Palaeoenvironmental changes in the eastern Kumtag Desert, northwestern China since the late Pleistocene

-Supplementary Information-

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This file includes:

1. Supplementary Section: S-1 OSL signal strength
2. Supplementary Section: S-2 Sample specific selection of aliquot size and age model
3. Supplementary Section: S-3 Determination of the optimal number of end members (EMs) in EMMA
4. Supplementary Figures: S1-S2
5. Supplementary Tables: S1-S2

S-1 OSL signal strength

Initially, we used 2-mm diameter aliquots for D_e measurement of all samples. However, as Fig. S1 shows, for some samples in the YG and ASK sections, the OSL signals are quite dim, even close to the background noise. Such low OSL signals have been regularly observed in regions where quartz grain underwent limited sedimentary cycles (Preusser et al., 2006). Apparently, OSL sensitivity in quartz is induced by repeated bleaching and dosing cycles (Pietsch, 2009). A second round of measurements was carried out for all samples with the same measurement set-up but using 4-mm diameter aliquots. As expected, these reveal much brighter OSL signals and better signal-to-noise ratios. In the absence of partial bleaching, the Central Age Model (CAM) of 4-mm aliquots will likely provide the most robust results. However, for each sample it needs to be investigated if the D_e distribution appears normal or shows indication for partial bleaching, which will require using the Minimum Age Model (MAM) of the 2-mm aliquot results.

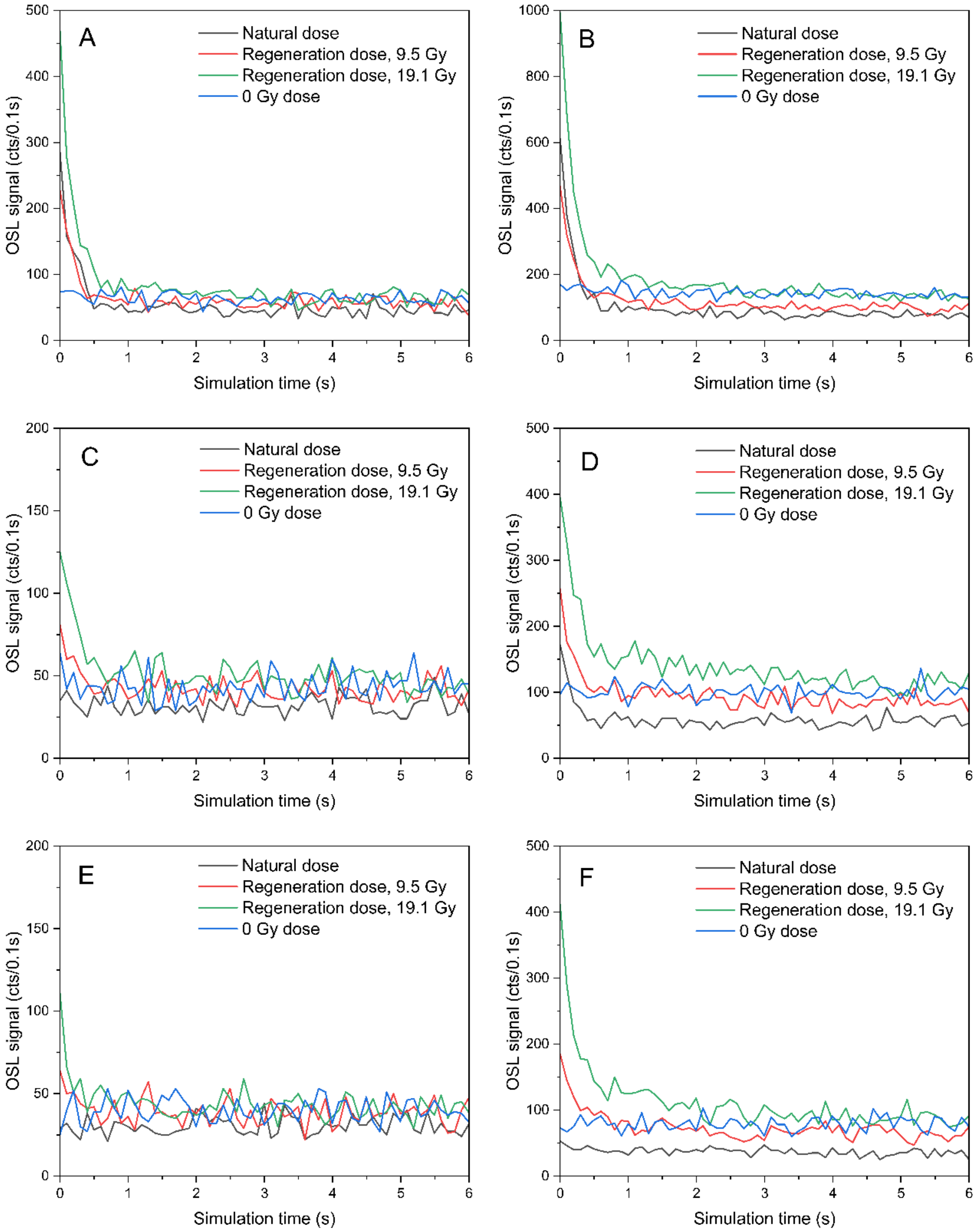
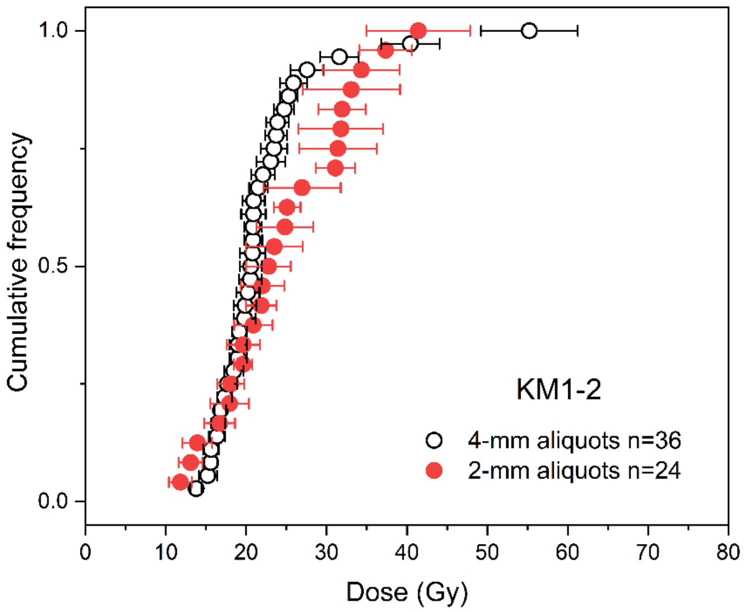


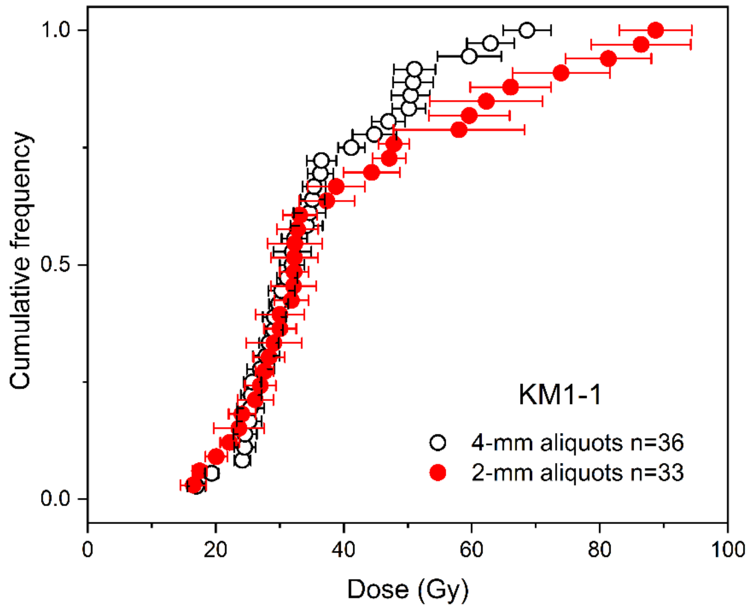
Fig. S1 A, C, E: Example OSL decay curves of natural dose, regenerative dose (9.5 Gy and 19.1 Gy) and 0 Gy dose of samples KM2-1, YG1-4 and ASK-2 using 2-mm diameter aliquots; **B, D, F:** Example OSL decay curves of natural dose, regenerative dose (9.5 Gy and 19.1 Gy) and 0 Gy dose of the same samples using 4-mm diameter aliquots.

S-2 Sample specific selection of aliquot size and age model

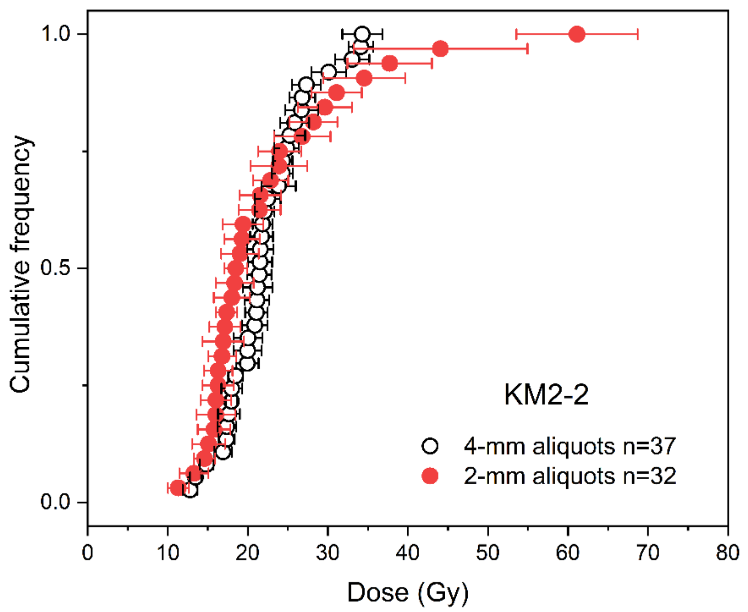
The following will for each sample discuss individually the D_e distribution and its statistical parameters to justify the choice of aliquot size and age model. The relevant parameters are listed below in Table S1.



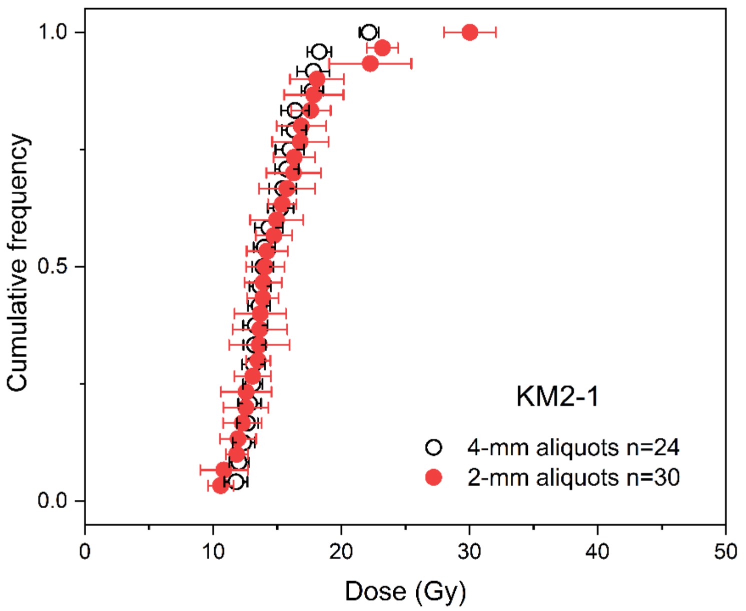
KM1-2: Symmetric distribution for 4-mm with moderate overdispersion (24%). Within errors identical mean D_e values (ca. 20 Gy) but much lower MAM 2-mm (17.6 ± 2.3 Gy). The latter is caused by tail of D_e values at lower edge with large uncertainties and low OSL signals. **Selected: CAM 4-mm.**



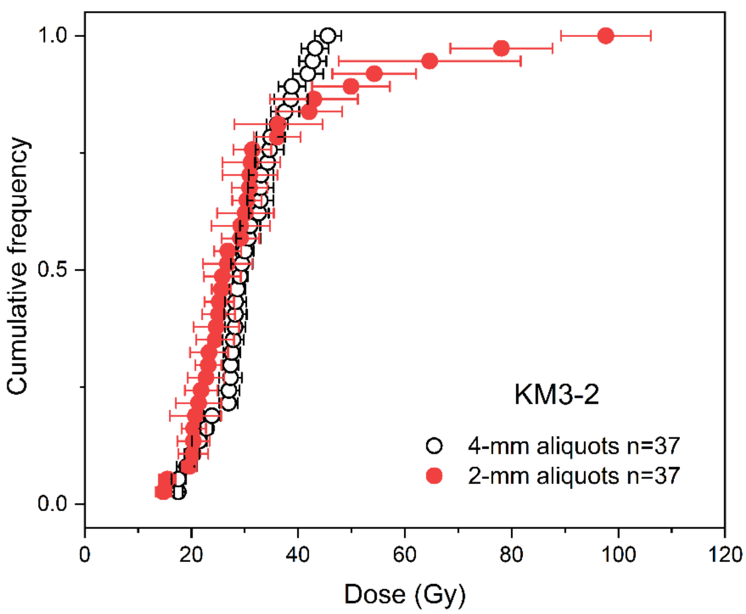
KM1-1: Almost identical, slightly skewed D_e distributions for both 2-mm and 4-mm aliquots, with slightly elevated overdispersion (44% and 32%, respectively). Likely reflecting the presence of partial bleaching. **Selected: MAM 4-mm.**



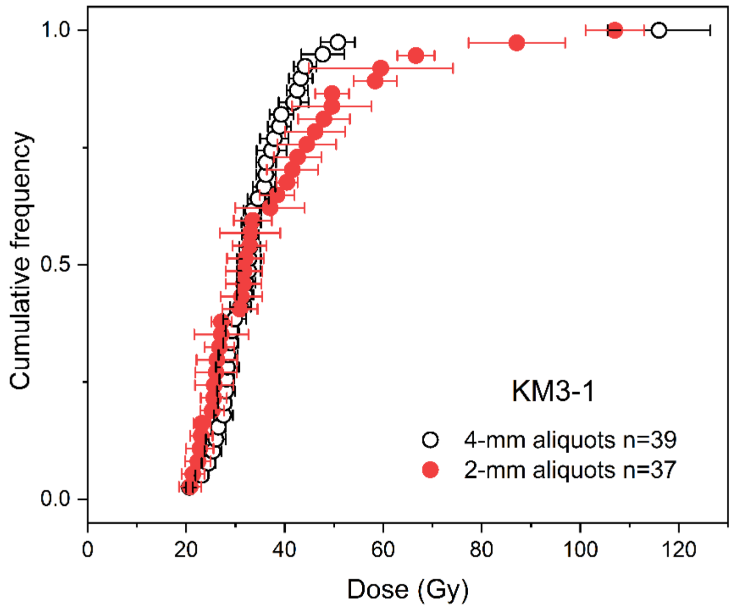
KM2-2: Almost symmetric D_e distributions with slightly elevated to moderate overdispersion for both 2-mm and 4-mm aliquots (33% and 18%, respectively). The higher overdispersion for 2-mm aliquots is caused by tail at upper edge of values with large uncertainties. **Selected: CAM 4-mm.**



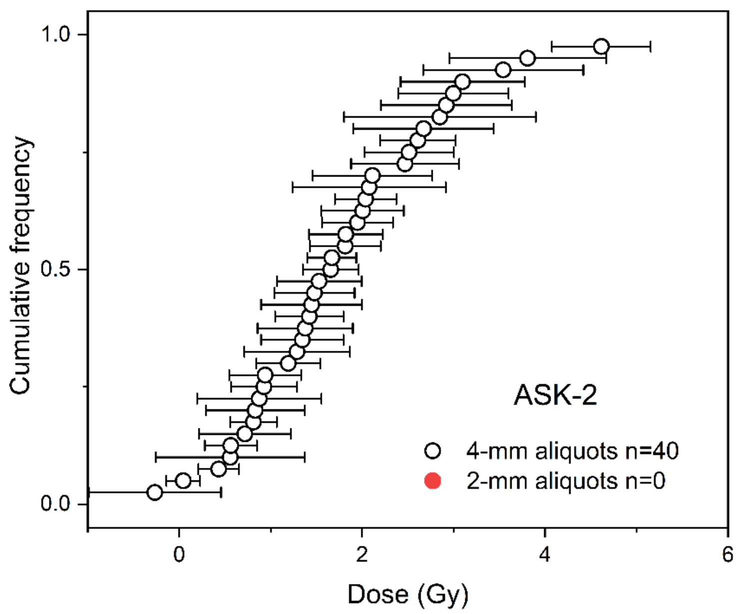
KM2-1: Almost symmetric D_e distributions with moderate to low overdispersion (21% and 14%, respectively). **Selected: CAM 4-mm.**



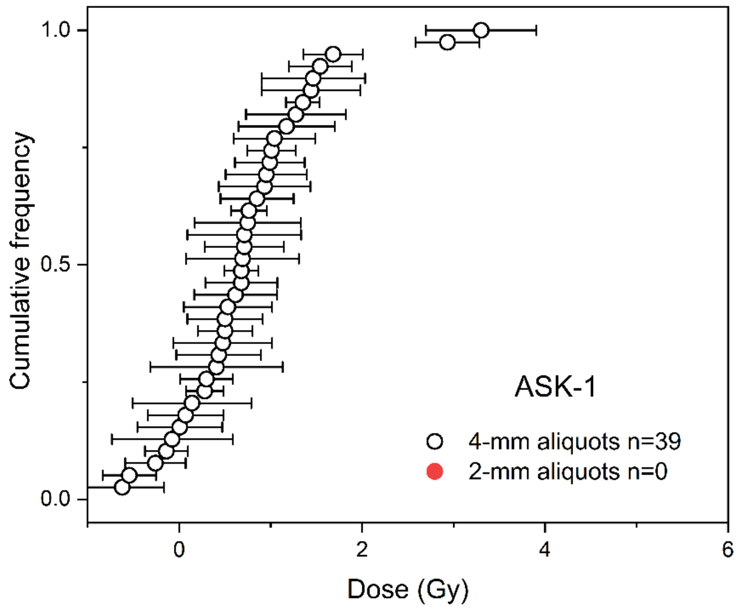
KM3-2: Slightly skewed D_e distributions with slightly elevated overdispersion for 2-mm (39%) and low overdispersion for 4-mm aliquots (23%). Possible reflecting the presence of partial bleaching and averaging effects. **Selected: MAM 2-mm.**



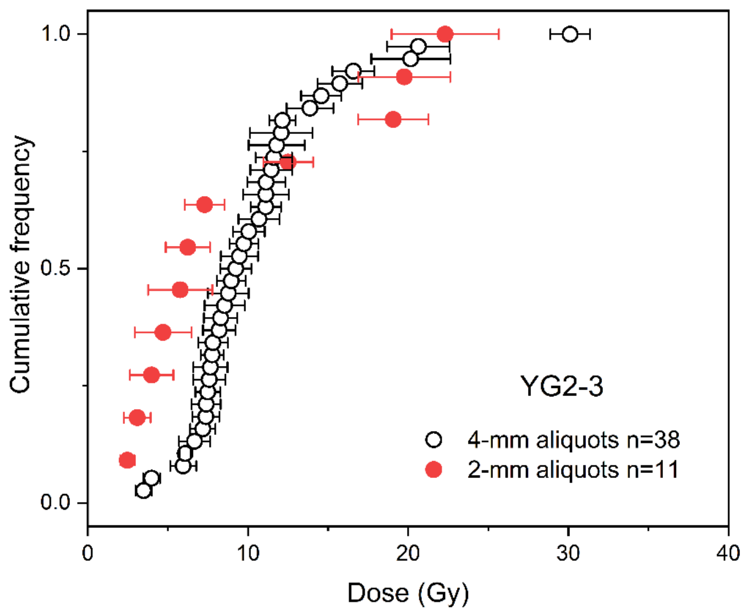
KM3-1: Almost symmetric D_e distributions with slightly elevated to moderate overdispersion (38% and 27%, respectively). Higher overdispersion of 4-mm data caused by one high value. **Selected: CAM 4-mm.**



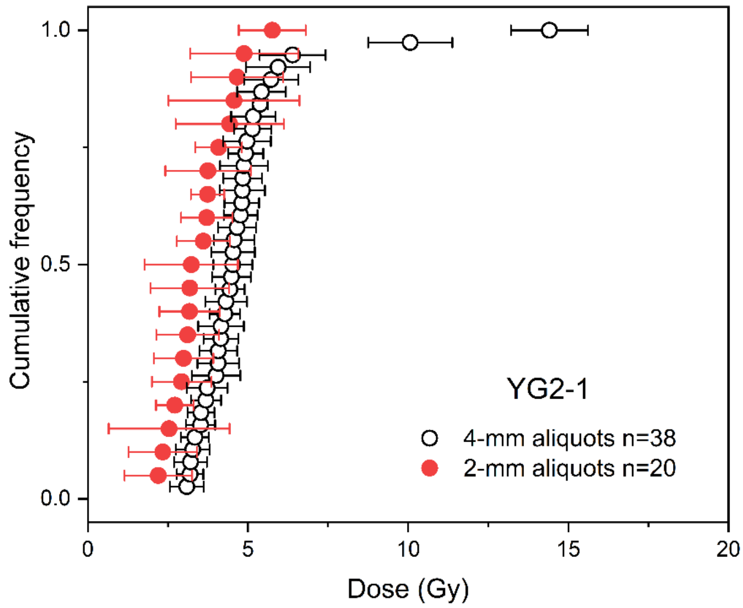
ASK-2: Very low OSL signal level for 2-mm, and low OSL signal level in 4-mm aliquots. Only few 2-mm aliquots could be analysed, all with enormous individual uncertainties. The 2-mm data set is considered not suitable. The 4-mm data also shows broad distribution and scatter, slight skewness. **Selected: MAM 4-mm.**



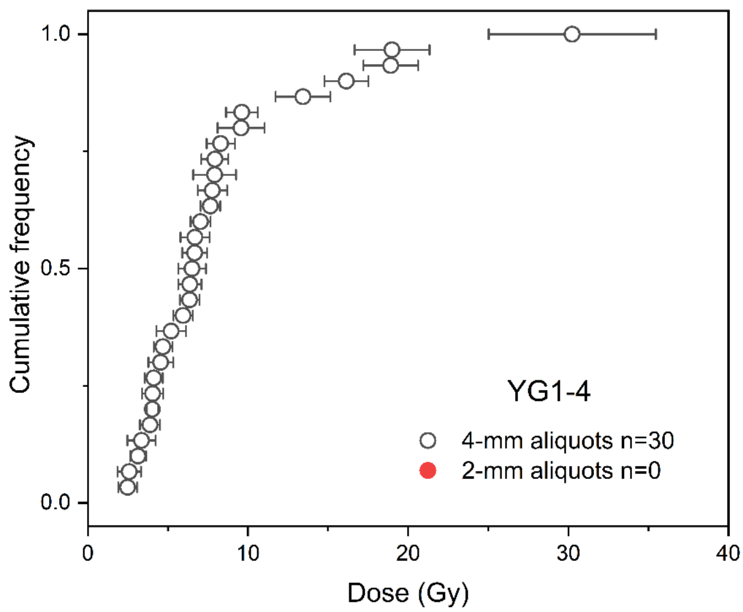
ASK-1: Very low OSL signal level for 2-mm, and low OSL signal level in 4-mm aliquots. Only few 2-mm aliquots could be analysed, with large individual uncertainties (no suitable). The 4-mm data shows slight skewness. **Selected: MAM 4-mm.** Consistent with all other models but 2-mm CAM (effect of error weighting).



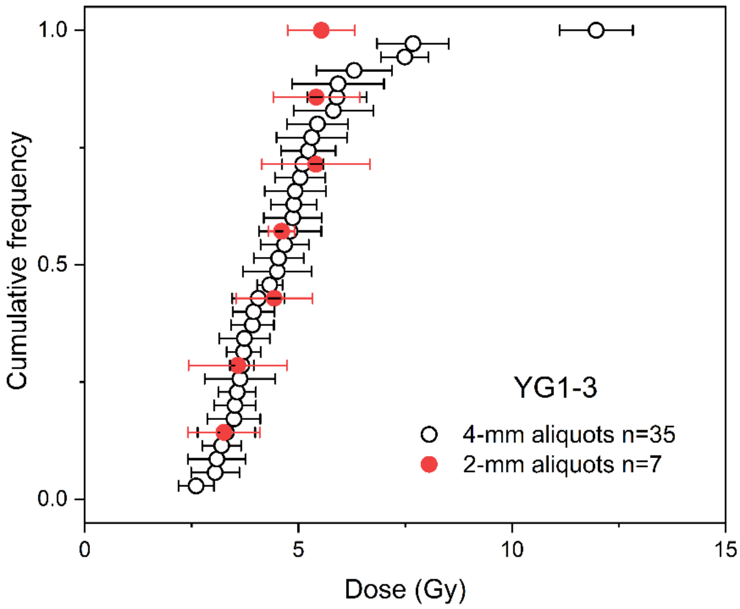
YG2-3: Low OSL signal level for 2-mm partly produces large individual D_e uncertainties. Slightly skewed D_e distributions with highly elevated overdispersion for 2-mm (72%) and moderate overdispersion for 4-mm aliquots (40%). Possible reflecting the presence of partial bleaching and averaging effects. **Selected: MAM 2-mm.**



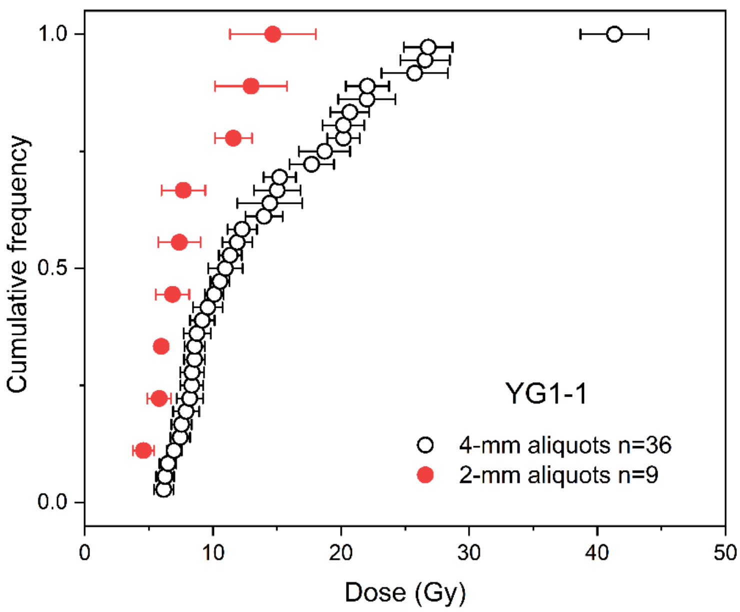
YG2-1: Almost symmetric D_e distributions with moderate overdispersion for 4-mm aliquots (27%). Large uncertainties cause no overdispersion in 2-mm data set. Higher overdispersion of 4-mm data caused by two high values. **Selected: MAM 4-mm.**



YG1-4: Low OSL signal level for 2-mm partly produces enormous individual D_e uncertainties (not suitable). Slightly skewed D_e distributions with elevated overdispersion for 4-mm aliquots (56%). **Selected: MAM 4-mm.**



YG1-3: Almost symmetric D_e distributions with moderate overdispersion for 4-mm aliquots (28%). Large uncertainties cause no overdispersion in 2-mm data set. Higher overdispersion of 4-mm data caused by one high values. **Selected: MAM 4-mm.**



YG1-1: Slightly skewed D_e distributions with slightly elevated overdispersion for both 2-mm and 4-mm aliquots (33% and 48%, respectively). Possible reflecting the presence of partial bleaching. **Selected: MAM 4-mm.**

Table S1

Summary of optically stimulated luminescence (OSL) data for both 2 mm and 4 mm aliquots from the KM, YG and ASK sections in the eastern KMD. **Bold letters** indicate aliquot size and age model chosen for age calculation.

Sample No.	Depth (m)	Aliquots 2 mm n	Aliquots 4 mm n	od. 2 mm (%)	od. 4 mm (%)	D_e (CAM) 2 mm (Gy)	D_e (MAM) 2 mm (Gy)	D_e (CAM) 4 mm (Gy)	D_e (MAM) 4 mm (Gy)
KM1-2	0.60	40/24	40/36	30	24	23.2±1.6	17.6±2.3	21.1±0.9	**20.1±0.8**
KM1-1	1.50	40/33	40/36	44	32	36.6±2.9	26.0±3.2	33.7±1.8	**27.5±2.7**
KM2-2	2.33	40/32	40/34	33	18	20.8±1.3	18.5±1.8	**22.6±0.8**	22.6±1.5
KM2-1	2.85	40/30	40/24	21	14	15.1 ± 0.7	14.5±1.1	**14.7±0.5**	14.7 ± 1.0
KM3-2	8.75	40/37	40/37	39	23	29.1±2.0	**24.6±2.3**	29.7±1.2	26.5± 2.4
KM3-1	9.55	40/37	40/39	38	27	35.2±2.3	**27.9± 3.1**	33.5±1.5	32.4±1.2
ASK-2	0.30	40/0	40/40	-	81	-	-	0.75±0.12	**0.69±0.22**
ASK-1	0.70	40/0	40/38	-	66	-	-	2.00±0.23	**1.31±0.34**
YG2-3	0.15	40/11	40/38	72	40	7.71±1.76	**3.02±0.90**	9.75±0.66	8.70±0.90
YG2-1	1.75	40/20	40/38	0	27	3.73±0.22	3.65±0.43	4.65±0.23	**4.39±0.19**
YG1-4	2.20	40/0	40/30	-	56	-	-	6.81±0.72	**3.60±0.66**
YG1-3	2.85	40/7	40/35	0	28	4.71±0.24	4.68±0.69	4.62±0.24	**4.43±0.36**
YG1-1	3.45	40/9	40/36	33	48	7.89±0.98	7.90±2.62	12.5±1.0	**8.21±0.93**

S-3 Determination of the optimal number of end members (EMs) in EMMA

Since the optimal number of EMs needs to be most strongly correlated with the dataset (e.g., high R^2), having both the lowest correlation between EMs themselves and the lower angular deviation, and minimizing the number of EMs (Paterson and Heslop, 2015; Duan et al., 2020), we made a discussion according to the results generated by the AnalySize software.

For the KM section, we first made the number of EMs into three, the results show that the correlations within the dataset (R^2) are almost close to one and the angular deviation degree is 5.8. However, the correlation between the EMs is relatively high ($R^2 = 0.38$). Therefore, we changed the number of EMs to two and found a higher angular deviation (9.8) with a low correlation between the EMs ($R^2 < 0.01$). In order to avoid a high correlation between the EMs, we identified two EMs for the KM section. For the YG section, the correlations within the dataset are close to one for both three and four EMs, while four EMs have much lower angular deviation (7.2) than three EMs (11.4) with relatively low correlation between the EMs (0.1), thus, four EMs were selected for the YG section. For the ASK section, when we made the number of EMs into two, the correlations within the dataset were also close to one and the angular deviation degree was 5.8; at the same time, the correlation between the EMs is low ($R^2 < 0.01$). Hence, two EMs were chosen for the ASK section.

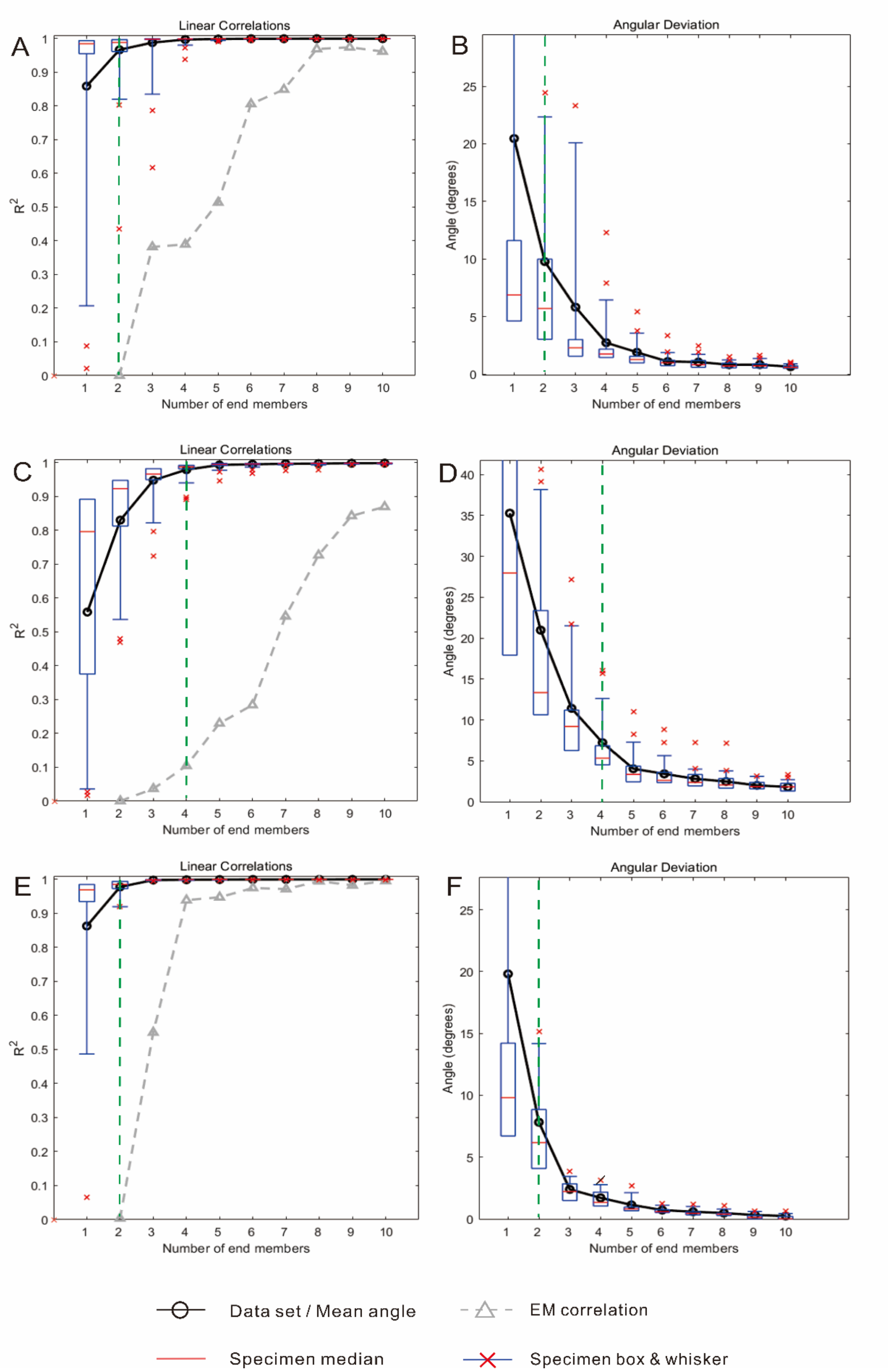


Fig. S2. Linear correlations (**A, C, E**) and angular deviation (**B, D, F**) of the grain-size end members for the KM, YG and ASK section. The vertical green dash line represents the optimal number of EMs.

Table S2

Major and trace element concentration, CPA and (CaO + Na_2O + MgO)/TiO_2 ratio values of the sediments of the KM section in the eastern KMD.

Sample No.	Depth (m)	Al_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	Zr (ppm)	Rb (ppm)	Ba (ppm)	Zr*100,000 /Al_2O_3	TiO_2/Zr	K/Ba	K/Rb	CPA	(CaO+Na_2O+MgO) /TiO_2
KM1-09	0.25	9.04	2.59	7.36	3.04	1.78	0.42	42.00	61.00	477.00	46.46	99.05	37.32	291.80	64.38	28.35
KM1-08	0.45	9.84	2.91	8.36	2.35	1.94	0.48	58.30	71.40	476.00	59.25	82.33	40.76	271.71	71.79	22.74
KM1-07	0.50	8.54	2.39	7.22	2.18	1.66	0.39	62.30	53.70	480.00	72.95	62.44	34.58	309.12	70.43	24.45
KM1-06	0.70	9.54	2.33	6.53	2.38	1.59	0.49	52.20	54.10	504.00	54.72	94.06	31.55	293.90	70.90	20.02
KM1-05	0.90	8.94	2.62	7.39	2.18	1.60	0.51	49.50	53.20	491.00	55.37	102.83	32.59	300.75	71.37	19.58
KM1-04	1.10	8.99	2.64	7.40	2.18	1.59	0.52	41.80	55.60	524.00	46.50	125.36	30.34	285.97	71.48	19.10
KM1-03	1.30	9.16	2.67	7.59	2.17	1.59	0.55	40.30	54.20	510.00	44.00	135.24	31.18	293.36	71.96	18.43
KM1-02	1.50	9.10	2.67	7.46	2.21	1.56	0.57	54.50	52.40	506.00	59.89	104.22	30.83	297.71	71.45	17.84
KM1-01	1.70	8.60	2.50	7.25	2.15	1.62	0.44	49.70	52.80	492.00	57.79	89.34	32.93	306.82	70.86	21.77
KM2-16	1.92	8.76	2.36	6.90	2.11	1.66	0.38	42.10	54.10	506.00	48.06	90.97	32.81	306.84	71.62	24.28
KM2-15	1.96	9.41	2.83	8.12	1.95	1.89	0.44	38.50	67.40	515.00	40.91	115.32	36.70	280.42	74.58	22.25
KM2-14	2.06	9.05	2.34	6.98	2.26	1.57	0.45	43.30	53.90	545.00	47.85	103.23	28.81	291.28	70.88	21.45
KM2-13	2.23	8.84	2.50	7.26	2.18	1.66	0.45	44.00	52.40	502.00	49.77	102.50	33.07	316.79	71.14	21.57
KM2-12	2.33	8.82	2.46	7.14	2.18	1.65	0.44	35.60	51.70	483.00	40.36	123.60	34.16	319.15	71.09	21.93
KM2-11	2.43	8.80	2.39	6.96	2.11	1.65	0.41	37.60	56.20	512.00	42.73	108.78	32.23	293.59	71.71	22.88
KM2-10	2.53	9.13	2.46	7.18	2.08	1.63	0.46	44.00	57.10	517.00	48.19	103.64	31.53	285.46	72.74	20.68
KM2-09	2.63	8.82	2.54	7.36	2.14	1.61	0.46	75.40	50.90	500.00	85.49	61.54	32.20	316.31	71.47	20.95
KM2-08	2.67	13.30	4.36	10.75	1.51	2.70	0.64	39.30	109.00	501.00	29.55	163.10	53.89	247.71	84.26	18.64
KM2-07	2.70	8.90	2.55	7.63	2.26	1.55	0.49	49.00	47.90	478.00	55.06	100.82	32.43	323.59	70.53	20.25
KM2-06	2.80	8.76	2.43	7.20	2.14	1.53	0.44	45.20	52.80	497.00	51.60	97.79	30.78	289.77	71.33	21.50

KM2-05	2.90	8.44	2.29	6.59	2.12	1.58	0.40	42.00	49.20	465.00	49.76	94.52	33.98	321.14	70.76	23.13
KM2-04	3.00	8.62	2.43	7.14	2.26	1.52	0.45	41.10	51.40	511.00	47.68	110.46	29.75	295.72	69.87	21.51
KM2-03	3.10	8.59	2.29	6.73	2.12	1.55	0.43	38.90	52.20	510.00	45.29	109.77	30.39	296.93	71.12	21.50
KM2-02	3.20	8.45	2.07	5.95	2.07	1.59	0.37	48.70	51.70	523.00	57.63	76.39	30.40	307.54	71.28	23.22
KM2-01	3.30	8.57	2.43	6.92	2.03	1.61	0.43	38.60	53.60	481.00	45.04	111.14	33.47	300.37	71.96	21.59
KM3-06	8.40	8.71	2.33	6.90	2.05	1.63	0.40	66.30	54.80	520.00	76.12	59.58	31.35	297.45	72.09	23.06
KM3-05	8.85	8.84	2.87	8.27	2.09	1.61	0.59	52.70	54.60	525.00	59.62	111.95	30.67	294.87	72.00	17.40
KM3-04	8.95	9.17	2.65	7.67	2.10	1.61	0.54	49.20	52.10	498.00	53.65	108.94	32.33	309.02	72.64	18.38
KM3-03	9.30	8.94	2.52	7.39	2.08	1.62	0.47	49.10	51.40	493.00	54.92	95.32	32.86	315.18	72.32	20.41
KM3-02	9.65	9.38	2.76	7.89	2.07	1.63	0.58	59.50	54.90	539.00	63.43	97.98	30.24	296.90	73.37	17.16
KM3-01	10.05	8.63	2.94	8.41	1.98	1.52	0.60	37.00	52.50	494.00	42.87	162.43	30.77	289.52	72.59	16.91

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