NCL

Netherlands Centre for Luminescence dating

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Optical dating applications
Eke Buis, Arnaud Temme & Jakob Wallinga (eds.)

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Netherlands Centre for Luminescence dating

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The main aims of the NCL are to make luminescence dating widely available to Netherlands research and to develop new and improved luminescence dating methods. Research and facilities of the NCL at the Reactor Institute Delft of the TU Delft are partly financed by NWO-ALW and STW.

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SYMPOSIUM NETHERLANDS CENTRE FOR LUMINESCENCE DATING

Date: **Thursday April 24, 2008**
Theme: **Optical dating applications**
Venue: **Wageningen University, Auditorium Atlas 1**
Droevendaalsesteeg 4, Building no. 104
6708 PB Wageningen

PROGRAMME: **Page**

The medieval church of St. Catharine's in Eindhoven: archaeology and chronology of brick foundations and human graves and their implications

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Eindhoven is exceptional in the Netherlands for its urban archaeology. This is not because the town played an important political or economic role in the Middle Ages or the following centuries, or even because any important people came from here. On the contrary, Eindhoven was a backwater of the Duchy of Brabant. The distinction which Eindhoven can claim above other medieval town centres is the extent of its archaeological research. This is due to the number of large-scale developments, such as underground car parks, which has necessitated a number of excavations beforehand. As most medieval historical records were burnt in the 15th century, no archival data are available on the origin of the town. Both archaeological, dendrochronological and numismatical evidence suggests that Eindhoven was created as a new town in the beginning of the thirteenth century.

Till very recently it was presumed that in the new town during the first century of existence there was already a church. Saint Catharine's was the only church in medieval Eindhoven. This church is known from historical sources since 1340. Originally it was a daughter church of St. Peter's Church some two kilometres to the north. Till 1399 the two churches shared the same priest. In 1860 the medieval church was demolished and in 1867 a new, much larger, church was consecrated on the same place. The medieval choir was left inbuilt on a then new place in front of the nineteenth century church building.

Fig. 1 *The excavation in April 2006. Photograph by Laurens Mulkens.*

In 2002 a small trial excavation was conducted on the spot where the medieval choir of Saint Catharina's used to be. This excavation was meant to investigate the possible remains of the medieval church. At the very first day of the dig it was discovered that the brick foundations of the choir were still present. It was also discovered that there where quite a large number of human skeletons were in situ between the brick foundations. In one of these skeletons, the grave of a ten-years old child, ancient human DNA was discovered.

The discovery of ancient DNA was one of the mean reasons to conduct a complete excavation of the medieval choir and adjacent church-yard, which took place in 2005 and 2006. During this excavation various brick foundations of the medieval choir were uncovered as well as the remains of some 1500 individual human remains.

The technical results of the 2005-2006 excavations will be reported this year. One of the theme's is the chronology of the human graves and brick foundations. Based on archaeological evidence four periods are distinguished: circa 1225-1350, circa 1350-1500, circa 1500-1650 and circa 1650-1850. The oldest brick foundations cross the oldest graves, which means that there was a cemetery before the first brick church was build. Possibly there was a timber church in the period before the brick choir was erected. In order to establish an absolute chronology five OSL datings for bricks were performed. The results indicate that the bricks were made in 1393 ± 43, 1405 ± 35, 1409 ± 43, 1432 ± 45 and 1508 ± 36. These dates are currently verified by radiocarbon dates, but the results are not yet available.

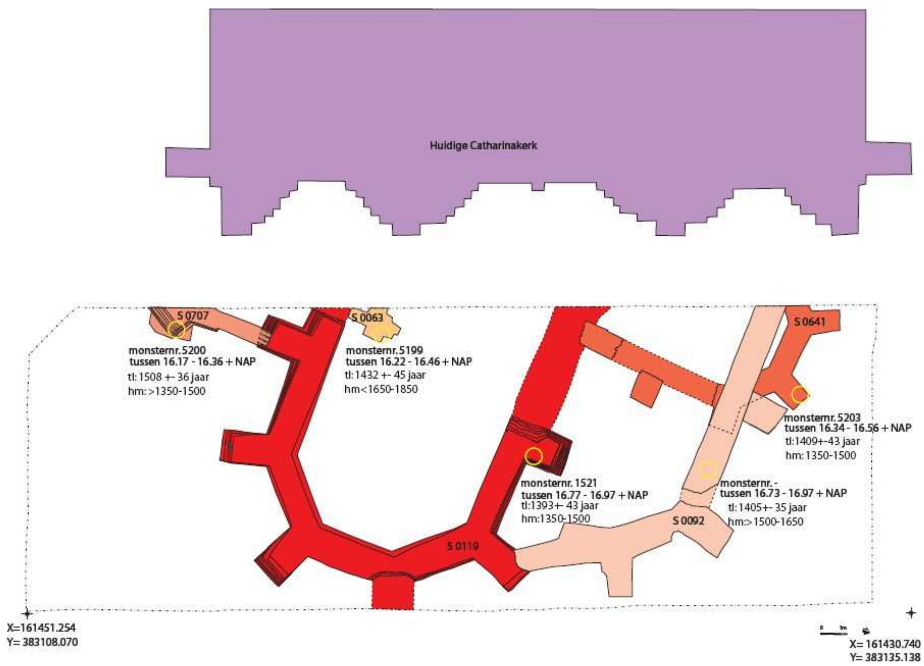

Fig. 2 *Plan of the brick foundations with OSL dates. Drawing by Joeske Nollen.*

The mean conclusion is that the brick choir of the medieval St. Catharine's Church in Eindhoven was not build in the thirteenth century, as was presumed earlier, but at the end of the fourteenth century (1393 ± 43).

This date fits well in the historical date of 1399 when St. Catharina's Church was raised by the bishop of Liege to the higher status of a collegiate church. According to the oldest OSL date the members of the collegiate church (the canons) erected a choir for their own religious purposes just before the bishop selected the church for a higher status. Also OSL dates such as 1508 ± 36 fits well into an historical event: the rebuilding of the church after the destruction of 1486. Some of the other OSL dates might reflect the re-use of bricks.

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History of a valley fill balancing between climate fluctuations and human occupation in the last 40 000 years, Northern Negev Desert, Israel

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The interactions between climate change, human occupation and semi-arid landscape dynamics are still poorly understood. In this study we aim to increase our insight in these interactions in a semi-arid environment by reconstructing the phases of incision and aggradation of the small Sayeret Shaked catchment in the northern Negev Desert. The catchment is covered by a thick Pleistocene loess layer.

Profile pits were excavated along a transect and described. In two profiles OSL samples were taken and dated. Grain size varied between 63 and 250 µm. The Single-Aliquot Regenerative-dose (SAR) procedure was used for D_e determination (e.g. Murray and Wintle, 2003). Standard, finite mixture and minimum age models were used for analysis of the D_e distribution. Based on these data and Dead Sea level and temperature records, we distinguished different phases of aggradation and incision and placed them in a temporal framework (e.g. Grootes et al., 1993, Migowski et al., 2006, Robinson et al., 2006). Human occupation was extracted out of a settlement record of the Beer Sheva plain near Sayeret Shaked (Grovin, 1992) (Fig. 1). Volumes (m^3) of aggradation and incision were calculated for a 1 meter segment at the transect.

Four Pleistocene aggradation and incision phases were recognized (Fig. 2). Deposits of aggradation phase A1 were dated to 37.5 ± 3.0 ka, while the deposits of aggradation phase A2 were dated to 28.7 ± 3.1 ka. Incision phase I2 is the strongest Late Pleistocene incision phase recognized and is likely to date from the termination of the Younger Dryas.

During the Early Holocene wet period sediments were deposited in a connected slope-gully system, with additional loess deposition

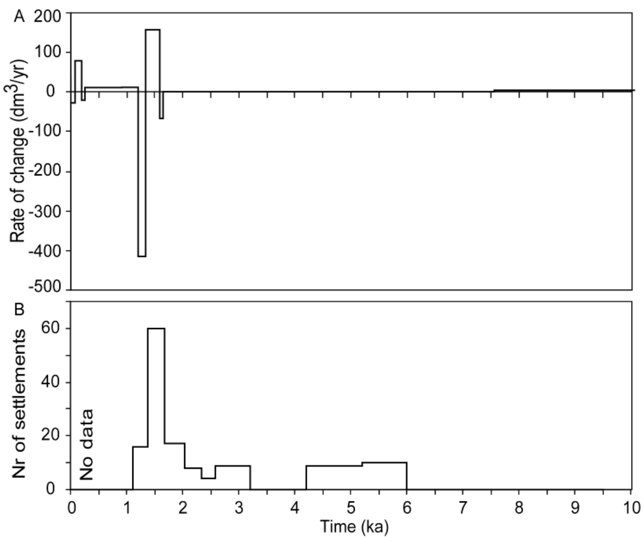

Fig. 1. *A) estimated rate of volume change (dm^3/year) at the transect and B) number of archaeological settlements in the Beer Sheva basin after Grovin, 1992.*

(aggradation phase A3). Afterwards up to the Roman period (37 BC – 324 AD) relatively stable conditions occurred resulting in soil formation. The top of this phase was dated to 806 ± 296 BC.

After the Roman period eight phases were recognized (phase I3 – A7), with varying intensities (Fig. 1). The phases with the largest aggradation and incision occurred during the Byzantine period (324 – 800 AD) and since the Ottoman period (>1760 AD). Aggradation phase A4 deposited large amounts of sediment, while incision phase I4 locally eroded to the bedrock (Fig. 2). During the Byzantine period human occupation was high (Fig. 1). Overgrazing increased erosion, while rainfed agriculture caused infilling of the gully. Incision phase I4 is related to a strong aridification at the end of the Byzantine period and a still high human pressure on the land (Fig. 1). Several potsherds of the Byzantine-Islamic transition period (5th to 8th century) and an OSL date of 393 ± 127 AD confined these layers to the Byzantine period.

The period after 1760 AD (phase I5 – A7) was characterized by relatively high incision and aggradation rates due to heavy grazing by Bedouin herds. Two OSL dates of 1914 ± 8 AD and 1926 ± 6 AD and potsherds of the Late Ottoman period (18th to 20th century) were found.

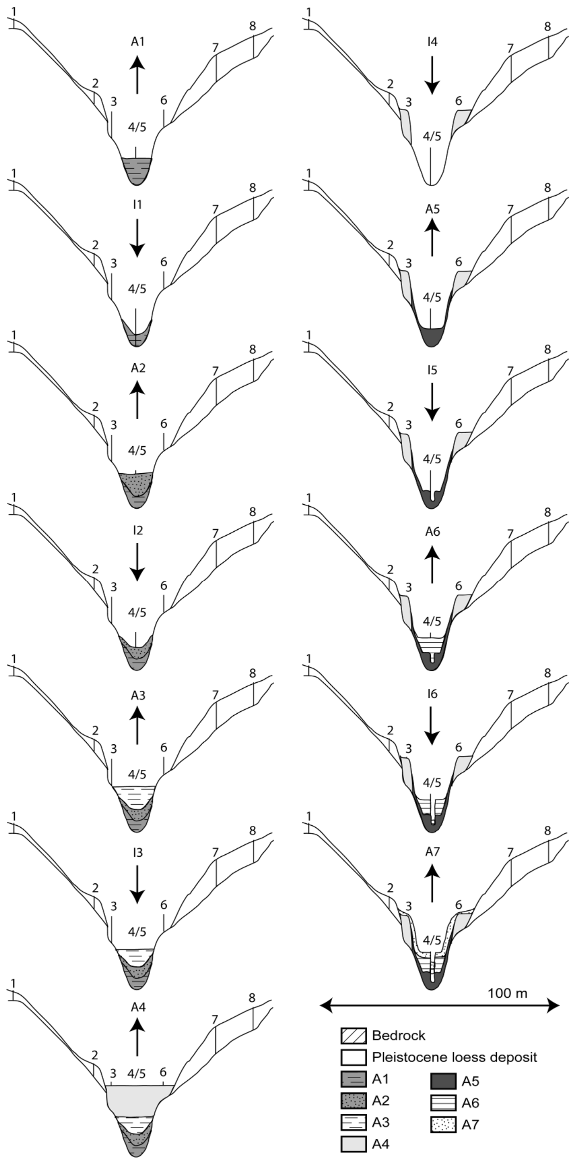

Fig. 2 *Reconstruction of aggradation and infilling phases of Sayeret Shaked.*

In Sayeret Shaked two Late Pleistocene and four Holocene aggradation and incision cycles were recognized. The aggradation and incision cycles appeared stronger in the Late Holocene than before, even though the amplitude of climate fluctuations reduced since the Pleistocene. The strongest incision and aggradation phases in the Late Holocene, coincided in time with the rise and fall of the Byzantine Empire and seemed related to the high human pressure on the landscape during that period. It demonstrated that although the phases of aggradation and incision were initiated by changes in humidity, the climate driven phases were strongly amplified by human influence. The interplay between human activity and climate fluctuations had therefore a much stronger effect on the landscape than climate fluctuations alone.

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OSL-dated Holocene fluvial terrace formation in the northern Upper Rhine Graben: allogenic control vs. autogenic evolution

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Even though the northern Upper Rhine Graben is a subsiding basin, an extensive terrace sequence was formed during the Late Weichselian and Holocene. The well preserved terrace levels differ from each other in elevation, morphology, overbank sediment characteristics and soil formation. In many previous studies in this area, the focus was very much on allogenic forcing in explaining the terrace sequence, whereby the role of autogenic processes and site-specific characteristics in terrace formation (such as preservation potential) remained unaddressed. Our purpose is to determine and re-evaluate the importance of allogenic controlling factors versus autogenic evolution during successive formation of the Late Weichselian and Holocene terraces in the northern Upper Rhine Graben.

For a representative valley segment (map Gernsheim), results from previous research were integrated with newly obtained borehole data and digitized elevation maps to construct palaeogeographic maps and cross-sections. Accumulated results from past research allowed rough age estimation of the deposits, but most terrace levels in the region Gernsheim lacked direct dating. We therefore cored sandy in-channel deposits for Optically Stimulated Luminescence dating at 5 locations, using two coring methods. Above the groundwater table, we used the Van der Horst sampling equipment to hammer 30 cm long plastic tubes into the sandy sediments (Fig. 1). Below the groundwater table, the Van der Staay-suction corer was used to retrieve the sand. For each palaeo-meander to be OSL-dated, we obtained 2-3 samples from locations either just below cored residual channels and/or right next to such a fill in the sandy top of inner bend point bar. Residual channel fills were dated using pollen stratigraphy and radiocarbon dating as verification. All OSL dates fit with the ages obtained from palynological analyses, and seem to be approximately correct, even though dates in sequence are often not in the correct stratigraphic order. The results enabled us to refine the chronology of the terrace sequence.

The palaeogeographic reconstruction shows that climatic warming after the Last Glacial Maximum (~20 ka) triggered the onset of incision and the transition towards a meandering system. There are strong indications that during the Lateglacial the River Rhine was in a transition phase from braided to meandering and did not form a braided Younger Dryas terrace level. At the onset of the Holocene, the system became fully meandering. Locally two meandering streams, inherited from the multi-channel transitional system, were active until the middle Boreal (~9 ka). This indicates that climate change was the most important factor controlling fluvial development during the Late Weichselian, although the complete transition from a fully braided to a meandering system was slow.

Terrace formation continued during the Holocene, forming a patchy mosaic of abandoned palaeo-meanders. From the late Atlantic onwards, there is a trend of decreasing meander curvature, locally resulting in a shallow multi channel system. We suggest that these early to middle Holocene (~6 ka) changes in fluvial style are not necessarily controlled by climatic change. Instead, they may be the result of autogenic evolution of the system combined with river reach-specific characteristics. Because intra-Holocene climate changes are small, autogenic fluvial evolution became dominant. During the Subatlantic (last 2.7 ka), incision of the river system ceased and overbank sediments became coarser, probably as a result of human impact in the hinterland.

Fig. 1 *The Van de Horst sampling equipment used for OSL sampling in channel sands*

Overall, the terrace sequence is explained by a complex interplay of both allogenic and autogenic controlling factors and site-specific characteristics such as preservation potential and tectonic background situation. Because the terrace levels form an event-like sequence, they are easily misinterpreted to be a result of specific events or changes. However, we argue that climate change was important as an initial trigger, but did not necessarily influence individual terrace formation afterwards. Because under non-allogenic forcing conditions incision is still influenced by non-linear autogenic river behaviour, produced terrace levels may sometimes have different morphological characteristics. As a result, the final appearance of the terrace sequence in the northern Upper Rhine Graben, and perhaps elsewhere, is to a large extent the product of intrinsic behaviour and complex response.

The fact that terrace levels differ in characteristics should, therefore, not automatically be seen as indicators of changes in external controls. This interpretation differs from earlier work, which interpret Holocene terraces along the Rhine trunk valley (including the northern Upper Rhine Graben) to be a direct result of repeated changes in climate and human impact later in the Holocene. Consequently, attributing terrace levels over larger distances to a single allogenic factor must be done with care.

Dating burial mounds using optically stimulated luminescence

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Several methods for determining the age of man-made burial mounds exist, most of them based on the findings of organic material (for ^{14}C-dating, dendrochronology or pollen analyses) or artefacts (for chronological reconstruction). These methods depend on full or substantial excavation of the monuments, causing their destruction, which prevents further investigation, resulting in a one-time possibility to study these monuments in their original composition. Moreover, time and money for extensive excavation and subsequent investigation are often not available. Presently, no techniques exist for prospecting these monuments to determine their age and method of construction without excavation and hence leaving them intact for further studies. Their initially assumed purpose of solely functioning as graves for the elite has also been refuted and new hypotheses would benefit from knowledge based on new research.

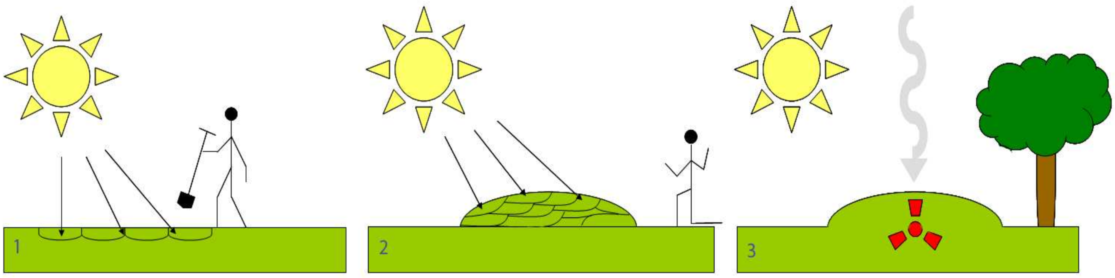

Fig. 1 *Graphical representation of the history of a burial mound. 1: bleaching of the surface. 2: bleaching of the stacked sods. 3: exposure to natural ionising radiation.*

It is assumed that burial mounds of the kind we are investigating were built up from individual upside-down stacked sods of grassland or heath, but this hypothesis needs confirmation through testing on more mounds. When sods are used for construction the surface of these sods is likely bleached prior to their use in a burial mound (fig. 1-1). When stacked downside up on the mound they may have undergone bleaching on their downsides as well (fig. 1-2). The occurrence of light-exposed grains of quartz suggests that optically stimulated luminescence (OSL) dating allows us to determine the time of construction of a burial mound. One of the main advantages of the use of OSL dating is that it could be practically non-destructive to the monuments if samples were taken using a core.

We investigate the feasibility of quartz OSL dating through application to a large Bronze Age burial mound in the vicinity of Oss (Southern

Fig. 2 *Sampling of material from clearly recognisable sods in Oss, Zevenbergen.*

Netherlands), which was constructed from clearly recognisable sods. Macroscopic identification of the sods *in situ* (fig. 2) allows us to investigate whether grains at the surface of the sods are better bleached than those on the inside of the sods. We have tested this by measuring equivalent doses on a large number of samples taken in a vertical profile (fig. 3). We used a simplified sample preparation and measurement procedure to facilitate measurements on a large number of samples. Results confirm the presence of relatively well-bleached layers near the sod surfaces. In addition, the results suggest that the palaeosurface just underneath the mound may provide good opportunities to date the construction time.

Based on these findings we have selected apparently well-bleached sections to take our samples for full OSL dating analysis. These measurements are presently being carried out, and first results will be presented at the NCL symposium.

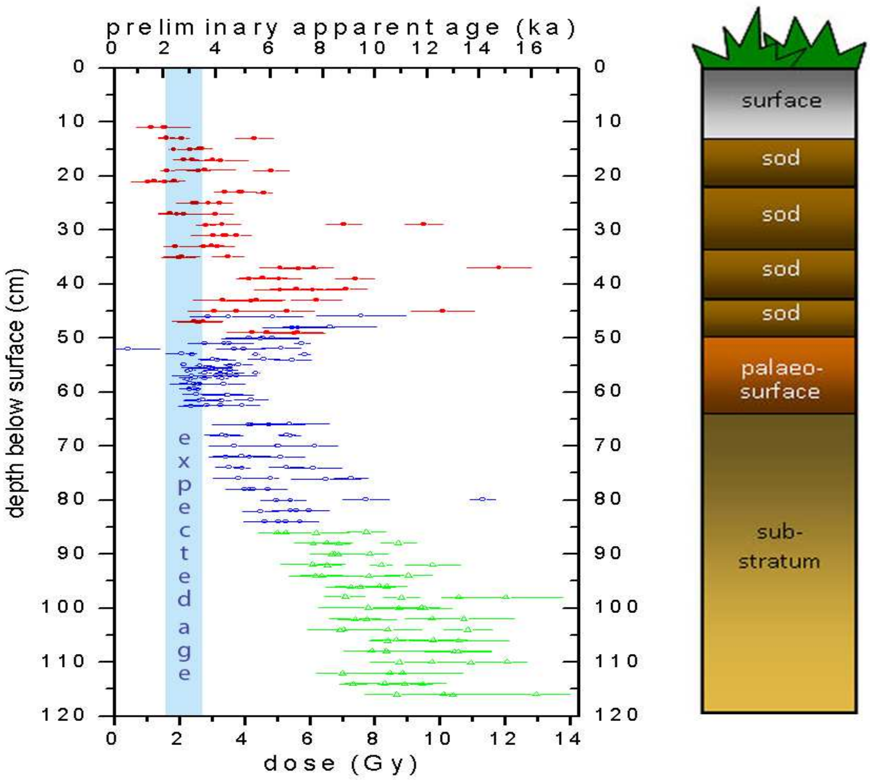

Fig. 3 *Preliminary results of measured palaeodose and calculated age. On the right is a schematic representation of the burial mound corresponding to the depth mentioned on the left.*

Dating fluvial and solifluction deposits in a study of late Quaternary landscape evolution in KwaZulu Natal, South Africa

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Hillslopes in the central and western parts of KwaZulu-Natal province, South Africa, are often mantled by colluvial sediments. These sediments have accreted in response to climatic change over the last 100 ka. Currently, extreme gully erosion incises deeply into these sediments, creating badland topography and causing a loss in area and accessibility of agricultural land. Little attention has been given to the shared landscape context of the colluvial deposition and current extreme erosion.

Over the last few years, we have used a broad-spectrum geomorphological approach, combining fieldwork, micromorphology, stable carbon isotopes, Optical Stimulated Luminescence Dating and landscape evolution modelling to give us a better understanding of the controls on the geomorphic processes in Okhombe Valley (Fig. 1).

Here, we focus on Optical Stimulated Luminescence dating methods and results. Samples for OSL dating were initially taken as 50*40*40 cm blocks from A-horizons of selected layers of colluvium in three sites. These blocks were exposed to light during sampling and transport, making it necessary to remove the outer surfaces. This happened in two stages under subdued-light conditions. The first stage was at a laboratory at the University of KwaZulu Natal in Pietermaritzburg, before transport to the Netherlands. The second stage was at the Netherlands Centre for

Fig. 1 *A typical outcrop of palaeosols and deposits in Okhombe Valley*

Luminescence dating in Delft, where dating was performed. After these stages, blocks measured 20*10*10 cm. Material from these blocks was mixed and grains in a narrow grain size range (125-180 μm for sample NCL-2205121, 90-180 μm for sample NCL-2205125, 180-212 μm for all other samples) were obtained using sieving and chemical treatment (HCl, H_2O_2, HF). The Single-Aliquot Regenerative-dose (SAR) procedure was used.

The oldest deposits (XI-VIII), deposited by solifluction in upstream sites, were dated to a late Pleistocene OIS3 age (42.4 ± 3.7 ka BP - 29.4 ± 2.4 ka BP). Younger deposits (VII-I), resulting from fluvial redistribution, are of Holocene age (10.3 – 0.17 ka BP, OIS 1). No deposition from the LGM (OIS2) was in evidence.

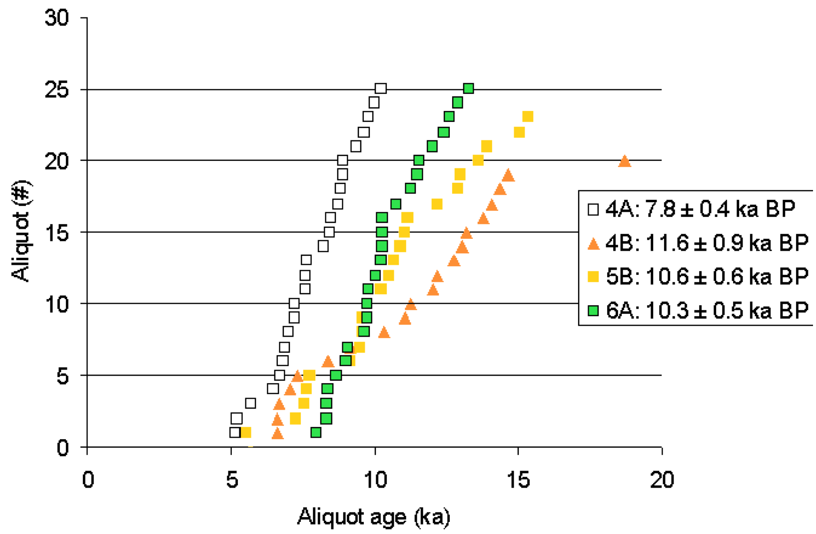

Fig. 2 *Ages of individual aliquots indicate that material of B-horizons is not completely bleached*

In sites 1 and 11, the OSL dates are internally consistent; lower deposits are older. In site 3, the dates are not internally consistent; samples taken in master horizons 4B and, less problematically, 5B are older than the sample from underlying master horizon 6A. These two samples were the only samples taken from B-horizons. A comparison of ages of the individual aliquots from samples taken in horizons 4A – 6A (Fig. 2) shows that larger differences exist between the aliquots of the samples from the B-horizons, especially for horizon 4B (indicated by the lower gradient of the triangles in Fig. 2). This is an indication of incomplete bleaching, leading to an overestimation of the age of burial of this deposit.

To check the consistency of our correlation between sites, two deposits were sampled in two sites. Deposit II was dated to 8.76 ± 0.66 ka in one site (site 3) versus 7.73 ± 0.36 ka in another site (site 11). Deposit IV was dated to 9.67 ± 0.44 ka (site 3) versus 7.86 ± 0.42 ka (site 11). This may indicate that our correlation between the two sites has been unsuccessful and that deposits in site 3 belong lower in the stratigraphic sequence. However, these differences of up to 2 ka could also be attributed to lags in landscape response.

These luminescence results have provided valuable age-control that allowed us to couple landscape processes to climatic conditions. From there, we formulated a hypothesis of landscape evolution that we tested with landscape evolution models.

Optical dating of storm surge deposits from Heemskerk, North Holland

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Coastal defence in The Netherlands is designed to withstand the impact of a 1 in 10,000 year storm-surge, but accurately assessing the magnitude of such an event is difficult given the short (116 years) tide-gauge record on which the magnitude – frequency distribution is based. It may be possible to supplement the tide-gauge record using sedimentary evidence of former storm surges.

Here we test the feasibility of OSL dating for determining the timing of storm surges. We obtained samples from storm surge deposits and aeolian dune sands at a fresh exposure near Heemskerk, North Holland. This site became available in November 2007, when high waters during a minor storm eroded the outer ~30 m of the fore-dunes. In the exposure, an elevated shell layer containing pebble-sized fragments of brick and coal was observed. Several sedimentological features indicate this layer to be deposited underwater. The shell layer is up to 20cm thick, and undulates over a 1 km stretch with highest occurrences over 6.5m above sea level. Samples were taken from several exposed sections of dune. The first 12 OSL results from one section are presented here.

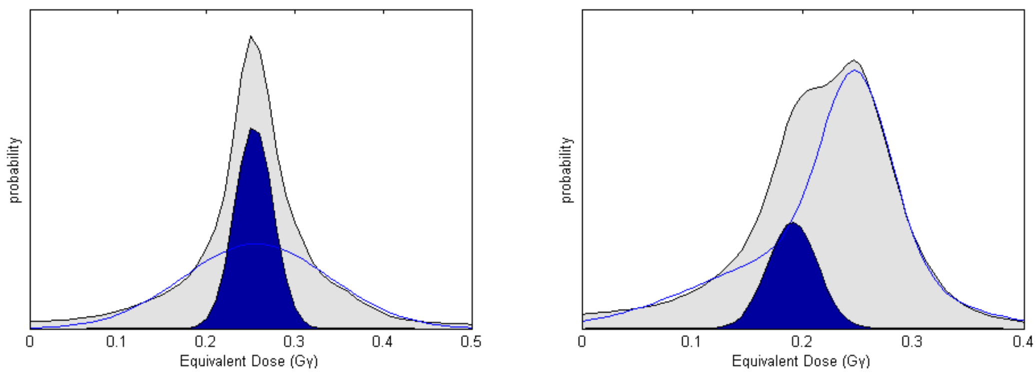

Fig. 1 *Probability density function (PDF) for an aeolian (left) and and storm-surge (right) sample. The PDFs were created by summing the equivalent dose and error term for each of 24 sub-samples. The average burial dose is then obtained by fitting two Gaussian curves to this dataset; the blue curve indicates the part of the population with completely reset OSL signals and no otherwise rogue behaviour. The age is then defined as burial dose / dose rate.*

Aeolian sand is well suited to OSL dating because the OSL signal of all grains may be expected to be reset by light exposure prior to deposition and burial. To further increase the accuracy and precision of the results we modified the analysis by using only the 'fast' component of the OSL signal. The 'fast' OSL component in quartz is ideal for dating because it is rapidly bleached in nature and stable on geological timescales. Isolating this component is desirable, but is made difficult by the weak signal-noise ratio encountered with young samples. We apply a curve-fitting approach to solve this problem, after identifying key trap parameters with artificially generated signals. Using Monte Carlo simulations of the decay curves, the uncertainty on each measurement can be estimated, and summed to produce characteristically-shaped probability density functions (Fig. 1). The age of each sample can then be estimated by Gaussian fitting of these functions.

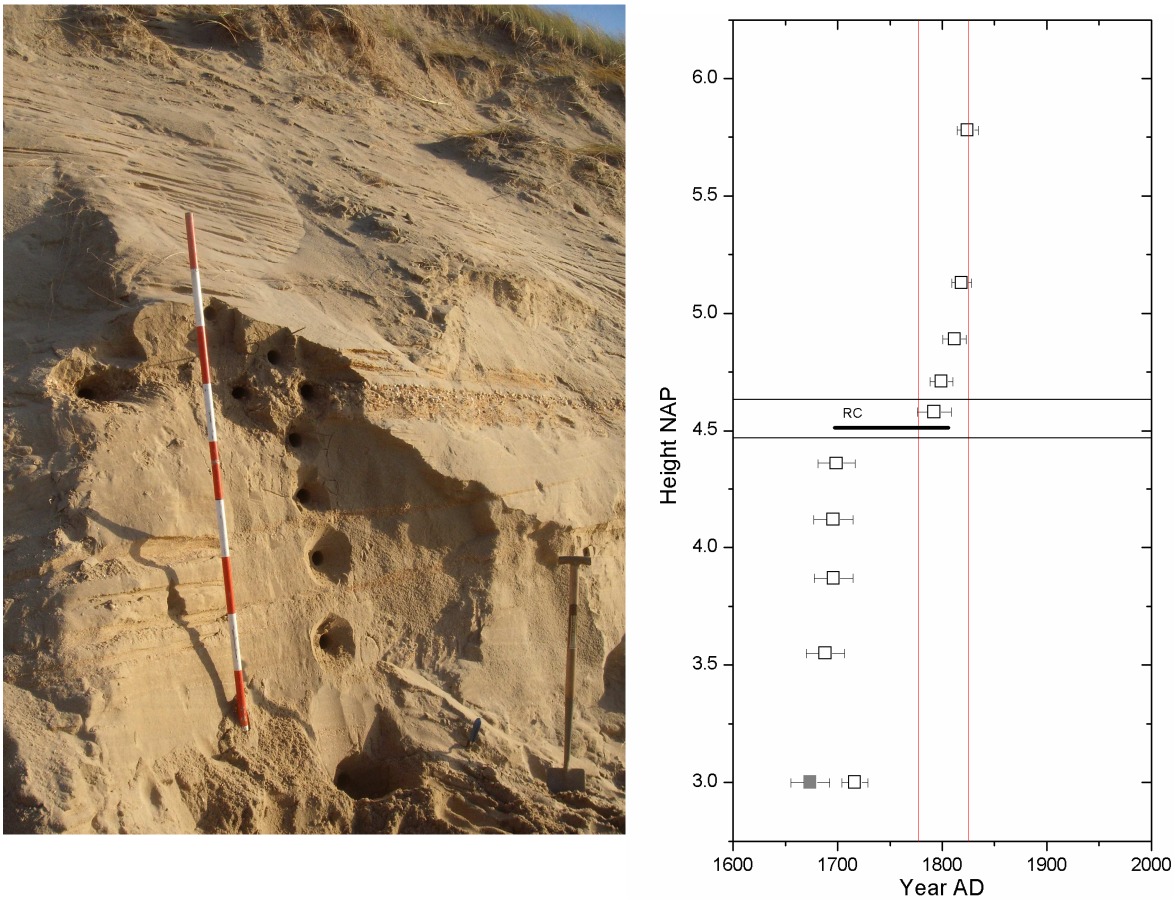

Fig. 2 *The Heemskerk section, showing sampling locations and corresponding OSL age estimates. The apparent age inversion of the deepest sample may be due to the influence of groundwater, which attenuates the dose rate. If the average water content of this sample is taken as saturation level, then the calculated age (shown in grey) is stratigraphically compatible with the other samples. The result of a single radiocarbon date on a closed bivalve shell is also shown. Vertical red lines indicate the timing of known historical storm surges that affected the area.*

The OSL ages (Fig. 2) show good internal consistency, and clearly identify the shell-layer truncation of the underlying sediment. Using the analysis method described, the storm surge can be dated to 1795 AD (± 12). This places it between 2 major storm surges in the historical record, which took place in 1776/7 and 1825. A radiocarbon date obtained from a juvenile shell is also in broad agreement (1σ age range: 1697-1805 AD). The precision of this estimate is affected by plateaus in the calibration curve for this period.

The results from this section show the potential of OSL for precise and accurate dating of storm surge deposits. With further work on the Heemskerk site, we hope to specify which historical storm surge is responsible for the shell-layer. Following this, the methods developed will be employed in dating other storm surge and fluvial flood deposits.

Netherlands Centre for Luminescence dating

HIGHLIGHTS 2007

The Netherlands Centre for Luminescence dating (NCL)

In recent years a cutting-edge luminescence dating laboratory was established at the Reactor Institute Delft (TUDelft). The NCL aims to develop new and improved methods of luminescence dating and to make luminescence dating widely available to Netherlands' research. The NCL now processes more than 100 samples for optically stimulated luminescence (OSL) dating per year.

Archaeology joins NCL

In 2007 the Centre for Arts and Archaeological Science (CAAS; TUDelft / Leiden collaboration) and the Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten (RACM) joint the NCL. Thereby the NCL collaboration now includes archaeologist, earth scientists and physicists. Archaeologist want to use OSL dating for landscape reconstruction, and for dating artefacts and man-made structures (e.g. burial mounds).

Dating storm-surge deposits

One of the most interesting novel applications of optical dating is the dating of a storm-surge layer that was uncovered by a storm in November 2007. The research at a dune site near Heemskerk received abundant attention in the media (Volkskrant; VARA nieuwslicht); preliminary results of NCL PhD Alastair Cunningham indicate that the storm surge occurred around 1800 AD.

Methodological developments

Research at the NCL concentrates on 1) developing suitable methods to date fluvial and coastal deposits formed during the past centuries to decades; 2) developing reliable methods for dating sediments beyond the last glacial-interglacial cycle. Important advances were made in both fields (see references below).

Information

See www.ncl-lumdat.nl or contact Jakob Wallinga (j.wallinga@tudelft.nl, ☎ 015-2781056).

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