

Supplementary Information for:

Using geophysical subsurface data for the reconstruction of valley-scale spatio-temporal floodplain evolution: Implications for upland river restoration.

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Optically Stimulated Luminescence Dating – methodology, instrumentation and results.

Sampling for optically stimulated luminescence (OSL) dating was undertaken using 3 cm diameter by 20 cm long stainless-steel tubes, driven into the sediment horizontally and capped at one end to prevent accidental light exposure. Around 300 g of additional material was gathered in zip-lock bags during the excavation of each tube for environmental dose rate determination. In total six OSL samples were collected; two from Pit 1, three from Pit 2 and one from the NW facing stream bank (Pit 4).

All sample tubes were opened and the contents processed under subdued orange light conditions (Sohbati et al., 2017) at the Nordic Laboratory for Luminescence Dating, Risø, Denmark. The potentially light-exposed outermost 5 cm was retained and used to determine the saturated water content, and the unexposed inner portion was wet sieved to recover the 180-250 µm grain size fraction for optically stimulated luminescence (OSL) measurement. This was then processed in the manner outlined by Murray et al., (2021) to remove carbonate, organics and surface mineral coatings on the grains. Next the dried samples were density separated using a 2.58 g/cm³ solution of LST FastFloat™ to produce a quartz rich fraction and isolate the K-rich feldspar. For environmental dose rate determination the sub-samples were dried, heated to 450°C, crushed, then mixed with wax for casting into a fixed cup-shaped geometry, and stored for a minimum of 20 days before measurement using high resolution gamma spectrometry (Murray et al., 1987, 2018). The resulting radionuclide activity concentrations for ⁴⁰K and the Uranium and Thorium series were then converted into dry infinite matrix gamma and beta dose rates using the conversion factors of Guérin et al. (2011). These are summarized along with the radionuclide concentrations in Table S1. The assumed lifetime water contents for each sample are based upon Aitken (1985), and derivation of the cosmic ray dose

rate contribution follows the approach of Prescott and Hutton (1994). Total dose rates to quartz are presented in Table 1.

Table S1. Radionuclide concentrations and dry infinite matrix dose rates for the Swindale sediments.

Lab. Code	Radionuclide activities (Bq/kg ⁻¹)			⁴⁰ K	Dose Rate (Gy/ka ⁻¹)	
	²³⁸ U	²²⁶ Ra	²³² Th		β	γ
231401	28.52 ± 3.81	26.63 ± 0.63	35.32 ± 0.60	685.96 ± 12.59	2.35 ± 0.04	1.15 ± 0.03
231402	32.92 ± 11.58	24.06 ± 1.00	34.16 ± 1.03	726.86 ± 23.81	2.43 ± 0.07	1.15 ± 0.03
231403	28.35 ± 12.29	25.06 ± 1.06	34.52 ± 1.09	726.64 ± 24.63	2.44 ± 0.07	1.16 ± 0.03
231404	40.33 ± 14.42	27.34 ± 1.23	37.03 ± 1.25	762.27 ± 28.55	2.58 ± 0.08	1.23 ± 0.04
231405	34.79 ± 11.54	25.65 ± 1.01	36.62 ± 1.05	806.44 ± 24.77	2.68 ± 0.07	1.25 ± 0.03
231406	54.12 ± 12.46	26.70 ± 1.10	34.61 ± 1.12	823.43 ± 27.00	2.72 ± 0.08	1.25 ± 0.03

Luminescence signals were measured using multigrain aliquots (8 mm for quartz, 2 mm K-rich feldspar), mounted as a monolayer on stainless steel discs and cups. Aliquots were measured in a Risø OSL reader (model 15 or 20; Bøtter-Jensen et al., 2010) equipped with a calibrated ⁹⁰Sr/⁹⁰Y source (Hansen et al., 2015, Autzen et al., 2022), delivering a quartz dose rate of ~0.06 Gy/s. All quartz signals were measured using a blue (470 nm) light stimulation, with the sample held at 125°C for 40 s, and luminescence detected through a U-340 UV-pass filter. The OSL decay curve inset into the typical dose response curve shown in Figure S1 confirms that our quartz OSL signals are dominated by the fast component (Singarayer and Bailey, 2004).

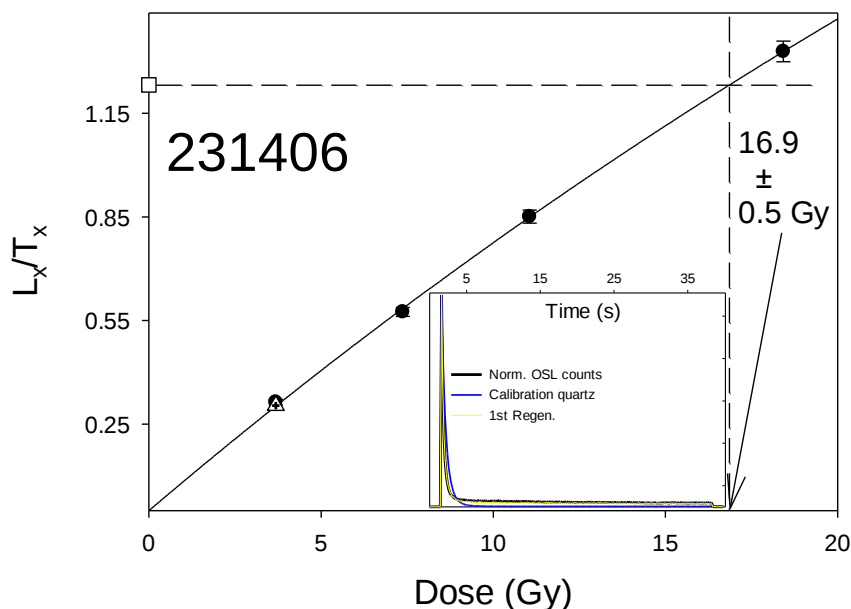


Figure S1. Typical quartz dose response curve for sample 231406 ($D_0 \sim 48$ Gy), inset with a natural OSL decay curve compared to that of the signal from the 1st regenerative dose. A decay curve from calibration quartz is also inset to illustrate the fast component dominated nature of the signal from this sample.

In order to properly quantify any residual feldspar contributions to the UV signal, an IR depletion ratio test was applied (Duller, 2003); the test confirmed that all our samples are free from feldspar contamination. Quartz equivalent doses (D_e) were measured using a standard SAR protocol with a preheat of 260°C for 10 s, a cutheat of 220°C, and a blue light bleach at 280°C for 40 s (Murray and Wintle 2000; 2003), as illustrated by Table S2.

Table S2. Quartz SAR protocol used for the Swindale samples.

Step	Observation/treatment
1	Natural → Regenerative dose
2	Preheat for 10s at 260° C
3	Stimulation with blue light at 125° C for 40s- L_x
4	Test dose (~100% of natural)
5	Cutheat at 220° C
6	Stimulation with blue light at 125° C for 40s- T_x
7	Elevated temperature blue light stimulation of 280° C for 40s
8	Return to step 1

Dose recovery measurements (Murray, 1996) were performed on quartz from each sample; these involved bleaching the aliquots twice at room temperature for 100 s in the reader with blue LEDs and a 10 Ks pause in between. A known dose of 10 Gy was administered in the reader to the bleached aliquots prior to measurement using the SAR protocol in Table S2. This resulted in an average measured to given dose ratio close to unity (0.9488 ± 0.0222 ; $n=20$), thus confirming that our SAR measurement protocol is sufficiently accurate to measure a known laboratory dose administered prior to any thermal treatment. The reproducibility of the data used to build our dose response curves, and accuracy of our sensitivity correction is further demonstrated by an average recycling ratio of 1.0402 ± 0.0253 ($n=40$) across all aliquots, and an average recuperation value of $0.522 \pm 1.709\%$ ($n=40$) of the natural signal. D_e values and final ages for our quartz samples are summarized in Table 1.

K-rich feldspar D_e was measured using a post-IR IRSL SAR protocol (Thiel et al., 2011), with a blue filter combination used to detect the IRSL (Thomsen et al., 2008). Please refer to Table S3 for details of the measurement protocol. The resulting feldspar equivalent dose estimates were obtained for the purposes of assessing the degree of signal resetting in the quartz, and because of this only two to three aliquots of feldspar were measured from each sample. There are also no fading corrections or dose recovery measurements. D_e values and uncorrected ages for K feldspar are summarized in Table S4.

Table S3. Post-IR IRSL₁₈₀ SAR protocol used for the Swindale K-rich feldspar

Step	Observation/treatment
1	Natural → Regenerative dose
2	Preheat for 60s at 200° C
3	IRSL for 200s at 50° C (with 15s pause before stimulation)
4	IRSL for 200s at 180° C (with 15s pause before stimulation)- L _x
5	Test dose (50% of natural)
6	Preheat for 60s at 200° C
7	IRSL for 200s at 50° C (with 15s pause before stimulation)
8	IRSL for 200s at 180° C (with 15s pause before stimulation)- T _x
9	IRSL for 200s at 250° C
10	Return to step 1

Table S4. Equivalent doses, luminescence ages (uncorrected) and total dose rates to K-rich feldspar for the Swindale samples.

Lab. code	Sample code	K feldspar						Total dose rate	Uncorrected age	
		IR ₅₀		PostIR IRSL ₁₈₀			K feldspar	Gy/ka	IR ₅₀	PostIR IRSL ₁₈₀
		D _e (Gy)	(n _r)	(n _a)	D _e (Gy)	(n _r)	(n _a)		(ka)	(ka)
231401	OSL 1.1	49 ± 18	0	3	56 ± 11	0	2	3.67 ± 0.13	13.2 ± 4.8	15.2 ± 3.1
231402	OSL 1.2	48 ± 4	0	2	40 ± 23	0	2	3.93 ± 0.15	12.3 ± 1.2	10.2 ± 5.9
231403	OSL 2.1	4.1 ± 2.9	0	2	40 ± 0.1	0	2	3.72 ± 0.14	1.10 ± 0.77	10.8 ± 0.5
231404	OSL 2.2	22 ± 21	0	2	52 ± -	0	1	4.07 ± 0.16	5.33 ± 5.13	12.8 ± -
231405	OSL 2.3	n.a.	-	-	n.a.	-	-	n.a.	n.a.	n.a.
231406	OSL 4.1	23 ± 2		3	38 ± 12	0	2	4.08 ± 0.15	5.65 ± 0.61	9.3 ± 3.0

*(n_a) number of aliquots accepted; (n_r) number of aliquots rejected.

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