Field Collection Technique

To insure that a sufficient quantity of silt-sized material was retrieved from the sample interval, we collected four samples in 6 by 22 cm stainless steel cylinders. To minimize contamination and sediment mixing within the tubes, the silt bed was first cleaned with a brush and covered with a sheet of paper prior to hammering in the sampling tubes. After the all of the tubes were completely inserted into the deposit, they were carefully excavated, capped and packaged for shipping. Special care was taken at every step to minimize exposure of the samples to light. Three tubes were designated for natural background radiation measurements. A fourth tube was labeled for luminescence analysis.

Preparation and Instrumentation

Optically Stimulated Luminescence (OSL) dating was performed at the Kansas State University luminescence laboratories on fine-grained quartz (125–175 µm). Dating procedures were carried out under low-intensity red safe-lighting. About 5 cm of sediment was removed from each end of the sampling cylinder to exclude the possibility of analyzing sediment that had been exposed to daylight during sampling. Standard preparation steps (e.g., Spencer and Robinson, 2008) included dry sieving, 10% HCl and 30% H2O2 pre-treatments to remove carbonates and organic matter, respectively, separation of heavy minerals (<2.70 g cm⁻³) with lithium metatungstate (LMT) heavy liquid, and treating with 48% HF for 40 min to dissolve feldspar minerals and etch the surface of quartz grains to minimize luminescence due to ionization from external alpha particles. Monolayers (~3 mm circles; ~240 grains) of quartz grains were dispensed onto ~10 mm diameter stainless steel discs using silicone oil and a spray template. OSL measurements were carried out using a Risø TL/OSL-DA-20 reader (Bøtter-Jensen et al., 2003), with optical stimulation of quartz provided by an array of blue light (470 ± 30 nm) diodes, optical stimulation of feldspar with infrared (880 ± 80 nm) diodes, a calibrated 90Sr/90Y beta source (~0.16 Gys⁻¹) to administer laboratory radiation doses, and a heating stage for thermal stabilization. All luminescence signals were detected in the ultraviolet (peak transmission ~340 nm) using 7.5 mm of Hoya U-340 filter with an EMI 9235QB photomultiplier tube.

Equivalent dose (De) measurement procedures

Determination of the equivalent dose (De) was carried out using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000, 2003; Wintle and Murray, 2006). Continuous power or continuous wave OSL (CW-OSL) was conducted in all measurements. Similar to other recent studies, post-infrared optically stimulated luminescence (post-IR OSL) was used to measure the luminescence from the quartz grains (Lukas et al., 2007; Morrocco et al., 2007; Spencer and Robinson, 2008). This procedure removes charge sensitive to infrared stimulation, commonly associated with remnant feldspathic minerals, before measuring OSL from the quartz grains. The post-IR OSL measurement comprised 40 s infrared stimulated luminescence (IRSL) at ~117.9 mWcm⁻² (22 Vishay TSFF5200 IR led’s at 90% power) at a sample temperature of 50 °C, followed by 40 s OSL at ~38.7 mWcm⁻² (28 Nichia NSPB500S blue led’s at 90% power) at a sample temperature of 125 °C.

For all measurements the net OSL signal was defined as the initial 0.8 s integral with subtraction of the final 8 s integral. Test dose administered for sensitivity correction was ~31 Gy (equivalent to between ~12%–185% of De). The De value was estimated by interpolation of the natural OSL with a saturating exponential curve fitted to regenerative OSL data (Fig. 4). Uncertainty in De was estimated by combining error from counting statistics for the natural OSL, curve fitting, and instrumental systematic uncertainty (Duller, 2007). Preheat plateau (Wintle and Murray, 2006) and dose recovery (Murray and Wintle, 2003; Roberts et al., 1999; Wallinga et al., 2000) with preheat variation (Spencer and Robinson,
tests were used to determine appropriate preheat and cutheat thermal treatments. Dose recovery and $D_e$ results were only accepted if the following test thresholds were met: measured-to-given ratios and recycling ratios between 0.9 and 1.1; recuperation <5% of the natural level (Murray and Wintle, 2000, 2003). A hot bleach measurement of 40 s OSL at 280 °C was incorporated at the end of each SAR cycle (Murray and Wintle, 2003).

The dose-distribution from replicated $D_e$ measurements was assessed using a radial plot (Fig. 4) (Galbraith, 1990) and estimate of over-dispersion ($\Delta b$; Galbraith et al., 2005), together with geomorphological and sedimentological details (e.g., young, course alluvial nature of deposit) from the sampling site. The latter details provide context to the dose-distribution data (e.g., whether over dispersion is to be expected from the depositional environment, or laboratory error). On the basis of this assessment either the Minimum Age Model or Central Age Model (Galbraith et al., 1999) was chosen to calculate final $D_e$.

Assessment of dose-rate

Environmental dose-rate applied during age calculation was based on U, Th and K measurement using high-resolution gamma spectrometry. These data were converted to annual dose-rate using conversion factors from Adamiec and Aitken (1998). Calculated beta dose was corrected using attenuation factors for grain size and HF etching (e.g., Spencer and Owen, 2004). Attenuation of dose-rate via moisture conditions over the burial time of the samples was initially calculated by using present day (April) field moisture content with a maximum absolute error of 5% to allow for past changes. To better account for seasonal variation of ground moisture content, and the sample’s unique position within the abandoned channel, a 5 ± 5% moisture range was applied. The dose-rate from the ionizing cosmic ray component was calculated following Prescott and Hutton (1994).

Dating results and discussion

Initial OSL measurements generally indicated low specific luminescence sensitivity in natural signals and poor sensitivity to laboratory dose. Initial decay of natural luminescence signal varied in rapidity and, although linearly modulated OSL (LM-OSL) measurements were not made, significant variation in the proportion of fast to medium and slow components in CW-OSL is evident from aliquot-to-aliquot. These observations are consistent with a proximal and geologically young source, and lack of recycling from earlier sedimentary deposits. To ensure adequate test dose signals for all aliquots measured, test dose used in SAR measurements of dose recovery and $D_e$ was ~31 Gy. For a particular sequence of preheat and cutheat treatments dose recovery data were generally inconsistent from aliquot-to-aliquot. However, measured-to-given ratios were closest to unity for lower preheat treatments at 220 °C or 240 °C for 10 s, with best overall data with preheat at 220 °C for 10 s and cutheat at 160 °C. This combination of heat treatments was used to generate $D_e$ data. The $D_e$ distribution obtained from 32 aliquots shows a large spread with over-dispersion of ~61% (Fig. 4). The sample was collected from a silt lens in an arid alluvial fan; an asymmetric distribution is not unexpected given the debris flow depositional mechanism. Partial bleaching is a reasonable explanation for the asymmetry shown in Figure 4 and the Minimum Age Model was used to calculate the weighted mean $D_e$. Measured data, calculated dose-rate and OSL age are shown in Table 3. The OSL age quoted is in ka before AD 2011. For direct comparison with radiocarbon ages in ka BP, OSL ages should be adjusted to AD 1950 by subtracting 0.061 ka.

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