Supplementary Material

1. Borehole information

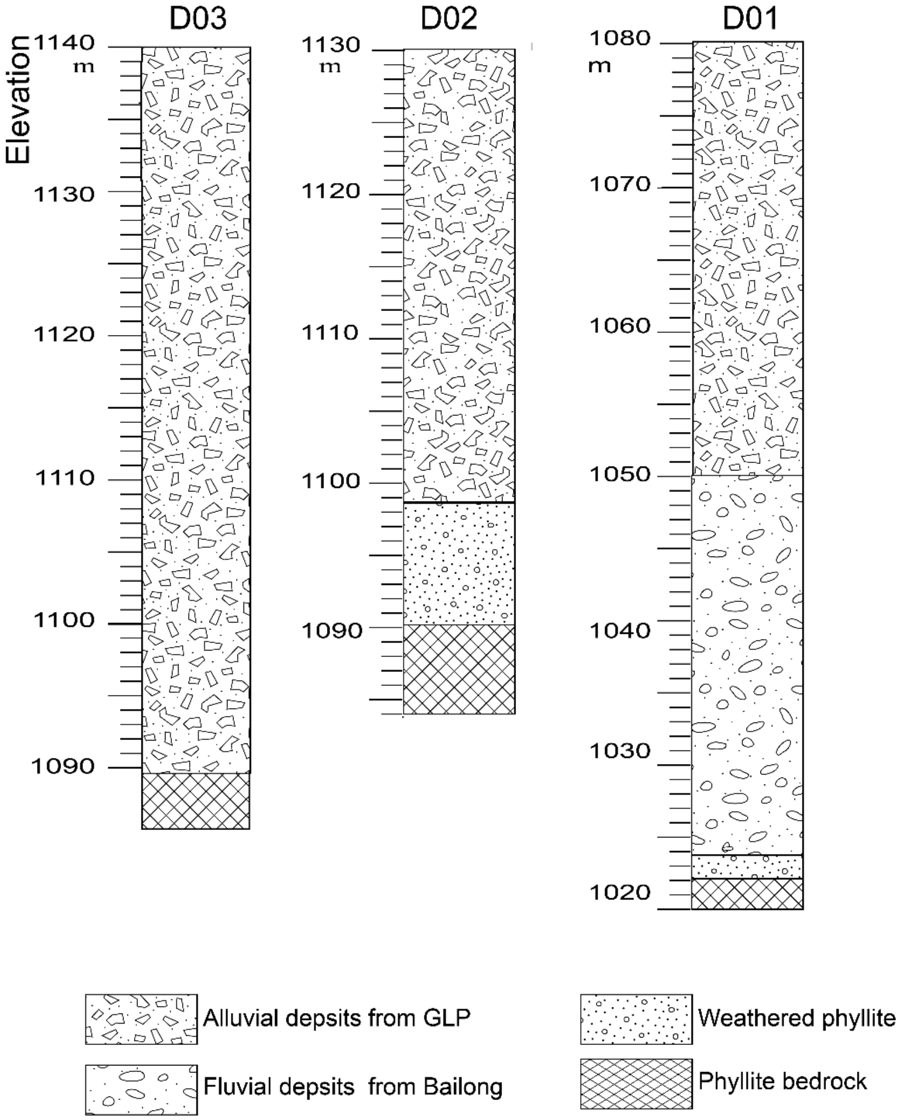

Figure S1 Simplified sedimentary logs of Core D01, D02 and D03. The three boreholes all reached the basal phyllite bedrock. Core D01 attained to 62 m, Core D02 to 45 m and Core D03 to 52 m beneath the present channel.

2. OSL dating information

Table S1. SAR protocol steps and parameters used in the study for equivalent dose determination.

Natural dose
1. Preheat for 10 s at 160 °C, PH
2. OSL at 125 °C for 40 s, measure natural intensity, L_{n}.
3. Test dose (e.g. 5 Gy), D_t
4. Cut heat to 160 °C
5. OSL at 125 °C for 40 s, measure test dose intensity, T_n
6. Regeneration dose, R_x
7. Preheat for 10 s at 160 °C, PH
8. OSL at 125 °C for 100 s, measure regenerated intensity, L_x
9. Test dose, D_t
10. Cut heat to 160 °C
11. OSL at 125 °C for 40 s, measure test dose intensity, T_x
12. Repeat steps 6 – 12 to build a growth curve

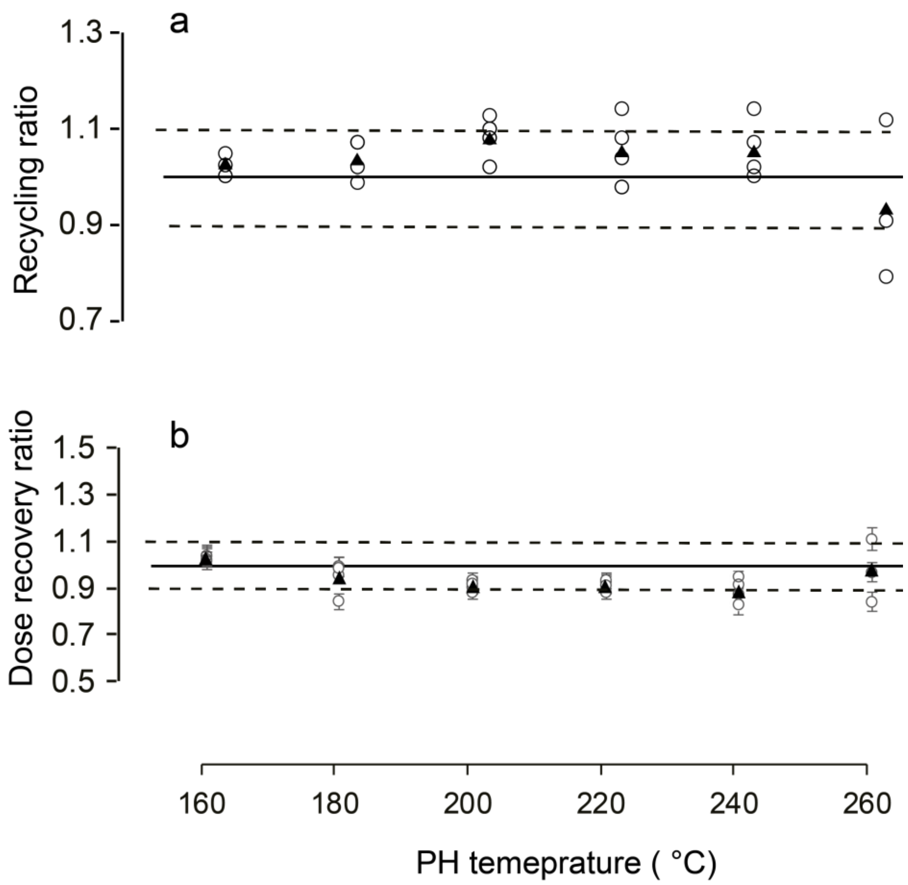

Figure S2. Recycling ratios (a) and dose recovery ratios (b) at different preheating temperatures for sample F3L18. Open symbols represent individual aliquots whereas filled triangles represent the mean result for that preheat temperature. Dashed lines define the area within 10% of 1 (straight line).

Table S2. OSL dating results. W is water content. For most samples in dry conditions upon sampling, the water content is taken as 10 ± 5% which is roughly a half of the saturated water content. For samples which are in wet conditions, their saturated water contents are measured in laboratory. σ is the over-dispersion value. (n) is the number of accepted aliquots.

Sample	Sample	Radionuclide concentrations			Sample	W	Cosmic dose	Dose rate	Equivalent	(n)	σ	Age
		K (%)	U (ppm)	Th (ppm)	(m)	(%)	(Gy/ka)	(Gy/ka)	(Gy/ka)		(%)	(ka)
D01-30	Alluvial	1.64±0.36	3.94±0.34	4.03±1.2	30±0.2	20.2±2	0.02±0.00	2.90±0.31	120.7± 6.3	23	25	41.6±5.0
D02-4.7	Alluvial	2.08±0.42	3.47±0.45	9.31±1.59	4.7±0.2	20.3±2	0.14±0.01	3.68±0.36	12.2±0.4	10	9.4	3.3±0.3
D03-39	Alluvial	1.72±0.17	3.05±0.31	9.89±0.99	39±0.2	22.4±2	0.02±0.00	3.13±0.22	135.6±2.6	21	8.1	43.3±3.2
F2700	Loess	1.86±0.41	3.81±0.44	6.62±1.52	0.5±0.2	10±5	0.22±0.01	3.79±0.39	4.1±0.1	22	12	1.1±0.1
SG-01	Alluvial	1.86±0.41	3.81±0.44	6.62±1.52	5.0±0.2	10±5	0.12±0.01	3.26±0.19	2.7±0.2	15	24	0.8±0.1
F2RBL02	Alluvial	2.22±0.45	3.19±0.54	11.67±1.86	1.0±0.2	10±5	0.2±0.01	4.37±0.43	6.1±0.1	23	4.4	1.4±0.1
HDG	Alluvial	2.37±0.45	3.27±0.51	10.3±1.79	0.5±0.2	10±5	0.21±0.01	4.42±0.43	2.8±0.1	18	7.5	0.6±0.1
F3RCK01	Loess	1.66±0.17	2.3±0.23	10.84±1.08	1.0±0.2	10±5	0.2±0.01	3.49±0.24	48.0±0.8	20	6.8	13.8±1.0
F3RCK02	Alluvial	1.39±0.3	2.59±0.33	7.51±1.16	17.0±0.2	10±5	0.04±0.00	2.86±0.3	53±2.9	18	23	18.5±2.2
F3L06	Loess	1.74±0.23	2.1±0.33	9.78±1.45	0.5±0.2	10±5	0.22±0.01	3.41±0.27	29.0±0.4	18	4.9	8.5±0.7
F3L16	Alluvial	1.52±0.37	5.31±0.51	5.63±1.78	15.0±0.2	10±5	0.04±0.00	3.71±0.42	48.7±3.8	20	35	13.1±1.8
F3L17	Alluvial	1.68±0.36	4.3±0.4	5.64±1.39	14.0±0.2	10±5	0.05±0.00	3.53±0.37	53.3±1.5	21	12	15.1±1.7
F3L18	Alluvial	1.18±0.31	3.61±0.37	6.31±1.32	16.0±0.2	10±5	0.04±0.00	2.9±0.32	62.9±1	23	6.4	21.7±2.5
F3L19	Alluvial	1.76±0.36	2.97±0.44	10.4±1.52	13.0±0.2	10±5	0.05±0.00	3.61±0.36	47.9±1.4	24	13	13.3±1.4
F3R01	Alluvial	1.92±0.41	4.53±0.45	5.45±1.57	8.0±0.2	10±5	0.09±0.00	3.85±0.41	180.3±2.1	24	1.8	46.8±5.1
F3R02	Alluvial	0.76±0.29	4.43±0.48	6.14±1.63	5.0±0.2	10±5	0.12±0.01	2.85±0.35	23.4±0.2	24	2.3	8.2±1.0
PB-F3L	Alluvial	1.93±0.42	4.31±0.54	9.73±1.89	10.0±0.2	22.4±2.2	0.07±0.00	3.7±0.38	60.2±0.5	23	0.8	16.3±1.7
F3L-P	Alluvial	1.46±0.37	3.73±0.47	9.66±1.65	8.0±0.2	10±5	0.09±0.00	3.55±0.38	51.9±2.8	11	16	14.6±1.8
SG-06	Alluvial	2.87±0.52	3.54±0.5	11.7±1.76	2.0±0.2	10±5	0.18±0.01	5.06±0.49	36.1±0.5	10	1.3	7.1±0.7
NS-L27	Loess	1.62±0.4	4.6±0.48	5.52±1.65	2.7±0.2	5±2	0.17±0.01	3.86±0.42	177.6±2.8	24	5.6	46.0±5.1
NS-L70	Loess	1.93±0.26	3.04±0.41	10.27±1.45	7.0±0.2	5±2	0.1±0.00	4.02±0.32	247.3±3.2	26	3.4	61.6±5.0
NS-86	Loess	1.71±0.58	3.17±0.39	9.31±1.37	8.6±0.2	5±2	0.08±0.00	3.74±0.51	299±8.5	12	8.8	79.9±11.1
NS-U100	Paleosol	1.75±0.61	3.60±0.49	8.36±1.73	10.0±0.2	5±2	0.08±0.00	3.84±0.54	200±18	8	25	52.1±8.7
NS-DZ	Loess	1.42±0.35	3.3±0.41	8.26±1.41	2.0±0.2	5±2	0.18±0.01	3.50±0.36	315±13	14	14	90±10

3. OSL age assessment

The general accuracy of these OSL ages are assessed here by considering the geological (stratigraphic order) and luminescence (over-dispersion of the D_e values) properties of each sample. The OSL ages of the samples, as well as their relative locations, are presented in Figure S3.

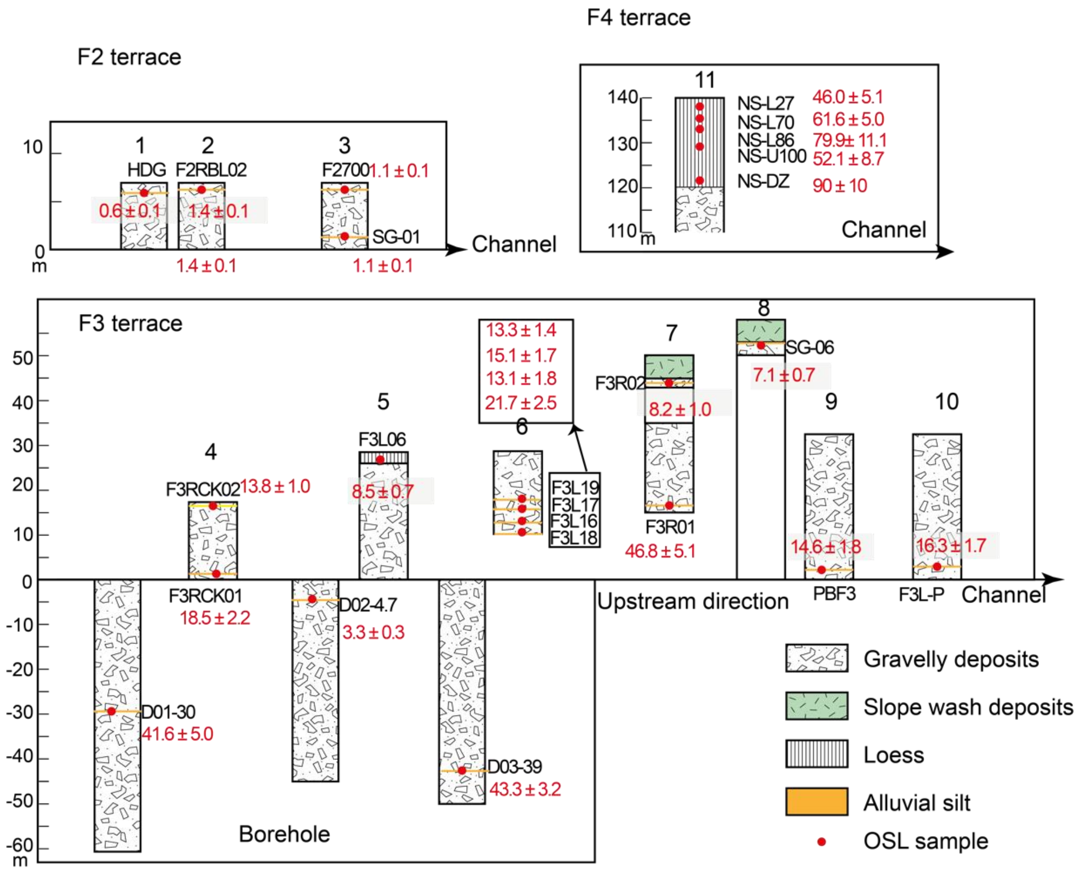

Figure S3 Location and OSL ages (Red numbers / ka) of the samples within each terrace profile or borehole. The vertical axis represents the elevation relative to the present channel. Upstream profiles are represented towards the right of the figure, while downstream profiles are represented towards the left. The numbers above each profile represent the locations of the profiles, which are shown in Figure 2.

3.1. Samples from F2 terraces

Four samples were taken from the F2 terraces for OSL dating. Samples F2RBL02 and HDG were taken from separate F2 terraces (Figure S3 and S4) and provide D_e values of 6.05 Gy and 2.79 Gy respectively, with low over-dispersion values (Table S2, 4.4 – 7.5%). These D_e values likely indicate satisfactory OSL signal resetting upon deposition.

Figure S4. Photograph showing the location of sample F2RBL01 and HDG

Samples F2700 and SG-01 were taken from the same F2 terrace location (Figure S5). They both produce low D_e values, with F2700 being 4.05 Gy and SG-01 being 2.66 Gy (Table S2). The OSL ages for F2700 and SG-01 are 1.07 ± 0.11 ka and 0.77 ± 0.07 ka respectively (Figure S3), which are identical within 2 sigma errors. Similarly, these two ages indicate that no significant residual OSL signals remained at deposition.

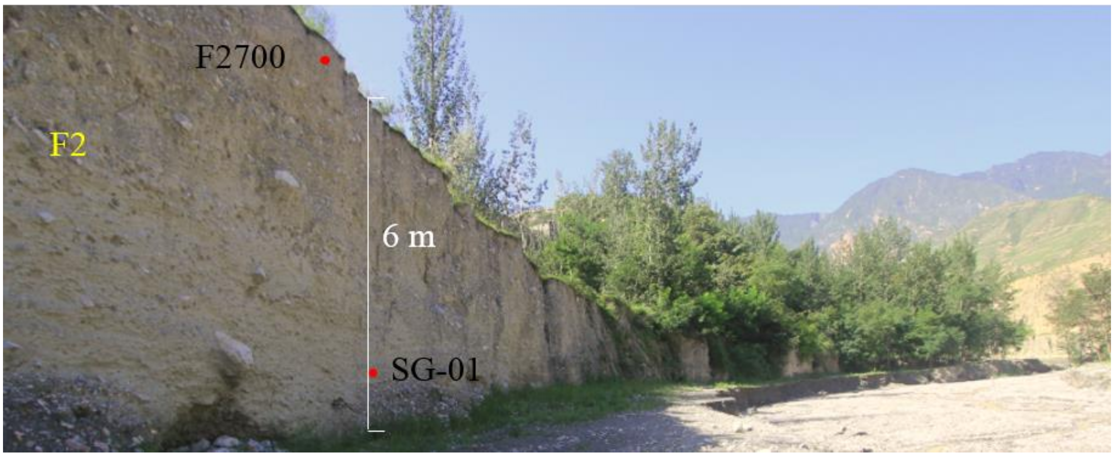

Figure S5. Photograph showing the locations of sample F2700 and SG-01

Overall, the D_e and OSL ages for the sediments of the F2 terraces indicate that they were wellbleached prior to deposition and are suitable for OSL dating, though the OSL ages for the young samples cannot be distinguished.

3.2 Samples from the F3 terraces

A total of 14 samples were taken from the F3 terraces (Figure S3) and dated.

Sample F3L16, F3L17, F3L18 and F3L19 were taken from a single F3 terrace profile (Figure S6). Sample F3L18 is at the profile base and provides the oldest OSL age, 21.7 ± 2.5 ka; Sample F3L17 is from the middle of the profile and provides an intermediate OSL age, 15.1 ± 1.7 ka; Sample F3L19 was taken from the profile top (Figure S5) provides the youngest OSL age, 13.3 ± 1.4 ka. These three samples provide over-dispersion values between 6.4 – 13% (Table S2) indicating relatively low scatter in OSL ages. However, sample F3L16 yields a higher over-dispersion value (35%). Nevertheless, the age (13.1 ± 1.8 ka), which is younger than that of sample F3L18 and overlaps with those of sample F3L17 and F4L19, still fits the stratigraphic order. Overall, the four samples, F3L18, F3L16, F3L17 and F3L19 therefore provide stratigraphically consistent OSL ages.

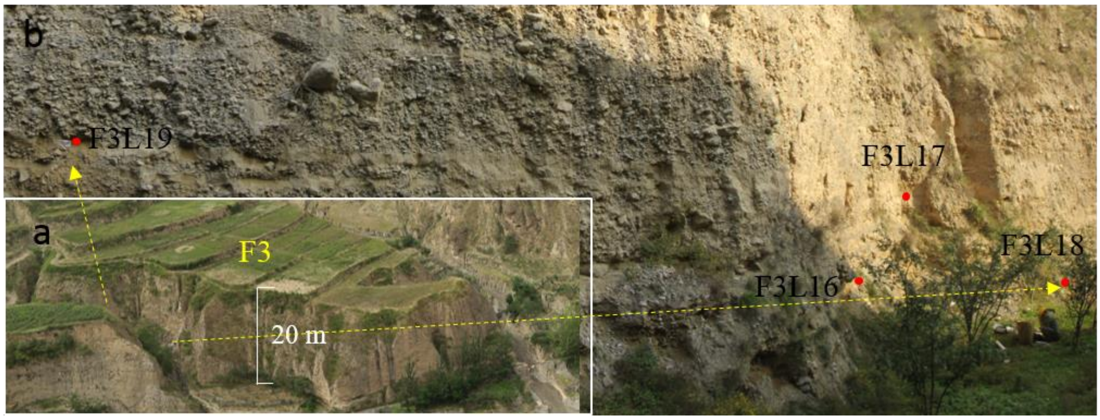

Figure S6. Location of samples F3L16, F3L17, F3L18 and F3L19 in the F3 terrace. a. Overview of the F3 terrace from which the samples were taken. b. The locations of the four samples in the F3 terrace.

Sample F3RCK01 and F3RCK02 were taken from a same F3 terrace at the mouth of the GLP valley (Figure S7). Sample F3RCK02 produces an OSL age of 13.8 ± 1.0 ka with an over-dispersion value of 6.8%. Sample F3RCK01 produces an OSL age of 18.5 ± 2.2 ka with an over-dispersion value of 23%. These two samples also result in OSL ages that are in stratigraphic order

Figure S7. Photograph showing the location of samples F3RCK01 and F3RCK02.

Samples F3R01 and F3R02 were taken from a single F3 terrace, which was cut into two levels (Figure S8). The ages of F3R01 and F3R02 are 46.8 ± 5.1 ka and 8.2 ± 1 ka respectively, and they both have low over-dispersion values, around 2% (Table S2). The age of F3R01 (46.84 ± 5.05 ka) is much higher than the ages of samples taken from the other F3 terraces. This age is considered as close to onset of the F3 terrace aggradation because it is taken from close to the bedrock base (Figure S8). The age is also close to that of the borehole sample D03-39 (Table S2).

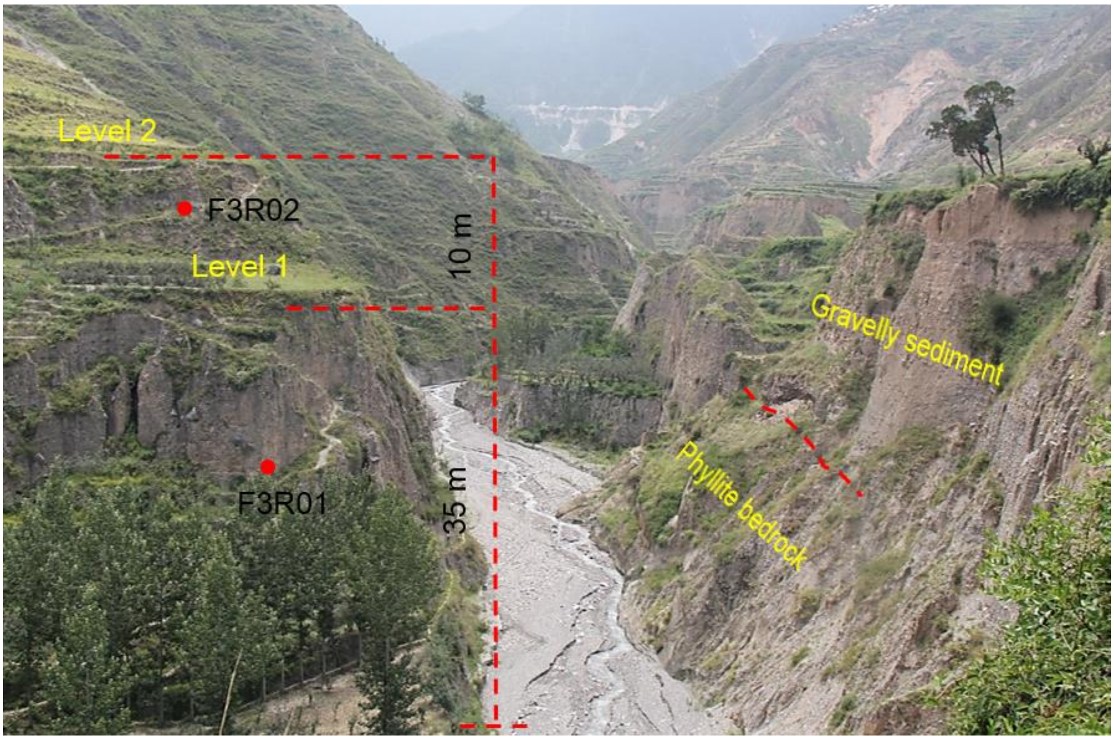

Figure S8 Photograph showing the location of sample F3R01 and F3R02 and the exposed bedrock.

The remaining samples, i.e., SG-06, PB-F3L01, F3L-P and F3L06, were each taken from separate F3 terraces (Figure S3). These four samples provide OSL ages that are within the age ranges provided by the F3 terrace samples previously described, and are, therefore, accepted as broadly accurate.

3.3 Samples from the F4 terraces

Five samples, NS-L27, NS-L70, NS-86, NS-U100 and NS-DZ, were taken from one loess profile overlying the F4 terrace at the downstream end of the GLP valley (Figure S3). These samples were taken at a certain depth beneath the terrace surface, and the depth is indicated from their sample codes, e.g., NS-L27 was taken from 2.7 m beneath the terrace surface. The ages for samples NS-L27, NS-L70 and NS-L86 are in the stratigraphic order, and the D_e values are characterized by low over-dispersion values (3.4 – 8.8%), consistent with aeolian deposition(Lai, 2006; Lai et al., 2007; Stevens et al., 2008) . Conversely, the over-dispersion for sample NS-U100 is relatively high for aeolian material (25%), and its OSL age does not fit in stratigraphic order. The cause of this discrepancy is unclear from these results alone but is possibly caused by post-depositional mixing. Sample NS-U100 was taken from a layer interpreted as a palaeosol, owing to its colour and structure (dark reddish brown (5YR 3/3) silty clay with blocky structure), which in other luminescence studies of loess palaeosols has resulted in inaccurate ages in some soil units (Stevens et al., 2008). Consequently, the age for sample NS-U100 is regarded as likely unreliable. Sample NS-DZ was taken from the base of the loess profile. It yields an over-dispersion value of 14%, which is lower than that of NS-U100 but higher than those of NS-L27, NS-L70 and NS-L86. Because the D_e value is so high (315 Gy), and we know that quartz OSL ages from loess tends to yield age underestimates at such high doses (Buylaert et al., 2007; Chapot et al., 2012; Lai, 2010), the OSL age, 90.0±10.0 ka, is regarded as a minimum estimate of its true burial age.

3.4 Samples from boreholes

Three samples were taken from the boreholes (Figure S3). Sample D01-30 was taken from 30 m beneath the present channel at the borehole D01, Sample D02-4.7 from 4.7 m at D02, and sample D03-39 from 39 m at D03. The OSL age for D01-30 is 41.6 ± 5.0 ka with a relatively high over-dispersion value of 25%. Sample D03-39 yields an OSL age of 43.3 ± 5.0 ka with an over-dispersion value of 8.1%. Samples D03-39 and D01-30 are located at similar depths beneath the present channel, and as they both produce similar ages, these ages are accepted as broadly accurate. Sample D02-4.7 produces an OSL age of 3.3 ± 0.3 ka with an over-dispersion value of 9.4%. This OSL age is also in the stratigraphic order with those of the two other borehole samples and is also therefore considered a broadly accurate estimate of the burial ages.

References

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