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Optical dating of sediments

Analysis Report

GLL-015/07

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Submitter

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Samples

The samples for the OSL study were collected from a sequence of coversands and drift sands at the archaeological site Aalsterhut-A2 (The Netherlands). A total of 14 samples were collected during two subsequent field excursions; 11 cover- and drift-sand samples were collected by the submitter on 11/02/2009, while the GLL collected 3 additional drift-sand samples on 09/04/2009. The samples were taken by hammering stainless steel cylinders into freshly cleaned exposures. The sediment surrounding each sampling tube was collected for dose rate determination. From each unit, an additional undisturbed sediment sample was taken for assessing the effect of moisture; it was double wrapped and tightly sealed to retain moisture.

Additional information about the samples is summarised in Table 1.

Sample field code	*GLL Code*	*Date of sample collection*	*N/S latitude*	*E/W longitude*	*Altitude (a.m.s.l.)*	*Depth from surface*	*Estimated age*
OSL 1	GLL-090714	11/02/2009	51.3944°N	5.50876°E	23.82	158	Early Dryas
OSL 2	GLL-090715	11/02/2009	51.3944°N	5.50876°E	23.82	127	Allerød
OSL 3	GLL-090716	11/02/2009	51.3944°N	5.50876°E	23.82	112	Late Dryas
OSL 4	GLL-090717	11/02/2009	51.3944°N	5.50876°E	23.82	102	Late Dryas
OSL 5	GLL-090718	11/02/2009	51.3944°N	5.50876°E	23.82	78	Late Dryas
OSL 6	GLL-090719	11/02/2009	51.3944°N	5.50876°E	23.82	66	Holocene
OSL 7	GLL-090720	11/02/2009	51.3944°N	5.50876°E	23.82	152	Late Dryas
OSL 8	GLL-090721	11/02/2009	51.3944°N	5.50876°E	23.82	135	Late Dryas
OSL 9	GLL-090722	11/02/2009	51.3944°N	5.50876°E	23.82	98	Late Dryas
OSL 10	GLL-090723	11/02/2009	51.23368°N	5.30311°N	23.4	78	Early Dryas
OSL 11	GLL-090724	11/02/2009	51.23368°N	5.30311°N	23.4	56	Late Glacial
C20	GLL-090725	09/04/2009	51.3944°N	5.50876°E	24.36	28	Holocene
A37	GLL-090726	09/04/2009	51.3944°N	5.50876°E	24.36	55	Holocene
A6	GLL-090727	09/04/2009	51.3944°N	5.50876°E	24.36	85	Holocene

Table 1: Sample information.

Sample preparation, analytical facilities and methods

a. Equivalent dose

Coarse (180-212 µm) quartz grains were extracted from the inner material of the sampling tubes using conventional sample preparation procedures (HCl, H_2O_2, sieving, and HF). The purity of the samples was confirmed by the absence of a significant infrared stimulated luminescence (IRSL) response at 60°C to a large (~50 Gy) regenerative β-dose. The sensitivity to infrared stimulation was defined as significant if the resulting IRSL signal amounted to more than 10% of the corresponding OSL signal (Vandenberghe, 2004) or if the OSL IR depletion ratio (Duller, 2003) deviated by more than 10% from unity.

The analyses were carried out on grains fixed on the inner 8 mm of 9.7 mm stainless steel discs. All OSL measurements were performed using an automated Risø TL/OSL-DA-12 reader, equipped with blue (470 ± 30 nm) LEDs and an IR laser diode (830 nm). The quartz luminescence emissions were detected through 7.5 mm of Hoya U-340 UV filter. Irradiations were carried out with a $^{90}Sr/^{90}Y$ β-source mounted on the reader. Details on the measurement apparatus can be found in Bøtter-Jensen *et al.* (2003) and references therein.

The equivalent dose (D_e) was determined using the single-aliquot regenerative-dose (SAR) protocol as described by Murray and Wintle (2000; 2003). A preheat of 10 s at 240°C and a test-dose cutheat to 200°C was used for the coversand samples. To avoid dose overestimation as a result of thermal transfer, a preheat of 10 s at 180°C and a cutheat to 160°C was chosen for the drift-sand samples (Derese et al., 2010). Optical stimulation with the diodes was for 40 s at 125°C. The initial 0.32 s of the decay curve, minus a background evaluated from the 1.44 – 2.08 s interval, was used in the calculations. Dose recovery tests (Murray and Wintle, 2003) confirmed the suitability of the SAR laboratory measurement procedure.

b. Dose rate

Low-level high-resolution gamma-ray spectrometry was used for the determination of the natural dose rate (see Hossain, 2003 and Vandenberghe, 2004, for details). For this, the sediment collected around the OSL sample tubes was dried (at 110°C until constant weight), pulverised and homogenised. A subsample of ~140 g was then cast in wax (see e.g. De Corte et al., 2006) and stored for one month before being measured on top of the detector.

The annual dose was calculated from the present-day radionuclide activities using the conversion factors of Adamiec and Aitken (1998). The external beta dose-rate was corrected for the effect of attenuation and etching using the data tabulated by Mejdahl (1979). An internal dose rate of 0.010 Gy ka^{-1} was assumed (Vandenberghe et al., 2008). Both the beta and gamma contributions were corrected for the effect of moisture following the procedure outlined by Aitken (1985). The saturation water content was measured in the laboratory using the undisturbed sediment samples that were collected for this purpose. Values in the range of 21-22% were obtained. The time-averaged water content was estimated to increase gradually from 50% (for the drift sand samples) to 80% (for the lowermost sample GLL-090714) of the water content at saturation (Kasse, priv. comm.); an uncertainty of 25% was associated with these values. The contribution of cosmic radiation was calculated following Prescott and Hutton (1994).

Results

Table 2 summarises all analytical results, and shows the calculated optical ages. Uncertainties on the luminescence ages were calculated following the error assessment system proposed by Aitken and Alldred (1972) and Aitken (1976). All sources of systematic uncertainty were as quantified by Vandenberghe et al. (2004; see also Vandenberghe, 2004).

GLL-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)
090714	220 ± 2	9.9 ± 0.8	12.5 ± 0.5	10.9 ± 0.9	11.1 ± 0.2	18 ± 4	1.09 ± 0.01	13.2 ± 0.2	12.1 ± 1.0
090715	178 ± 3	10.1 ± 0.9	10.3 ± 0.5	8.7 ± 0.6	8.7 ± 0.2	16 ± 4	0.94 ± 0.01	13.6 ± 0.2	14.4 ± 1.2
090716	161 ± 2	6.1 ± 0.8	8.2 ± 0.3	8.5 ± 0.8	6.8 ± 0.2	16 ± 4	0.86 ± 0.01	10.5 ± 0.2	12.3 ± 1.0
090717	174 ± 2	8.1 ± 1.0	9.2 ± 0.2	10.2 ± 0.8	8.0 ± 0.2	16 ± 4	0.94 ± 0.01	11.3 ± 0.2	12.0 ± 1.0
090718	131 ± 2	5.4 ± 1.1	6.0 ± 0.2	5.7 ± 0.6	5.1 ± 0.1	13 ± 3	0.74 ± 0.01	8.5 ± 0.2	11.5 ± 0.9
090719	123 ± 2	5.8 ± 0.8	7.3 ± 0.2	8.2 ± 0.9	5.2 ± 0.2	11 ± 3	0.77 ± 0.01	0.33 ± 0.01	0.42 ± 0.04
090720	131 ± 2	3.9 ± 0.6	5.6 ± 0.2	6.5 ± 0.5	4.8 ± 0.1	15 ± 4	0.71 ± 0.01	8.6 ± 0.2	12.1 ± 1.0
090721	139 ± 2	5.0 ± 0.8	6.3 ± 0.2	6.8 ± 0.7	5.4 ± 0.1	15 ± 4	0.75 ± 0.01	9.5 ± 0.1	12.6 ± 1.0
090722	150 ± 2	6.6 ± 0.8	7.7 ± 0.3	6.0 ± 0.8	6.3 ± 0.1	13 ± 3	0.81 ± 0.01	9.4 ± 0.2	11.6 ± 0.9
090723	282 ± 3	18.6 ± 1.7	19.5 ± 0.4	15.6 ± 1.2	18.4 ± 0.2	16 ± 4	1.50 ± 0.02	19.9 ± 0.3	13.3 ± 1.1
090724	171 ± 2	9.1 ± 0.8	9.9 ± 0.2	9.9 ± 0.7	8.2 ± 0.2	13 ± 3	0.98 ± 0.01	14.3 ± 0.3	14.6 ± 1.2
090725	120 ± 2	5.7 ± 1.2	4.8 ± 0.3	4.6 ± 0.6	4.1 ± 0.1	11 ± 3	0.72 ± 0.01	0.21 ± 0.01	0.29 ± 0.02
090726	123 ± 2	3.9 ± 0.5	5.8 ± 0.3	6.5 ± 0.5	4.6 ± 0.1	11 ± 3	0.73 ± 0.01	0.26 ± 0.01	0.36 ± 0.03
090727	132 ± 2	7.6 ± 0.9	8.3 ± 0.3	7.6 ± 1.0	6.0 ± 0.1	11 ± 3	0.79 ± 0.01	0.41 ± 0.04	0.51 ± 0.06

Table 2: Radionuclide concentrations used for dose rate evaluation, estimates of past water content (w.c.), calculated dose rates, D_e's, and calculated ages. The dose rate includes the contributions from internal radioactivity and cosmic rays. The uncertainties mentioned with the dosimetry and D_e data are random; the uncertainties on the ages are the overall uncertainties, which include the systematic errors. All uncertainties represent 1s.

Discussion and Comments

The applied sample preparation method resulted in the extraction of pure quartz grains. The quartz extracts showed satisfactory luminescence characteristics in terms of brightness (clearly distinguishable from background), OSL decay (dominated by the fast component), recycling ratios (consistent with unity), recuperation (generally less than 1% of the sensitivity corrected natural OSL signal), and dose recovery (overall average recovered to given dose ratios ± 1 standard error are 1.015 ± 0.001 (n=30) and 1.01 ± 0.02 (n=12) for the coversand and drift sand samples, respectively). These characteristics suggest that the samples are well-suited for optical dating.

Given the depositional context (aeolian), it is expected that the samples have been exposed to sufficient sunlight for the OSL signal to be completely zeroed prior to deposition.

In general, an increase in water content of 1% corresponds to an increase in the optical age of about 1%.

OSL dating is an absolute dating method, yielding ages expressed as calendar years before the date of the measurement.

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Specific terms and conditions: citing the dating results

In the case of a scientific collaboration, the scientist(s) who realised the optical dating shall co-author all formal and informal publications that reproduce the dating results.

In all other cases, the sample submitter is entitled to use and to reproduce the data quoted in Table 2 (and its caption) of this report in all his (her) formal and informal publications. When doing so, the submitter should adopt the GLL laboratory codes and give full acknowledgements to the Ghent Luminescence Laboratory.

The further content of this report provides the submitter with the relevant information that is required to understand how the age results were obtained. This information is intended for private use only and cannot be included by the submitter in any publication, neither partially nor completely, without the written permission of the Ghent Luminescence Laboratory.

The GLL provides a fundamental scientific service, for which the appropriate remuneration is joint authorship.

References

Adamiec, G., Aitken, M.J., 1998. Dose-rate conversion factors: update. Ancient TL 16, 37-50.

Aitken, M.J., 1976. Thermoluminescent age evaluation and assessment of error limits: revised system. Archaeometry 18, 233-238.

Aitken, M.J., 1985. Thermoluminescence Dating. Academic Press Inc., London. 359 p.

Aitken, M.J., Alldred, J.C., 1972. The assessment of error limits in thermoluminescent dating. Archaeometry 14, 257-267.

Bøtter-Jensen, L., Andersen, L.E., Duller, G.A.T., Murray, A.S., 2003. Developments in radiation, stimulation and observation facilities in luminescence measurements. Radiation Measurements 37, 535-541.

De Corte, F., Vandenberghe, D., De Wispelaere, A., Buylaert, J.-P., Van den haute, P., 2006. Radon loss from encapsulated sediments in Ge gamma-ray spectrometry for the annual radiation dose determination in luminescence dating. Czech Journal of Physics 56, D183-D194.

Derese, C., Vandenberghe, D., Eggermont, N., Bastiaens, J., Annaert, R., Van den haute, P., 2010. A medieval settlement caught in the sand: Optical dating of sand-drifting at Pulle (N-Belgium). Quaternary Geochronology 5, 336-341.

Hossain, S.M., 2003. A critical comparison and evaluation of methods for the annual radiation dose determination in the luminescence dating of sediments. PhD-thesis Universiteit Gent.

Mejdahl, V., 1979. Thermoluminescence dating: beta-dose attenuation in quartz grains. Archaeometry 21, 61-72.

Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. Radiation Measurements 32, 57-73.

Murray, A.S., Wintle, A.G., 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability. Radiation Measurements 37, 377-381.

Prescott, J.R., Hutton, J.T., 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. Radiation Measurements 23, 497-500.

Vandenberghe, D., 2004. Investigation of the optically stimulated luminescence dating method for application to young geological sediments. Ph.D. thesis, Universiteit Gent, 358 pp.

Vandenberghe, D., De Corte, F., Buylaert, J.-P., Kučera, J., Van den haute, P., 2008. On the internal radioactivity in quartz. Radiation Measurements 43, 771-775.

Vandenberghe, D., Kasse, C., Hossain, S.M., De Corte, F., Van den haute, P., Fuchs, M., Murray, A.S., 2004. Exploring the method of optical dating and comparison of optical and ^{14}C ages of Late Weichselian coversands in the southern Netherlands. Journal of Quaternary Science 19, 73-86.