation flake, one probable splintered piece and one retouched frost flake of Wommersom quartzite (Tab. 3; Fig. 5). Unfortunately no typochronologically diagnostic artefacts were found.

Also this part of the study was affected by the same problems concerning the disturbed dune morphology and difficulty to differentiate multiple archaeological levels. Moreover, most artefacts from the hand borings on the eastern side of the dune were found in colluvial or disturbed layers and can therefore not be related to a site at that location. However, finds in four hand borings were likely located *in situ* of which three (WAB 12, 38 & 63) occurred at the same level as the nearby positive borings from the first survey (Tab. 3). The lithic artefact in the fourth boring (WAB 1), however, occurred at a different level than its positive boring (VAB29), suggesting the presence of a possible Late Glacial archaeological level.

Finally, the test pit also yielded finds in the lower levels (110-120 cm) that could potentially originate from Late Glacial occupation layers.

Fig. 4 – Picture (left) of the complete blade from hand boring 126 (105 cm depth) and the bladelet found in the test pit (115-120 cm depth). Picture (right) of the eastern profile of the test pit.

Boring / Test pit	Sample nr	Top boring / pit (TAW)	Depth artefact (cm)	Lithic artefacts	Soil development	In situ
WAB1	M6	16.43 m	270	Retouched flake fragment	No soil development	In situ
WAB12	M60	17.08 m	100-150	Chip	No soil development	Probably *in situ*
WAB33	M83	13.35 m	5-50	Flake fragment*	No? soil development	Not *in situ*
WAB35	M153	13.24 m	50-100	Proximal bladelet fragment	No soil development	Not in situ
WAB38	M103	14.86 m	150-200	Chip	No soil development	*In situ*
WAB41	M72	13.39 m	55	Striking platform rejuvenation flake*	Soil development underneath colluvium	Not *in situ*
WAB41	M73	13.39 m	95-150	Chip	Soil development underneath colluvium	Not *in situ*
WAB63	M118	13.70 m	90-100	Chip	No soil development	*In situ*
WAB70	M252	13.14 m	50-90	Chip	No soil development	Not *in situ*
WAB80	M278	13.29 m	100-150	Chip	No soil development	Probably *not in situ*
Test pit	Square D	13.66 m	12	Splintered piece (?) with white patina	No soil development	Not *in situ*
Test pit	Square A	13.66 m	50	Flake fragment with white patina*	No soil development	Not *in situ*
Test pit	Square B	13.66 m	105	Retouched frost flake of Wommersom quartzite	No soil development	*In situ*
Test pit	M323, square A	13.66 m	110-115	Chip, burnt	No soil development	*In situ*
Test pit	M325, square A	13.66 m	110-115	Chip, possibly burnt	No soil development	*In situ*
Test pit	M354, square B	13.66 m	115-120	Bladelet	No soil development	*In situ*
Test pit	M354, square B	13.66 m	115-120	Flake fragment	No soil development	*In situ*

* fine grained grey flint

Tab. 3 –Overview of the augered lithic artefacts (phase 2, WAB), their depth and location in colluvium/mixed layers or undisturbed (*in situ*) sediment, the absolute elevation (TAW) of the boreholes and presence of soil development per positive boring.

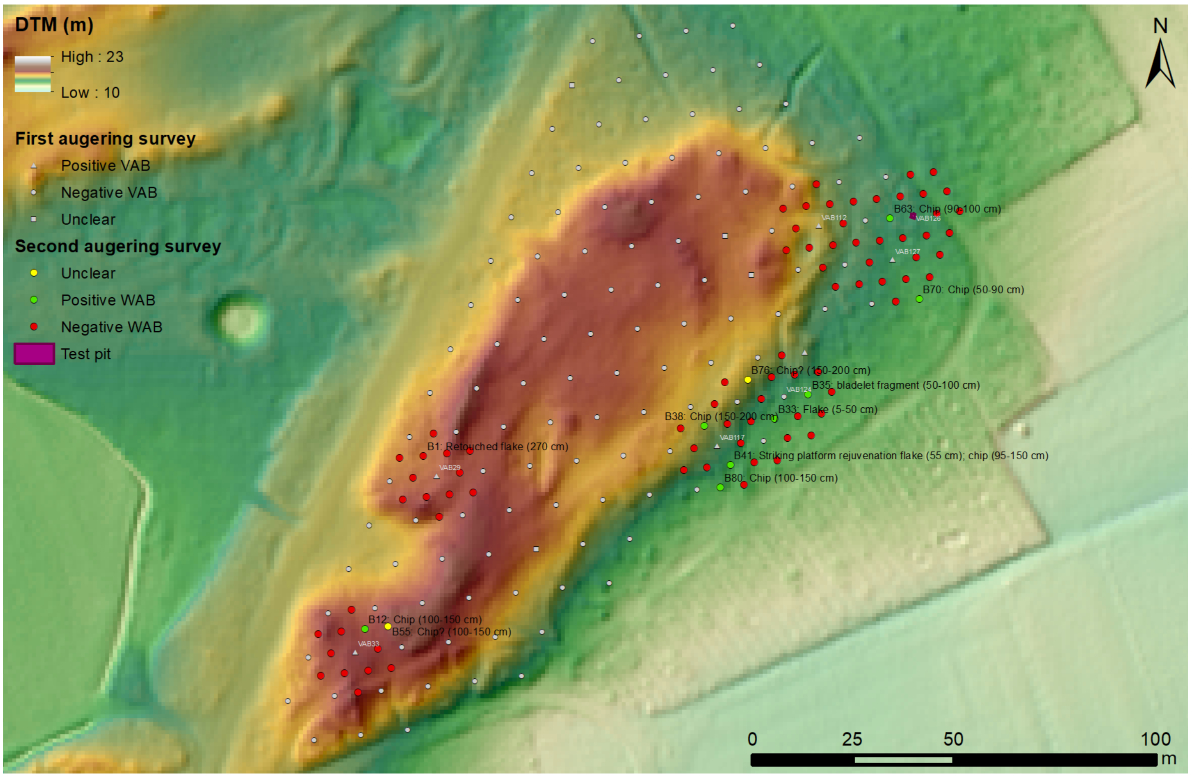

Fig. 5 – DEM with visualization of the found (possible) lithic artefacts and their depth inside these borings, the location of the test pit and the borehole numbers the positive borings from the first survey (AGIV 2014, 2019).

5. Conclusion

The eastern inland dune of the "Warandeduinen-Speelbos" in Wetteren is a well-preserved, homogeneous sand dune with a remaining height of about 6 m. However, different erosion processes and human activities in the past caused a disturbance in the morphology of this dune making it less high and steep. The OSL ages indicate a main formation of the dune during the Late Glacial, which is comparable to those of other similar deposits in the region. Furthermore, the archaeological augering and test pit survey yielded 25 lithic finds demonstrating a prehistoric presence. It remains, however, difficult to evaluate the present archaeological level(s) and the age and time span of the sites due to the disturbances of the dune, possible vertical migration of small artefacts and the limitations of the survey techniques.

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Abstract

A sand dune at the "Warandeduinen-Speelbos" in the municipality of Wetteren (province of East Flanders, BE) has been studied within the frame of a research project about the age and formation processes of inland dunes in the Scheldt basin (NW Belgium) and their potential for Late Glacial sites. First, Optically Stimulated Luminescence (OSL) dating was applied to determine the age of dune formation and enhance the chronological framework of the inland dune system and the changing aeolian landscape along the Scheldt river. The second step comprised an archaeological augering and test pit survey to detect and assess possible (sealed) prehistoric sites in this dune. The resulting OSL ages indicate a Late Glacial dune formation, which is consistent with similar other dated deposits in the region. The discovered lithic finds in the archaeological survey further indicate a prehistoric presence. Unfortunately, no differentiation in archaeological levels could be determined with certainty due to the disturbed and complex dune morphology and lack of typochronologically diagnostic artefacts.

Keywords: Scheldt river, inland dune, OSL dating, Late Glacial, archaeological augering survey, test pit.

Samenvatting

Een rivierduin dat deel uitmaakt van de "Warandeduinen-Speelbos" in Wetteren (Oost-Vlaanderen, BE) is bestudeerd in kader van een onderzoeksproject over de ouderdom en vorming van rivierduinen in het Scheldebekken (NW-België) en hun potentieel op Laat Glaciale sites. In de eerste stap werd optisch gestimuleerde luminescentiedatering (OSL) toegepast om de ouderdom van de duinvorming te achterhalen en het chronologisch kader over de vorming van rivierduinen en veranderingen in het eolisch landschap rond de Scheldevallei te verbeteren. Vervolgens is een archeologisch boor- en proefputonderzoek uitgevoerd om mogelijke (afgedekte) prehistorische sites te detecteren en evalueren. De resulterende OSL dateringen duiden op een voornamelijk Laat Glaciale vorming van deze duin en is in overeenstemming met vergelijkbare andere gedateerde afzettingen in deze regio. De aangetroffen lithische artefacten in het archeologisch onderzoek wijzen verder op een prehistorische bewoning van deze duin. Er kon echter geen duidelijkheid verkregen worden in de ouderdom van deze steentijdsite(s) en het al dan niet voorkomen van verscheidene archeologische niveaus omwille van de verstoorde en complexe duinmorfologie en het gebrek aan typo-chronologische diagnostische artefacten.

Trefwoorden: Schelde, rivierduin, OSL dateringen, Laat-Glaciaal, archeologisch booronderzoek, proefput.

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