**Supplementary Material**

**General principles of luminescence dating**

Luminescence dating is a dosimetric method that builds on the time-dependent accumulation of dose information in natural minerals (e.g., quartz or feldspar) in the form of trapped charge carriers as a result of exposure to ionizing radiation. The stored dose information can be released and therefore reset by external stimulation with heat or light. In the course of such stimulation, the mineral emits light (luminescence), that can be registered by sensitive photon detection devices. Owing to the natural variety of minerals, no universal relationship between dose and luminescence signal exists; instead a so-called dose-response curve has to be established for each sample. This allows comparing the natural luminescence signal with those signals induced by known doses of laboratory irradiation to infer the equivalent dose (*D*e), i.e., the laboratory dose that creates a signal of identical intensity as the natural signal. Under the assumption of constant dose supply over time (dose rate *Ḋ*) due to the environmental radiation, the luminescence age of a sample is given by the following equation (Aitken 1985; Aitken 1997; Aitken 1998) or the reviews by (Preusser et al. ,2008; Rhodes, 2011; Schmidt and Hambach, 2015):

Age [ka] = *D*e [Gy]/*Ḋ* [Gy ka-1]

Such an age represents the time elapsed since the last exposure of the mineral to light or temperatures >300–350 °C (= dated event). Sediment mobility can thus be directly dated using this method.

While the optically stimulated luminescence (OSL) signal of quartz requires shorter light exposure times for complete signal resetting compared to the infrared stimulated luminescence (IRSL) signal of K-feldspar (in the order of 101–102 s for quartz vs. >102–103 s for feldspar; Godfrey-Smith et al., 1988; Murray et al., 2012), the latter saturates at higher doses, allowing to extend the dating range by a factor of ~2–3 (see for example Wintle and Murray, 2006; Li et al., 2014) .

**Sample preparation**

After wet sieving to target grain sizes <63 µm, samples were treated with 10% HCl and 10% H2O2 to dissolve carbonates and oxidize organic matter, respectively. Settling the grains in a water column for specified periods (following Stokes' Law) allows separating the grain size range ~4–11 µm ('fine grains'). Readily prepared sample material was pipetted with water onto 9.6 mm diameter aluminum discs (~1.2 mg in 200 µl water per aliquot). Following the experience by Faust et al. 2015 for a comparable setting, no attempts were undertaken to extract coarser material ('coarse grains') and/or quartz for luminescence dating.

**Dose rate determination**

Surrounding material for dose rate assessment was milled to grain sizes <63 µm, sealed and stored in plastic containers for at least four weeks prior to thick-source α-counting analysis (Aitken, 1985; Zöller and Pernicka, 1989). Resulting count rates measured for the U and Th decay chains were translated to dose rates by means of published conversion factors (Aitken, 1985; Guerin et al., 2011). The K concentration was measured by ICP-OES at the BayCEER (University of Bayreuth). The cosmic dose rate as well as the total environmental dose rate and age were calculated with DRAC (v1.2; (Durcan et al., 2015) using α-attenuation factors by (Brennan et al., 1991) and β grain size attenuation factors by (Guerin et al., 2011). An α-efficiency (*a*-value) of 0.08 ± 0.01 was assumed based on (Schmidt et al., 2018). An interstitial water content of 10 ± 5 wt.% was estimated to be representative for the burial period (Faust et al., 2015). All dose rates were calculated based on the infinite matrix assumption (Guerin et al., 2011).

**IRSL measurement equipment**

IRSL was measured with a Risø DA15 TL/OSL reader (featuring a DA20 control unit; Bøtter-Jensen et al., 2003) by stimulation with IR LEDs (875 ± 80 nm; max. 135 mW cm-2) and signal detection using a Chroma D410/x interference filter (410 ± 20 nm) in front of an EMI 9235QB15 photomultiplier tube. The built-in 90Sr/90Y β-source delivers a dose rate of ~0.122 Gy s-1 to fine grain samples.

**Dose recovery and fading tests**

A dose recovery test (DRT) was carried out for sample BT1709. To this aim, several aliquots of this sample were bleached for >3 h using an Osram Duluxstar lamp and then irradiated with a dose similar to the expected *D*e (~40 Gy). A fading test was performed for the same sample to assess the impact of potential anomalous fading on the *D*e results. This test consisted of repeatedly irradiating the sample with a dose similar to the *D*e and stepwise increasing the delay times between irradiation and measurement, while always keeping the 20 min delay as inherent feature of the protocol. The sensitivity-corrected IRSL intensities (*L*x/*T*x) were then plotted versus the additional delay time prior to measurement to obtain the fading rate in terms of the *g*-value (Aitken, 1985) by utilizing the function analyse\_FadingMeasurement (Kreutzer and Burow, 2019) contained in the **R** package 'Luminescence' (Kreutzer et al., 2019, 2012).