Supplementary Materials

Table S1. Single-grain SAR procedures for dose recovery test and D_e estimation.

Step	Treatment	Observed
1	Give the regenerative dose, D_i [a]	-
2	Preheat (240°C for 10 s)	-
3	Green laser for 1.0 s at 125°C	L_i
4	Give test dose, Dt	-
5	Cut-heat to 180 °C	-
6	Green laser for 1.0 at 125°C	T_i
7	Return to step 1	

[a] For the natural dose, i = 0 and D_i = 0 Gy. The OSL signals induced by stimulation of the natural dose and its corresponding test dose are denoted L_n and T_n, respectively, and the OSL signals induced by stimulation of the regenerative doses and their corresponding test doses are denoted L_x and T_x, respectively. The entire sequence is repeated for several regenerative doses, including a zero dose and a duplicate dose, to monitor the extent of recuperation and to determine the recycling ratio, respectively. A further (triplicate) regenerative dose cycle was included at the end of the single-grain SAR sequence to check for feldspar contamination of individual quartz grains on the basis of their OSL IR depletion ratios (Duller, 2003). The regenerative dose was stimulated using infrared light-emitting diodes for 100 s at 50 °C prior to stimulation of the OSL signal using a green laser.

Table S2. Number of single grains or aliquots measured, rejected and accepted for each sample, together with the reasons for their rejection.

Sample	No. of measured	Rejection criteria						Accepted D_e values [b]	Proportion of saturated [c]
		T_n below 3σ above BG [a]	RSE of T_n > 20% [a]	Recuperation > 5%	Poor DRC [a]	D_e by extrapolation	No L_n/T_n intersection		
THD-OSL1	700	139	136	6	119	6	39	255 (36%)	15%
THD-OSL2	700	160	102	3	126	18	52	239 (34%)	23%
THD-OSL3	500	182	87	4	65	6	53	103 (21%)	36%
THD-OSL4	500	167	82	4	84	26	51	86 (17%)	47%
THD-OSL5	800	299	146	0	175	7	95	78 (10%)	57%
THD-OSL6	800	226	124	4	102	13	153	178 (22%)	48%

[a] BG, RSE and DRC represent background, relative standard error and dose response curve, respectively.
[b] The proportion of grains with acceptable D_e values is shown in the parentheses and was calculated as a ratio to the total number of measured grains.
[c] The proportion of saturated grains was calculated as the number of grains with D_e obtained by extrapolation and those without L_n/T_n intersection divided by the total number of grains that passed the first four criteria (columns 3–6).

Table S3. Summary of number of grains with saturated natural signal and D_e estimation results based on LS-normalised L_n/T_n for individual DRC groups and different grain sizes of each sample.

Sample	DRC Group	No. of accepted grains [a]	No. of saturated grains [b, d]	Over-dispersion (%)	Age model [c]	D_e (Gy) [d]	Final D_e (Gy) [f]
THD-OSL1	1	20 (6.4%)	9 (45%)	63 ± 10	MAM (65%)	saturated	158 ± 17
	2	57 (18.2%)	19 (33%)	51 ± 5	MAM (51%)	144 ± 34	
	3	86 (27.5%)	15 (17%)	60 ± 5	MAM (43%)	156 ± 22	
	4	69 (22%)	6 (9%)	70 ± 6	MAM (16%)	194 ± 68	
	5	69 (22.5%)	5 (7%)	74 ± 6	MAM (16%)	173 ± 64	
	6	9 (3%)	0 (0%)	50 ± 13	- [e]	-	
	7	3 (0.9%)	0 (0%)	89 ± 37	- [e]	-	
THD-OSL2	1	14 (4.4%)	6 (43%)	60 ± 11	MAM (93%)	98 ± 30	186 ± 12
	2	55 (17.4%)	23 (42%)	28 ± 3	MAM (91%)	184 ± 44	
	3	109 (34.4%)	31 (28%)	36 ± 3	MAM (72%)	192 ± 18	
	4	67 (23.2%)	9 (13%)	51 ± 5	MAM (55%)	190 ± 21	
	5	56 (19.4%)	3 (5%)	56 ± 5	MAM (34%)	236 ± 88	
	6	13 (5.7%)	1 (8%)	62 ± 13	- [e]	-	
	7	3 (0.9%)	0 (0%)	63 ± 27	- [e]	-	
THD-OSL3	1	14 (4.4%)	10 (71%)	7 ± 2	nMAD (93%)	saturated	202 ± 9
	2	27 (9.3%)	15 (56%)	9 ± 2	nMAD (85%)	saturated	
	3	50 (21.7%)	26 (52%)	39 ± 4	nMAD (80%)	346 ± 67	
	4	41 (20.1%)	7 (17%)	39 ± 4	nMAD (83%)	189 ± 11	
	5	24 (14%)	3 (13%)	40 ± 6	nMAD (83%)	212 ± 18	
	6	6 (3.6%)	0 (0%)	11 ± 5	nMAD (100%)	192 ± 18	
	7	4 (2.4%)	0 (0%)	43 ± 16	- [e]	-	
THD-OSL4	1	2 (1.3%)	2 (100%)	-	- [e]	-	277 ± 17
	2	20 (13.6%)	16 (80%)	11 ± 2	nMAD (100%)	saturated	
	3	65 (40.1%)	33 (51%)	13 ± 2	nMAD (89%)	356 ± 92	
	4	32 (20.9%)	14 (44%)	16 ± 2	nMAD (84%)	255 ± 28	
	5	37 (22.3%)	7 (19%)	29 ± 4	nMAD (78%)	283 ± 22	
	6	3 (1.8%)	0 (0%)	0	- [e]	-	
	7	2 (1.2%)	0 (0%)	-	- [e]	-	
THD-OSL5	1	24 (13.1%)	20 (83%)	9 ± 2	nMAD (88%)	saturated	300 ± 22
	2	34 (17.3%)	26 (76%)	12 ± 2	nMAD (88%)	saturated	
	3	60 (31.3%)	37 (62%)	33 ± 3	nMAD (87%)	saturated	
	4	35 (17.9%)	17 (49%)	14 ± 2	nMAD (89%)	442 ± 159	
	5	29 (15.5%)	6 (21%)	15 ± 2	nMAD (90%)	295 ± 23	
	6	2 (1.1%)	0 (0%)	-	- [e]	-	
	7	0 (0%)	-	-	- [e]	-	
THD-OSL6	1	28 (14.9%)	21 (75%)	11 ± 2	nMAD (86%)	saturated	317 ± 15
	2	73 (32.2%)	45 (62%)	30 ± 3	nMAD (86%)	saturated	
	3	129 (43.6%)	62 (48%)	11 ± 1	nMAD (89%)	277 ± 24	
	4	60 (18.7%)	26 (43%)	12 ± 1	nMAD (85%)	344 ± 30	
	5	56 (16.1%)	15 (27%)	29 ± 3	nMAD (86%)	332 ± 27	
	6	9 (2.5%)	2 (22%)	21 ± 6	nMAD (100%)	313 ± 56	
	7	0 (0%)	-	-	-	-	

[a] The percentage of grains in each DRC group is shown in parentheses.
[b] The percentage of the 'saturated' grains in each of the DRC group is shown in parentheses.
[c] The percentage of grains picked up by age models for D_e estimation is shown in parentheses.
[d] The D_e shown as 'saturated' means that the weighted mean of LS-normalised L_n/T_n is statistically consistent with the saturation level of the corresponding SGC at 2σ.
[e] The number of grains are insufficient to produce statistically significant results.
[f] The final D_e were obtained based on the weighted mean of the D_e values obtained from each of the groups.

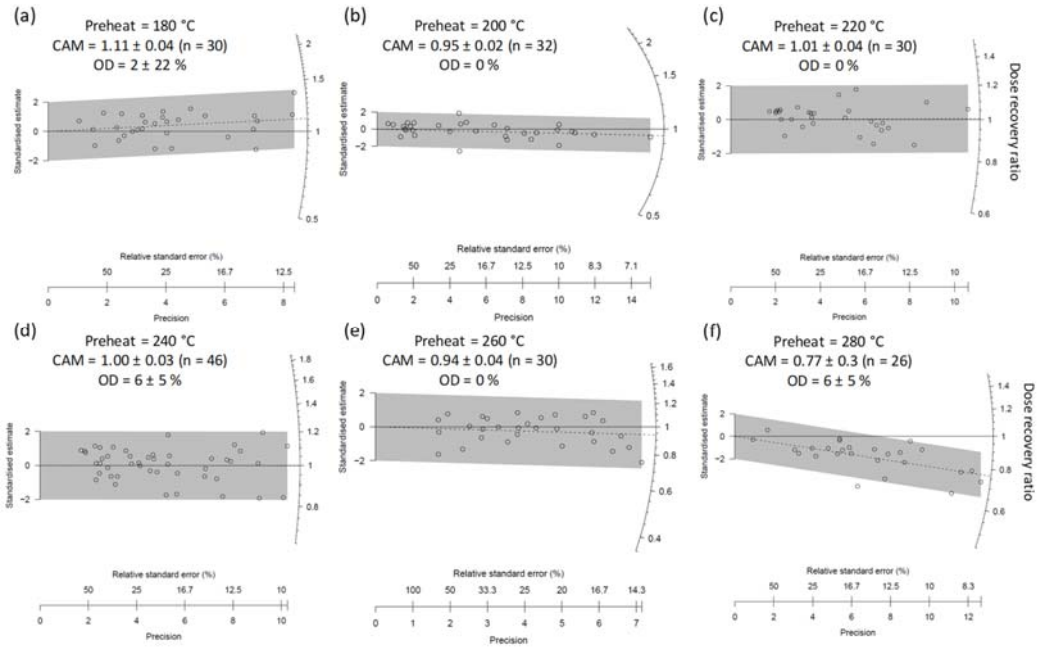

Figure S1. Dose recovery results for quartz OSL. (a-f) Radial plots showing the distributions of dose recovery ratios for individual grains for different preheat temperatures (from 280 to 180 °C, respectively) and the CAM and OD values.

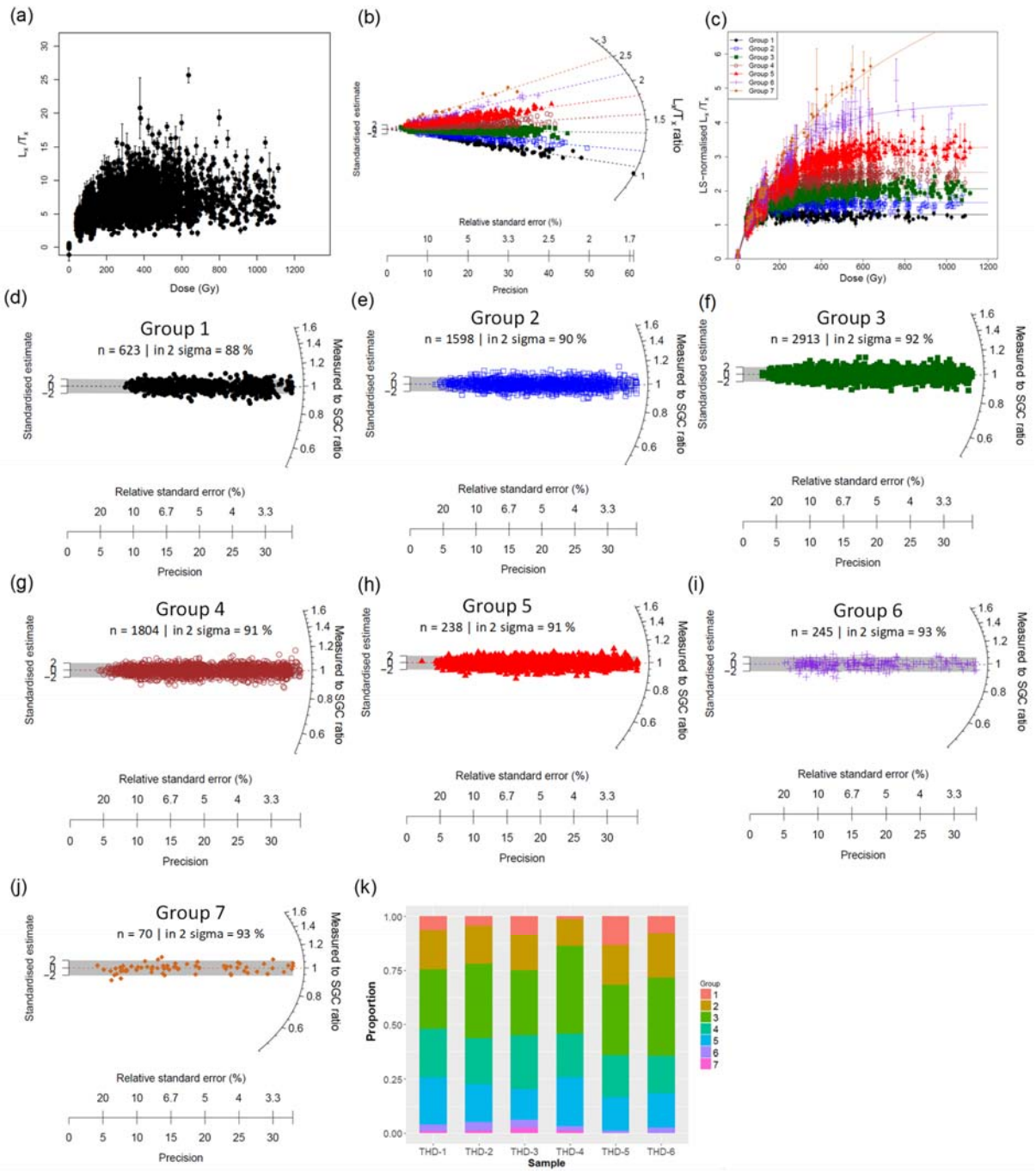

Figure S2. (a) Comparisons of all the DRCs that pass the rejection criteria for all the samples. (b) Radial plot showing the distribution of the ratios of L_x/T_x values between two regenerative doses of 400 and 100 Gy for all the accepted grains. The different colour and symbols represent different groups of grains identified using FMM. (c) Comparison of the LS-normalised L_x/T_x values for different groups. The data set for each group were fitted using a GOK function (full lines) and then normalised to unity at 50 Gy. (d–j) Radial plots showing the ratios between the LS-normalised L_x/T_x and the expected values based on the best-fit SGC shown in (c); the shaded band captures 2σ range from unity. The total number of grains (n) and percentage falling inside the 2σ band are shown for each group. (k) Proportion distribution of grains of each DRCs group for each sample.

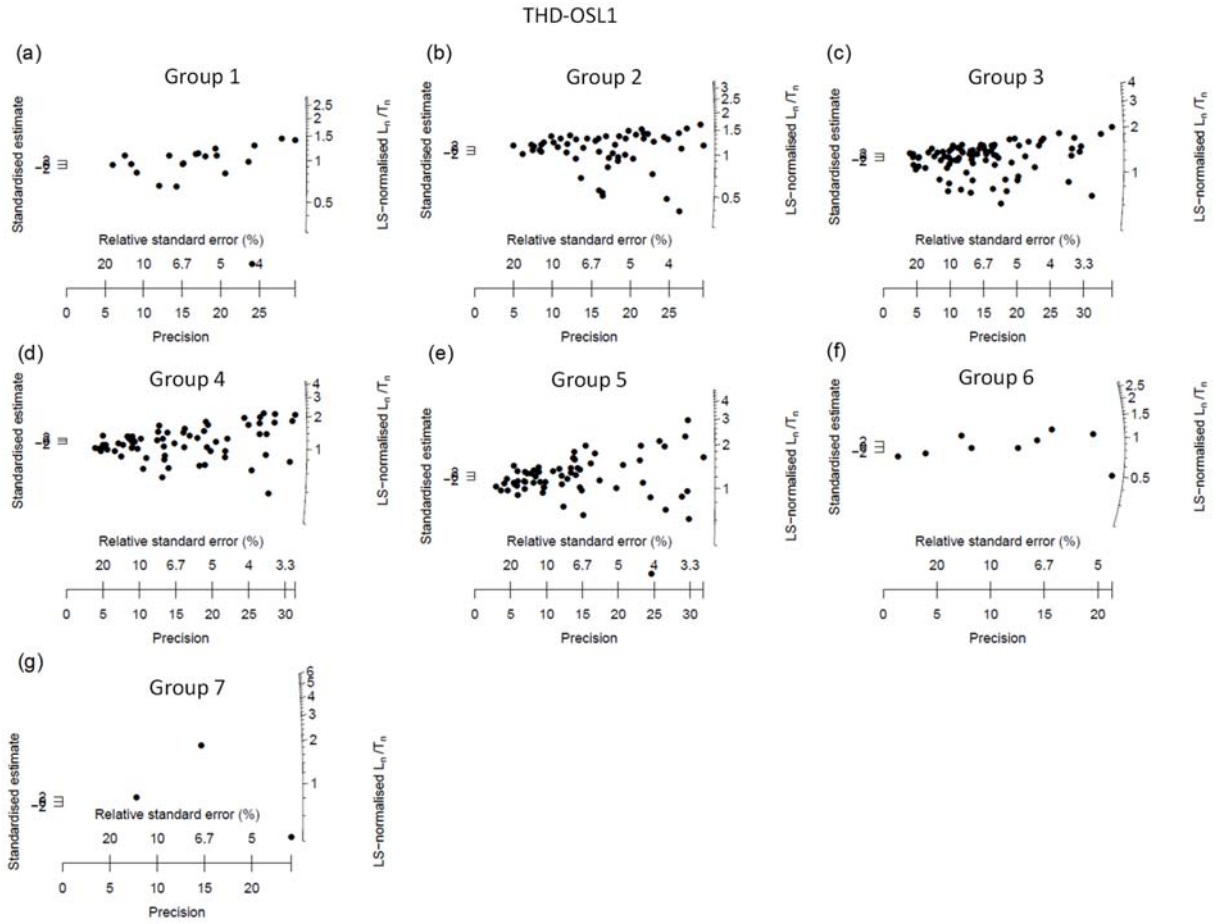

Figure S3. Radial plots showing the LS-normalised natural signals (L_n/T_n) of THD-1.

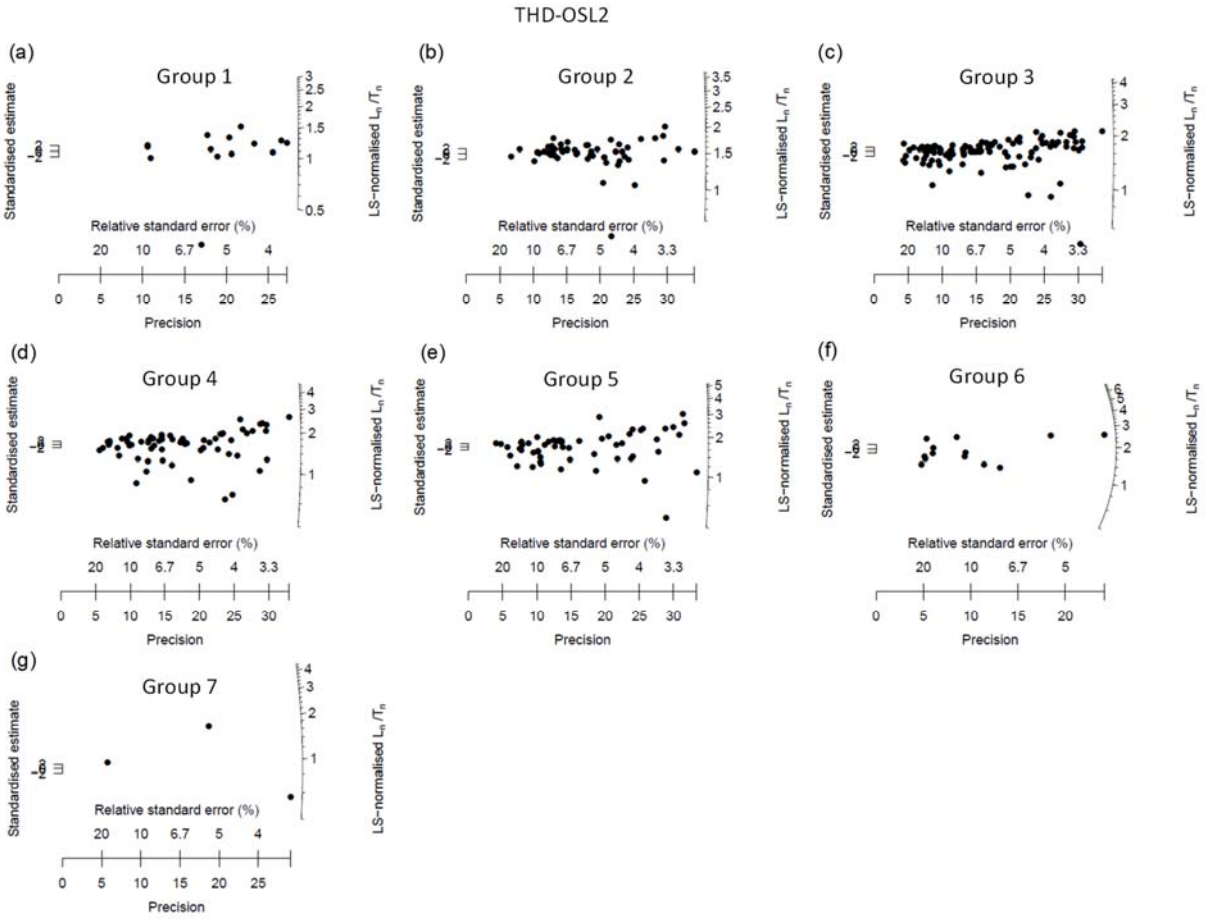

Figure S4. Radial plots showing the LS-normalised natural signals (L_n/T_n) of THD-2.

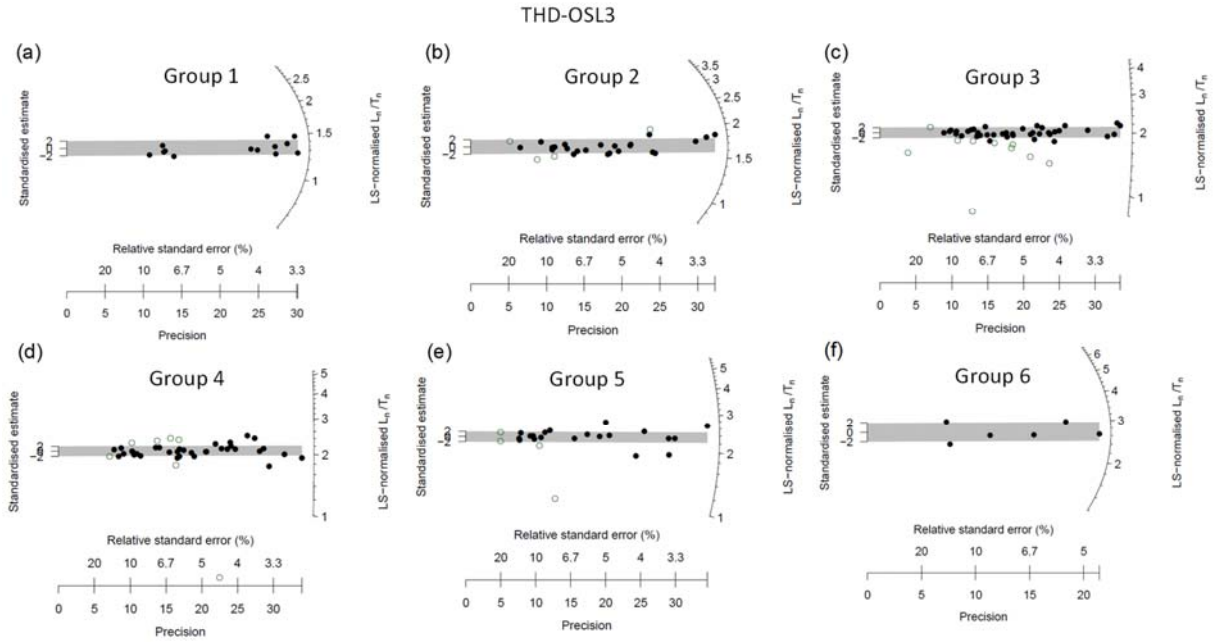

Figure S5. Radial plots showing the LS-normalised natural signals (L_n/T_n) of THD-3. Filled circles represent the outliers identified using the normalised median absolute deviation (nMAD) method. The grey bars represent the weighted mean (using CAM) value obtained based on the filled circles.

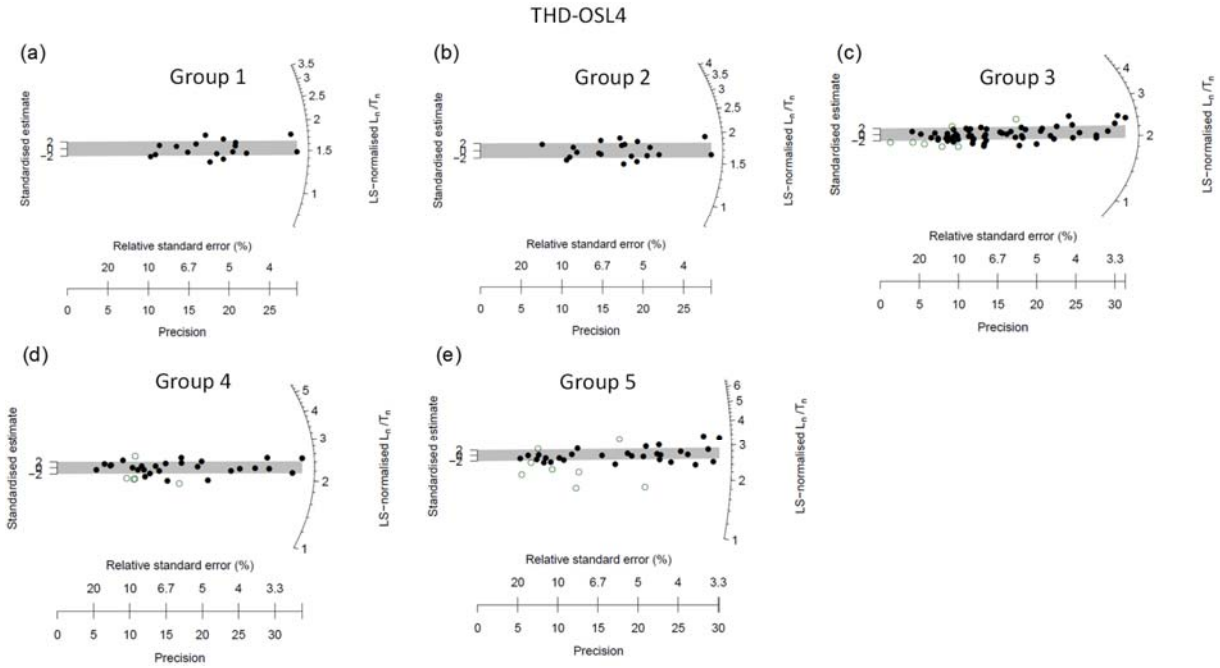

Figure S6. Radial plots showing the LS-normalised natural signals (L_n/T_n) of THD-4. Filled circles represent the outliers identified using the normalised median absolute deviation (nMAD) method. The grey bars represent the weighted mean (using CAM) value obtained based on the filled circles.

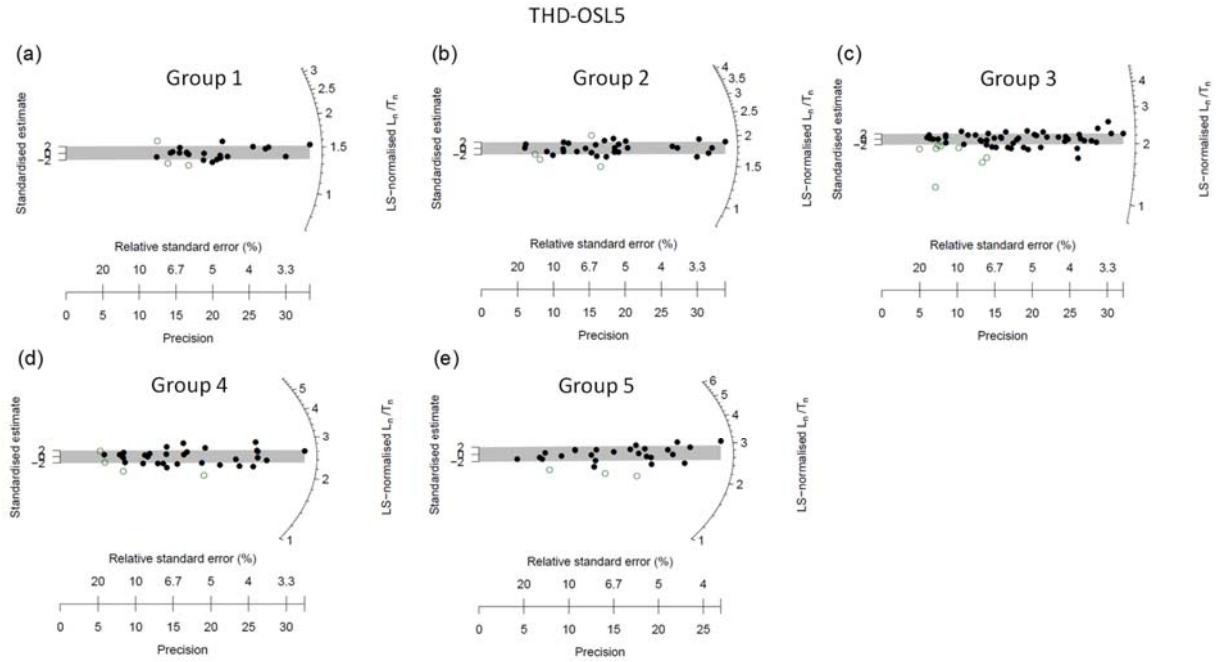

Figure S7. Radial plots showing the LS-normalised natural signals (L_n/T_n) of THD-5. Filled circles represent the outliers identified using the normalised median absolute deviation (nMAD) method. The grey bars represent the weighted mean (using CAM) value obtained based on the filled circles.

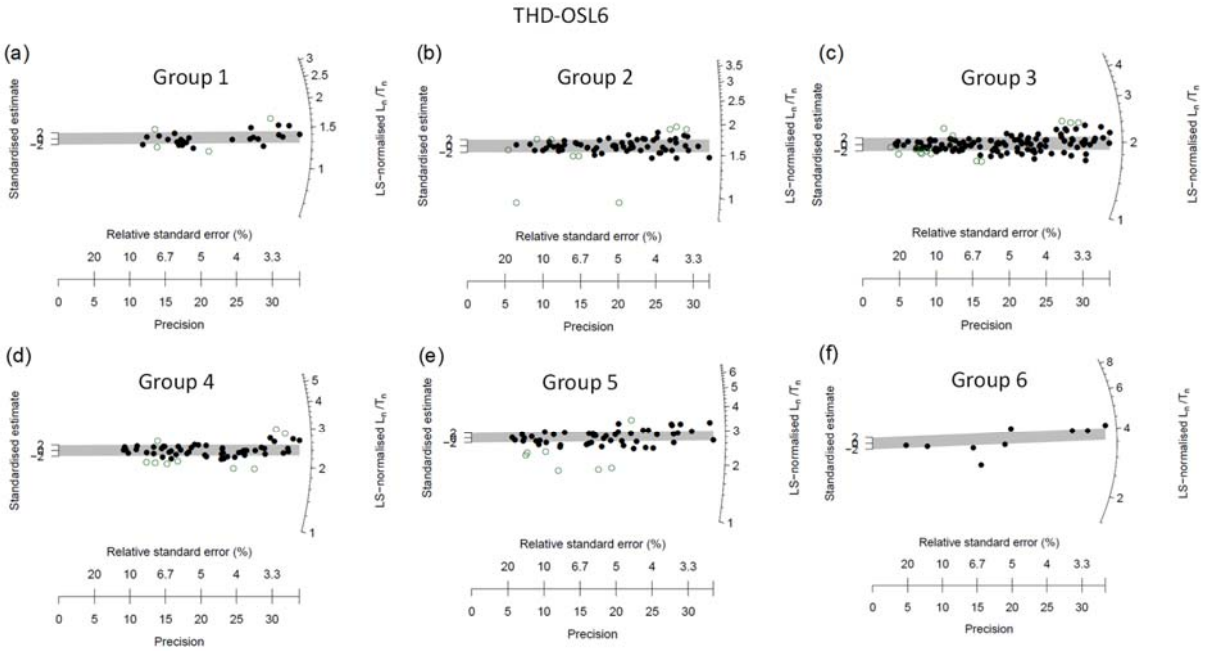

Figure S8. Radial plots showing the LS-normalised natural signals (L_n/T_n) of THD-6. Filled circles represent the outliers identified using the normalised median absolute deviation (nMAD) method. The grey bars represent the weighted mean (using CAM) value obtained based on the filled circles.