

Supplementary Materials for

Delta morphology reveals timings of early ocean regression and hydrologic shift on ancient Mars

Ren KITO, Hitoshi HASEGAWA*, Trishit RUJ†, Tetsuji MUTO, Gian Gabriele ORI,
Goro KOMATSU

Corresponding authors: *H. Hasegawa (hito_hase@kochi-u.ac.jp);

†T. Ruj (trishitruj@okayama-u.ac.jp)

This PDF file includes:

Figure S1: Overview of tank experimental set-up of Margi No. 5 at Nagasaki University.

Figure S2: Lobe-extruding deltas produced in water level fall experiments.

Figure S3: Stepped fan-deltas produced in water level rise experiments.

Figure S4: Schematic illustration how to measure the step height and deltaic plain area, and diagram showing deltaic plain area vs. step height of water-level rise experiments.

Table S1: Location and calculated age of lobe-extruding deltas on Mars.

Figure S5: Satellite images of Martian lobe-extruding deltas.

Figure S6: Age plots of lobe-extruding deltas.

Table S2: Location and calculated age of stepped fan-deltas on Mars.

Figure S7: Satellite images of Martian stepped fan-deltas.

Figure S8: Age plots of stepped fan-deltas.

Table S3: Location and calculated age of channelized SFDs in plains on Mars.

Figure S9: Satellite images of Channelized SFDs in plains on Mars.

Figure S10: Age plots of Channelized SFDs in plains on Mars.

Supplementary Videos (Timelapse video_Run 01 to Run 12) and **Crater Counting Files** (Crater Counting_Lobe-extruding delta_1-1 to 1-7; Crater Counting_Stepped fan-delta_2-1 to 2-30; Crater Counting_Channelized SFDs_3-1 to 3-4) are available in bellow website;
https://figshare.com/articles/dataset/Original_data_for_Kito_et_al_/30110344.

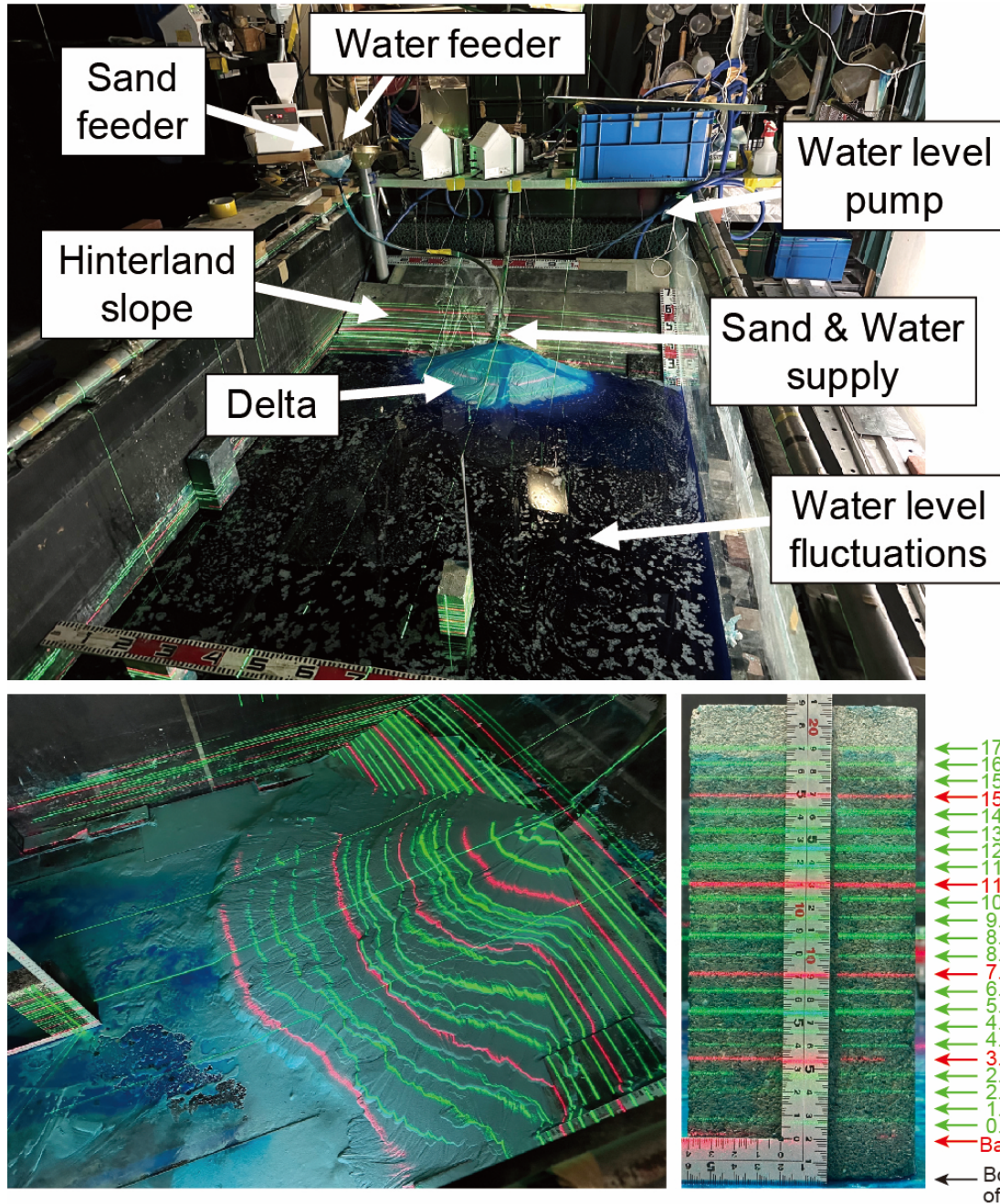


Figure S1: Overview of tank experimental set-up of Margi No. 5 at Nagasaki University. To represent the topographic contour lines, 23 horizontal laser planes are continuously projected onto the experimental area (spaced approximately 7.5 mm apart, with a reference plane set 2 cm above the bottom of the experimental tank). In the water level falling experiment, the initial water level is set to 13 cm above the baseline, and the final water level is 2 cm above the baseline. On the other hands, in the water level rising experiment, the initial water level is set to 2 cm above the baseline, and the final water level is 11 cm above the baseline.

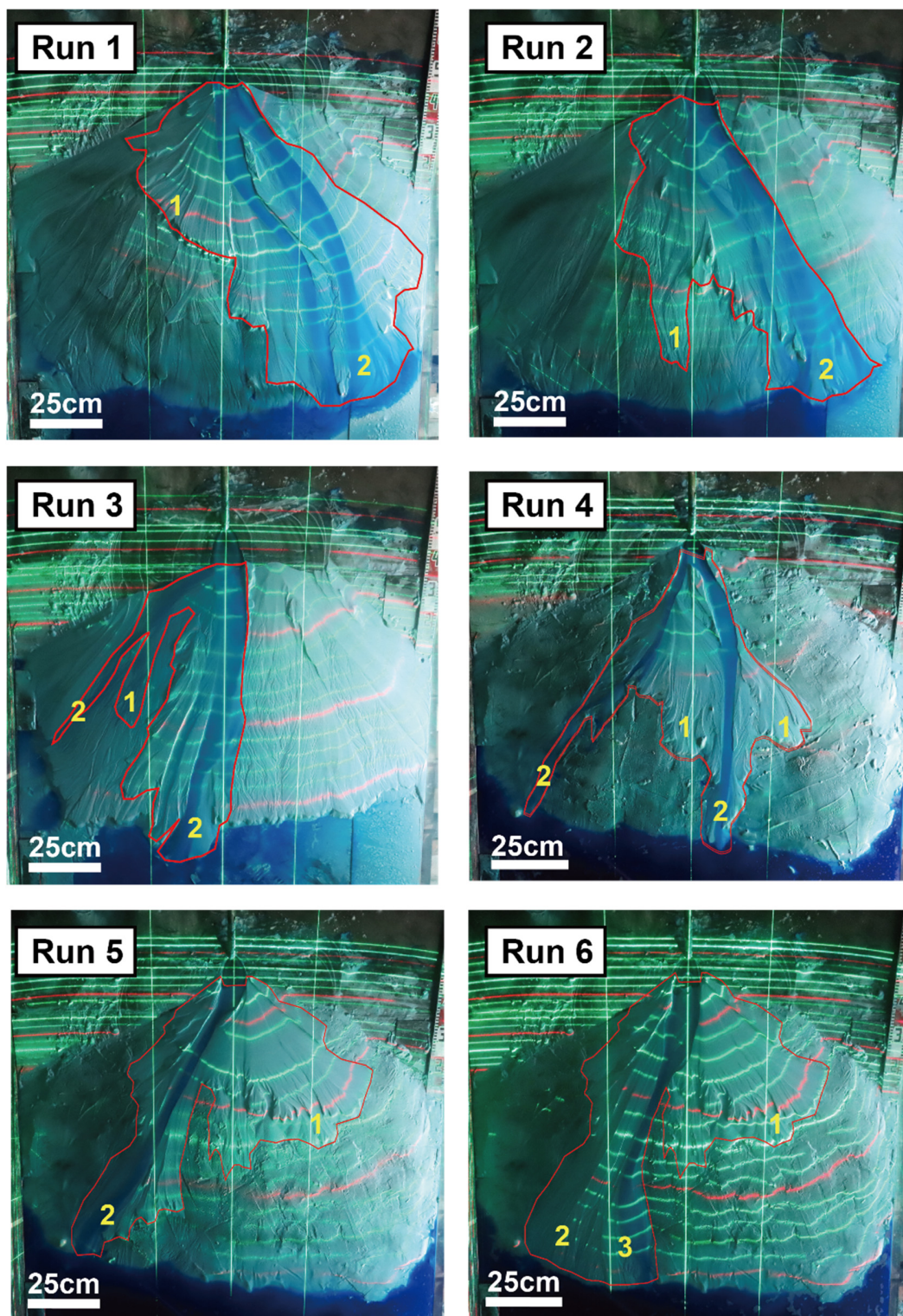


Figure S2: Lobe-extruding deltas produced in water-level fall experiments. The areas surrounded by the red lines are the formed deltas in experiments. The yellow numbers are the formation order of the lobes. Run 4 and Run 5 are shown in **Fig. 1C** and **Fig. 1A**, respectively. Three vertical laser planes were continuously projected (see **Fig. S1** for scale).

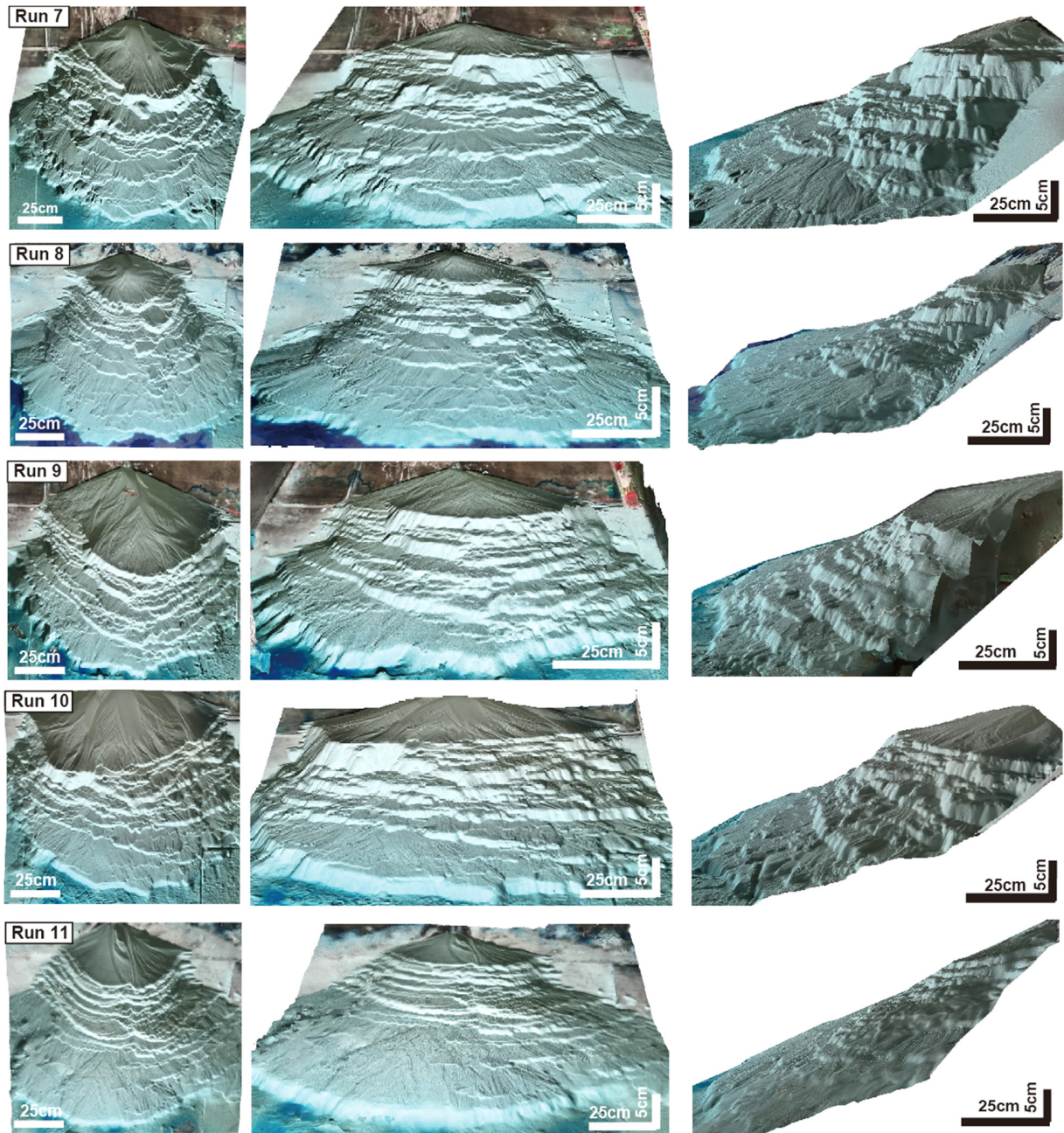


Figure S3: Stepped fan-deltas produced in water-level rise experiments. The left images show views from above, the center images show views from the front, and the right images show views from side. The images were captured from 3D images of experimental results constructed using Metashape software. Run7 is shown in **Fig. 2A**. The three-dimensional models were generated by the authors from the original image data using Agisoft Metashape Professional version (Agisoft LLC, St. Petersburg, Russia).

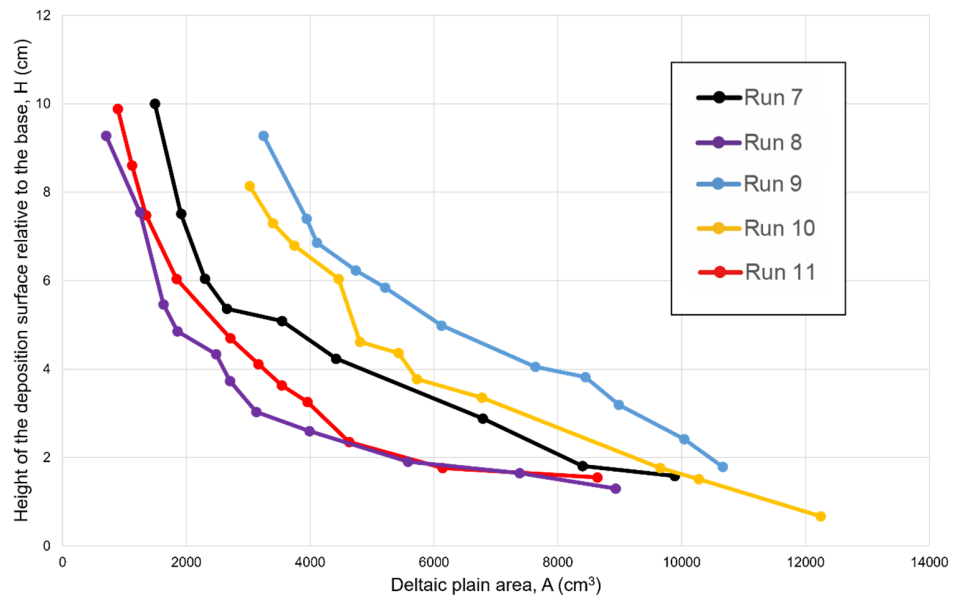
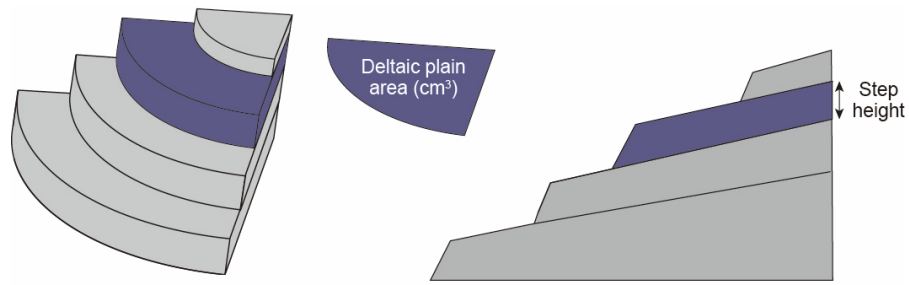


Figure S4 (Upper) Schematic illustration how to measure the step height and deltaic plain area.
(Lower) Diagram showing deltaic plain area vs. step height of water-level rise experiments.

Table S1: Location and calculated age of lobe-extruding deltas on Mars.

ID	Elevation (m)	Longitude (°)	Latitude (°)	Age (Ga)	Age error (Ga)	Delta Area (km²)	Channel length (km)	Basin type	Counted crater numbers
1-1	-3121.93	-53.12	36.4	3.80	+0.04 -0.05	97.42	155.7	Plain	334
1-2	-2760.24	155.9	4.47	3.30	+0.20 -0.70	167.5	418.4	Plain	69
1-3	-2633.29	-45.44	11.3	3.50	+0.04 -0.06	523.9	264.4	Plain	345
1-4	-2326.94	77.30	18.5	3.50	+0.07 -0.10	30.54	153.3	Open→ Closed	67
1-5	-2294.10	154.5	-4.94	3.20	+0.20 -1.00	1452	43.99	Plain	391
1-6	-2077.49	149.0	-6.29	3.60	+0.07 -0.10	910.0	123.6	Plain	153
1-7	-1718.14	-55.54	35.1	1.60	+0.30 -0.30	23.39	93.67	Open→ Closed	90

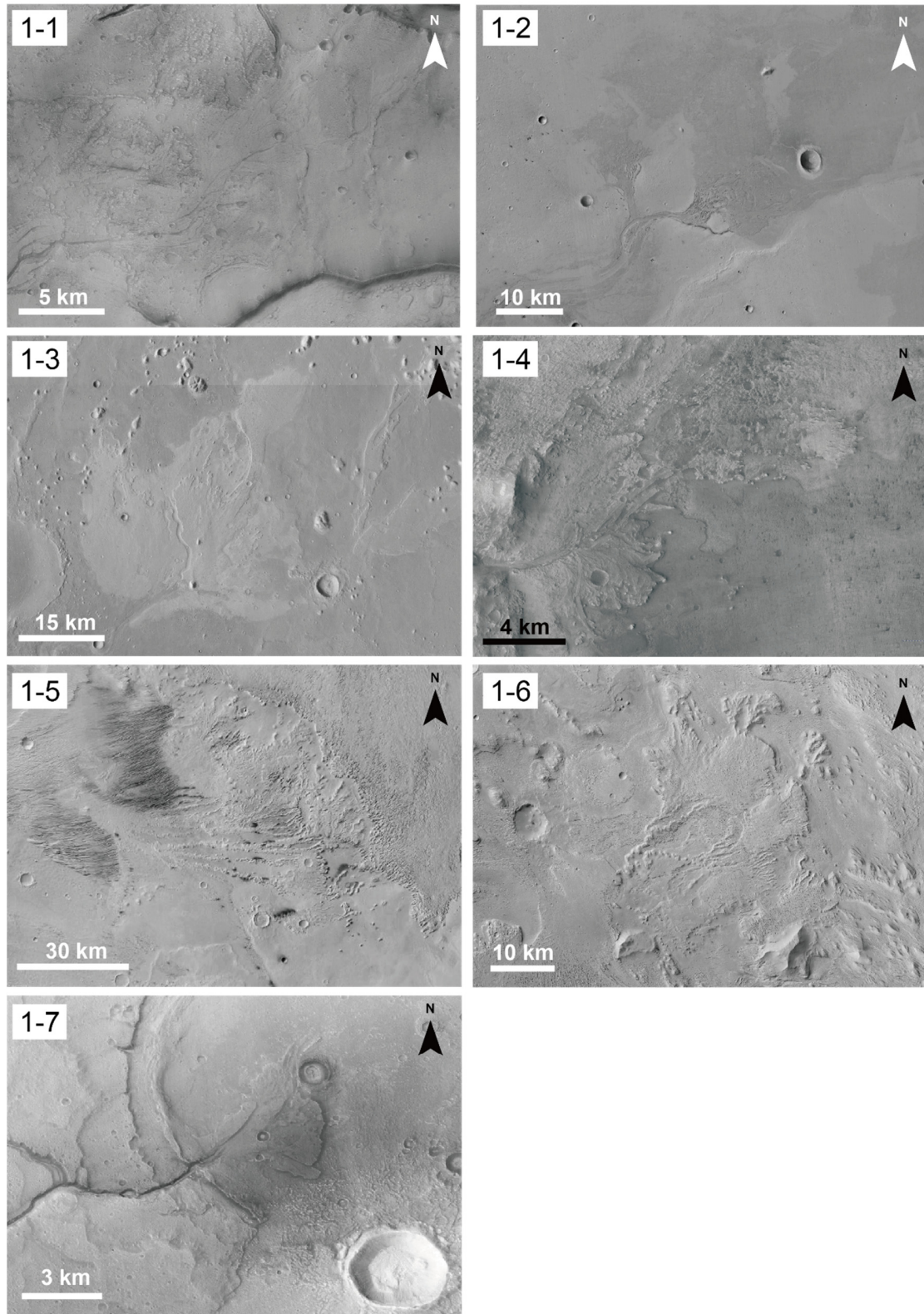


Figure S5: Satellite images of lobe-extruding deltas. The numbers at the top left indicate the IDs. ID 1-3 and ID 1-4 are shown in **Fig. 1d** and **1b**, respectively. CTX⁸¹ images were used.

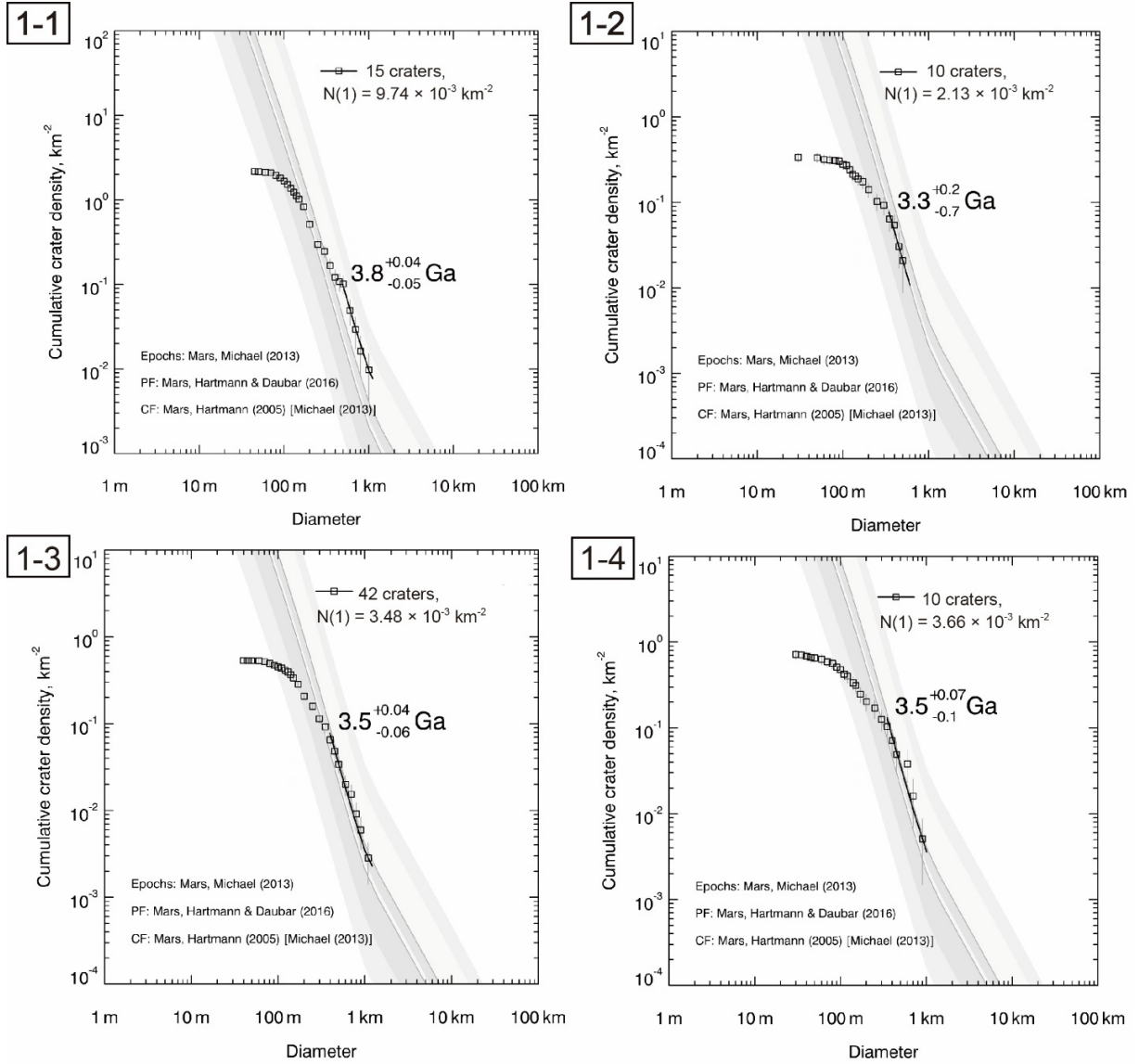
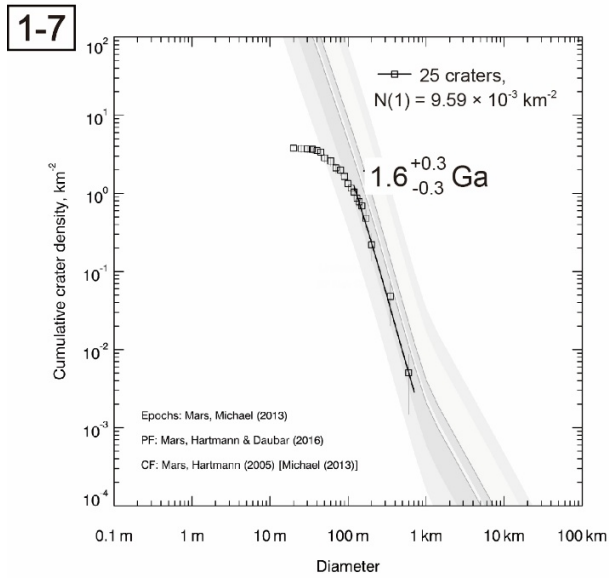
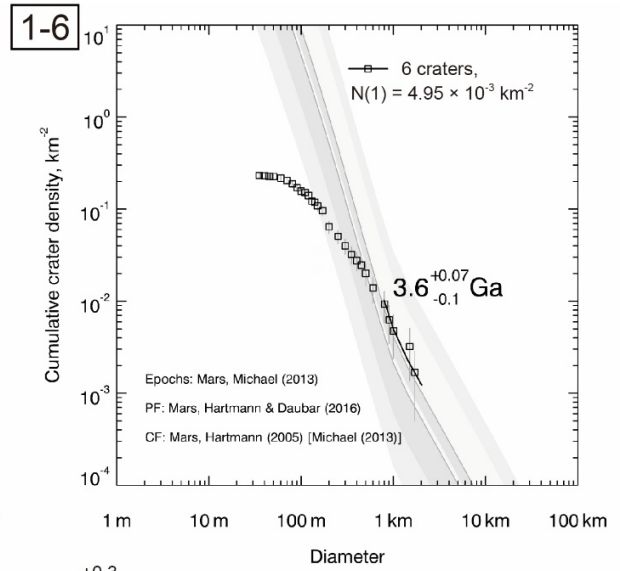
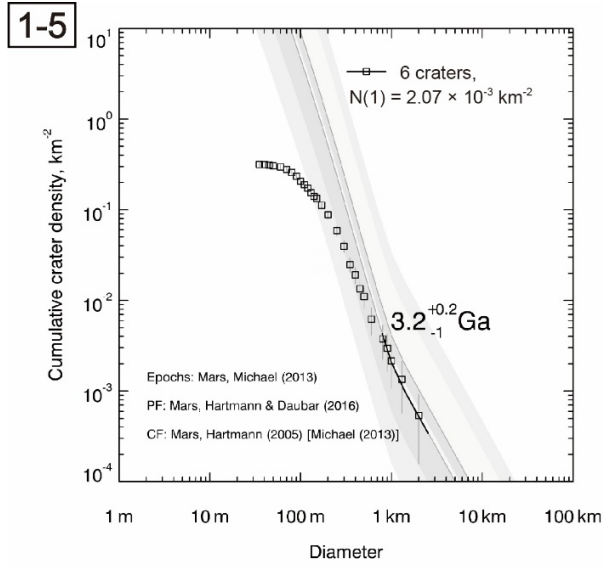


Figure S6: Age plots of lobe-extruding deltas. The numbers at the top left indicate the IDs. CSFD and model ages were calculated and plotted by the authors using Craterstats II software developed by G. G. Michael, Freie Universität Berlin^{14,76}.



$1.6^{+0.3}_{-0.3} \text{ Ga}$

Figure S6 (continued)

Table S2: Location and calculated age of stepped fan-deltas.

ID	Longitude (°)	Latitude (°)	Elevation (m)	Age (Ga)	Age error (Ga)	Delta Area (km²)	Channel length (km)	Counted crater numbers
2-1	-22.94	22.05	-4673	0.60	+0.20 -0.20	3.21	6.94	35
2-2	-11.15	33.23	-4360	0.34	+0.10 -0.10	4.92	6.22	13
2-3	-13.17	31.64	-4366	1.10	+0.20 -0.20	21.56	12.50	94
2-4	-8.49	22.46	-4131	0.60	+0.30 -0.30	1.39	4.21	13
2-5	-8.38	22.55	-4096	0.29	+0.09 -0.09	7.04	10.66	29
2-6	136.74	-4.99	-3740	1.70	+0.60 -0.60	12.38	32.51	19
2-7	0.40	35.85	-3486	0.65	+0.20 -0.20	9.06	7.58	29
2-8	-9.36	35.31	-3480	1.20	+0.60 -0.60	2.16	3.96	14
2-9	-24.31	14.05	-3111	0.21	+0.06 -0.06	8.65	7.28	31
2-10	-38.97	7.57	-2760	0.22	+0.04 -0.04	18.26	9.45	64
2-11	-3.42	34.82	-3098	0.85	+0.40 -0.40	7.45	5.56	24
2-12	2.45	33.39	-2848	0.18	+0.07 -0.07	19.19	3.46	37
2-13	-15.78	8.98	-2674	1.40	+0.50 -0.50	10.90	7.89	47
2-14	4.14	33.86	-2548	0.15	+0.03 -0.03	3.83	4.16	26
2-15	11.72	19.64	-2344	0.0049	+0.002 -0.002	17.01	16.98	10
2-16	17.16	31.15	-1897	0.38	+0.20 -0.20	8.72	12.42	27
2-17	-49.74	8.44	-1989	3.50	+0.04 -0.06	78.69	93.70	192
2-18	-51.67	2.73	-1623	0.68	+0.10 -0.10	74.24	18.41	156
2-19	-159.26	-8.63	-1903	2.00	+0.90 -0.10	68.82	18.33	67
2-20	141.12	-6.57	-1862	3.20	+0.20 -0.10	56.88	10.84	128
2-21	-52.97	11.71	-778	2.10	+0.70 -0.70	23.87	24.49	20

2-22	144.79	-10.40	-656	1.30	+0.40 -0.40	10.84	10.35	20
2-23	157.52	-12.78	-426	0.59	+0.10 -0.10	2.18	2.13	27
2-24	-146.57	-8.00	-608	0.66	+0.10 -0.10	15.13	12.42	26
2-25	116.20	1.40	-107	0.61	+0.20 -0.20	4.80	4.47	12
2-26	118.19	-0.89	357	1.50	+0.40 -0.40	22.71	5.59	45
2-27	-50.26	-4.59	242	0.15	+0.04 -0.04	14.56	7.18	12
2-28	-58.92	-15.10	274	0.78	+0.20 -0.20	12.87	3.89	21
2-29	-53.44	-9.85	1472	1.30	+0.30 -0.30	7.59	5.81	21
2-30	-60.26	-15.02	1948	1.00	+0.30 -0.30	33.65	41.52	59

* Almost all of stepped fan-deltas located in closed basins. But only ID 2-14 has an outflow channel and could potentially be classified as an open basin. However, since the elevation of outflow channel is higher than the top of the stepped fan-delta, we classified it as a closed basin.

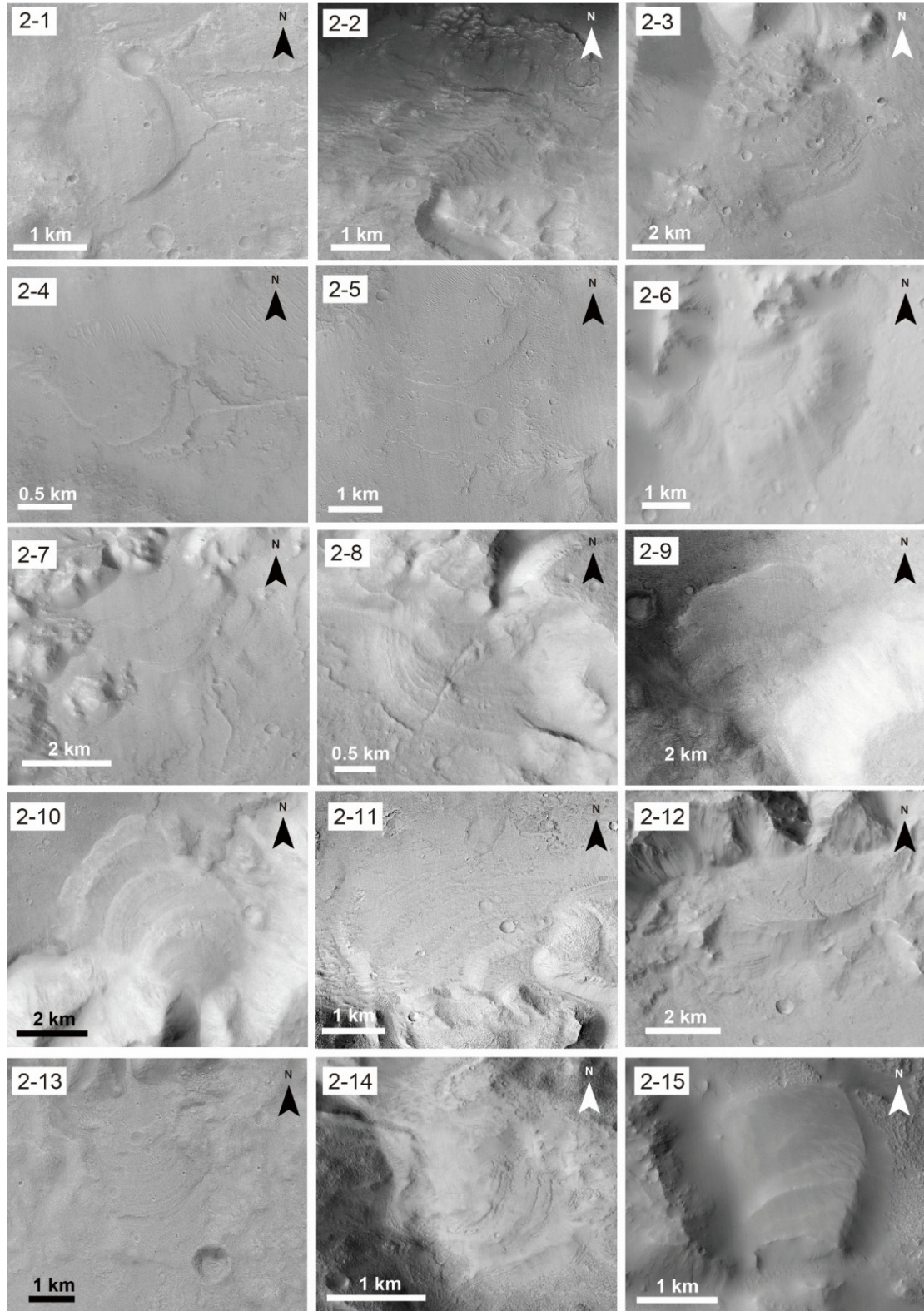


Figure S7: Satellite images of stepped fan-deltas in closed basins. The numbers at the top left indicate the IDs. ID 2-19 and ID 2-30 are shown in **Fig. 2b** and **2c**, respectively. CTX⁸¹ images were used.

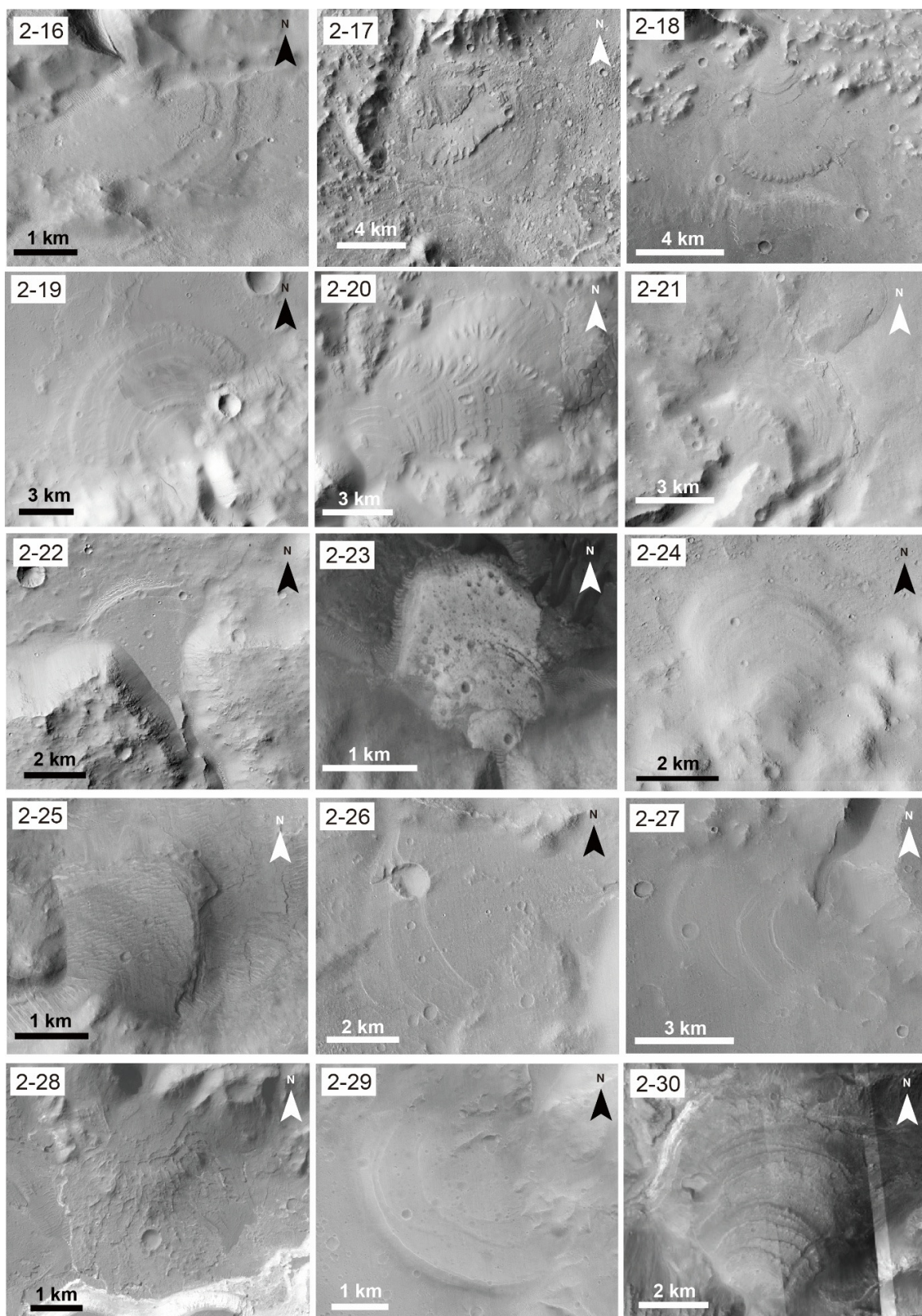


Figure S7 (continued)

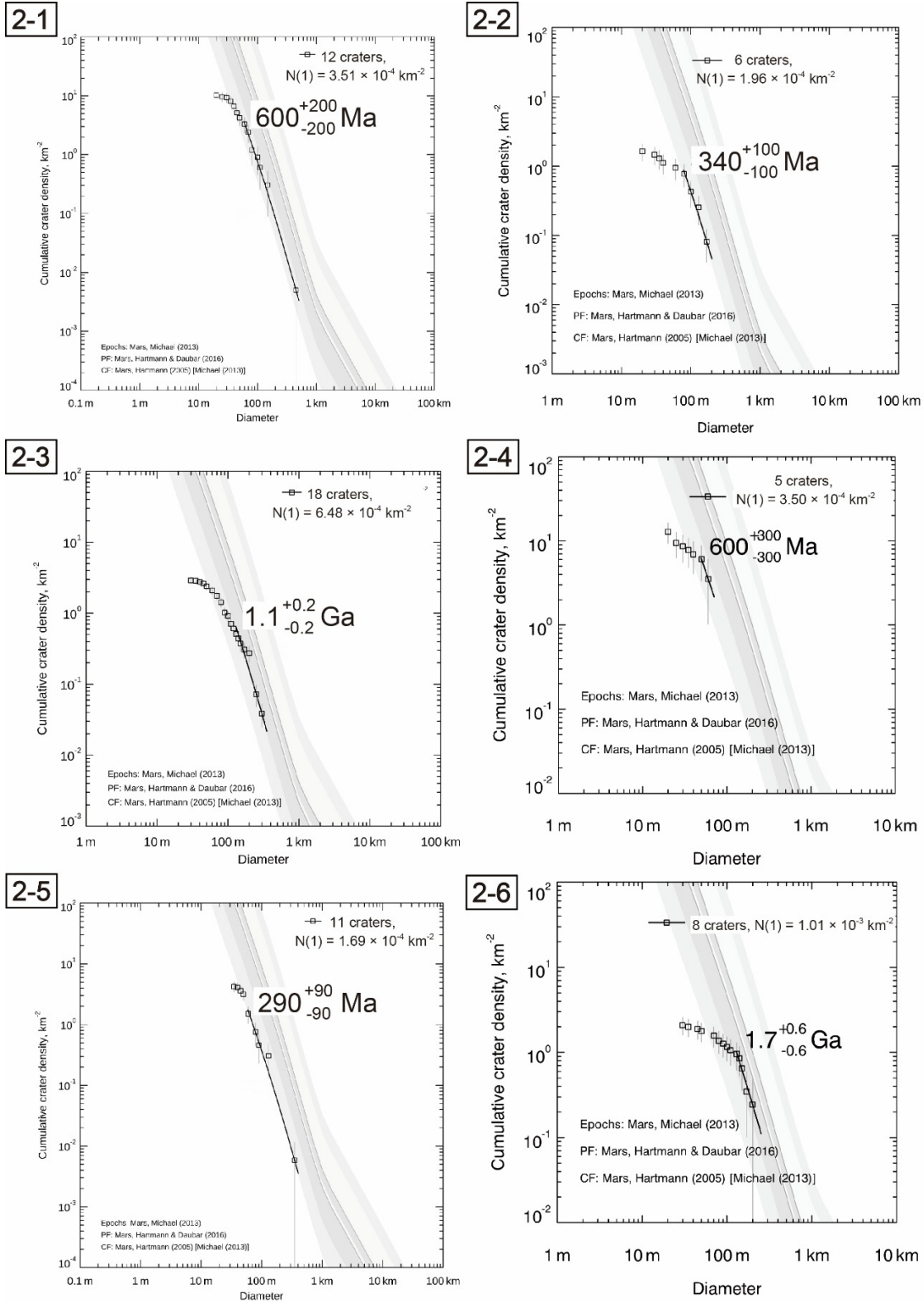
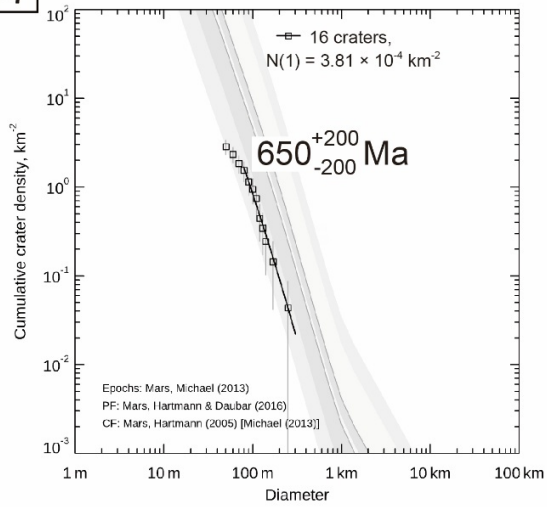
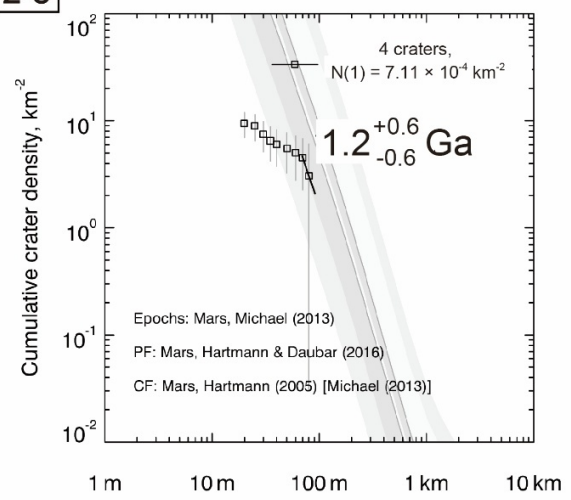


Figure S8: Age plots of stepped fan-deltas in closed basins. The numbers at the top left indicate the ID number of stepped fan-delta. CSFD and model ages were calculated and plotted by the authors using Craterstats II software developed by G. G. Michael, Freie Universität Berlin^{14,76}.

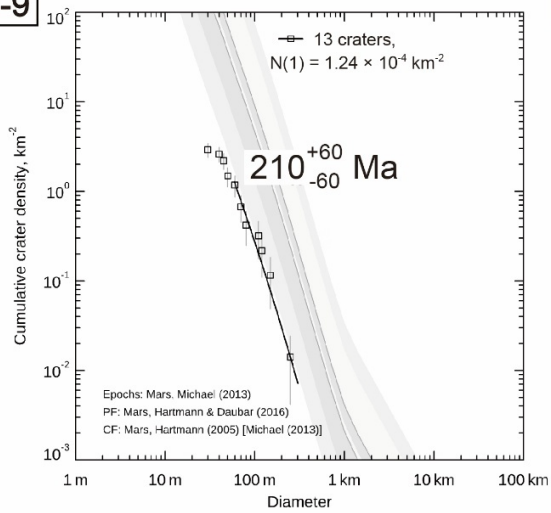
2-7



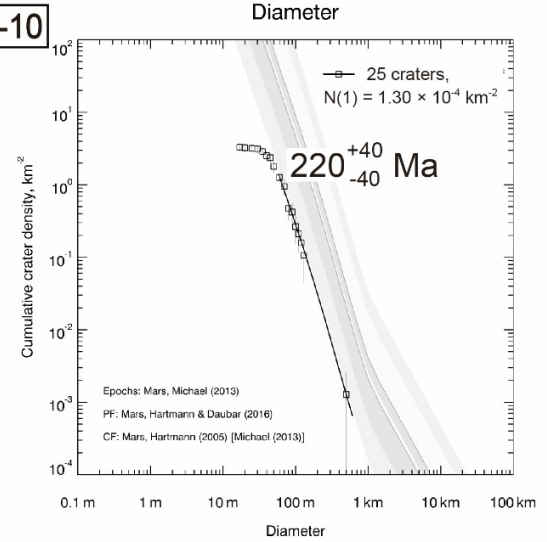
2-8



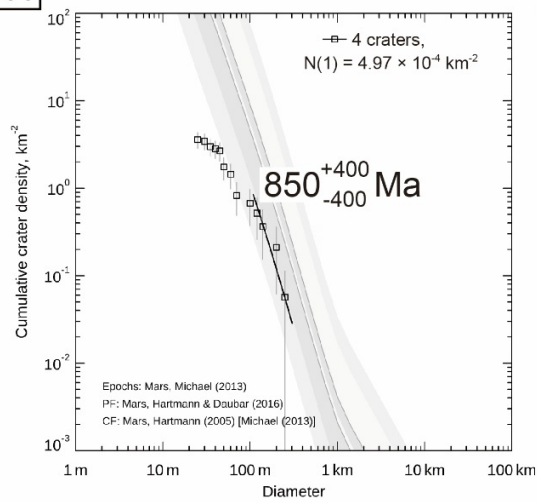
2-9



2-10



2-11



2-12

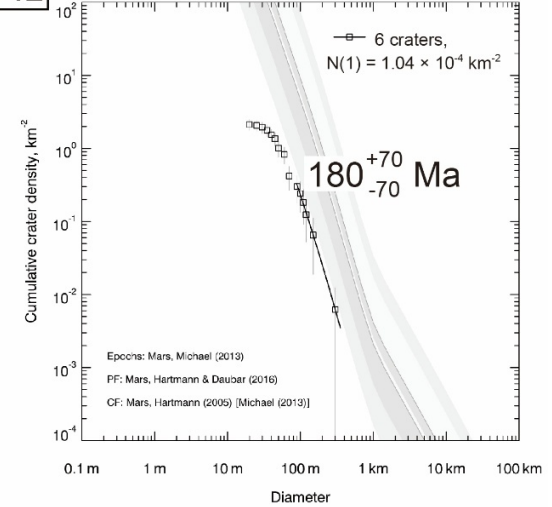


Figure S8 (continued)

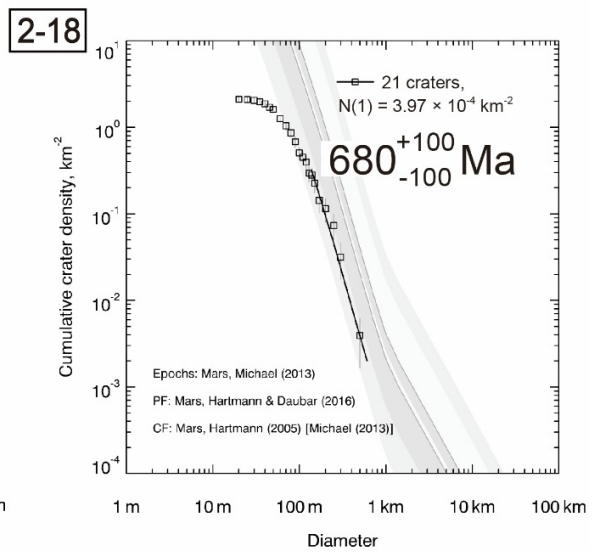
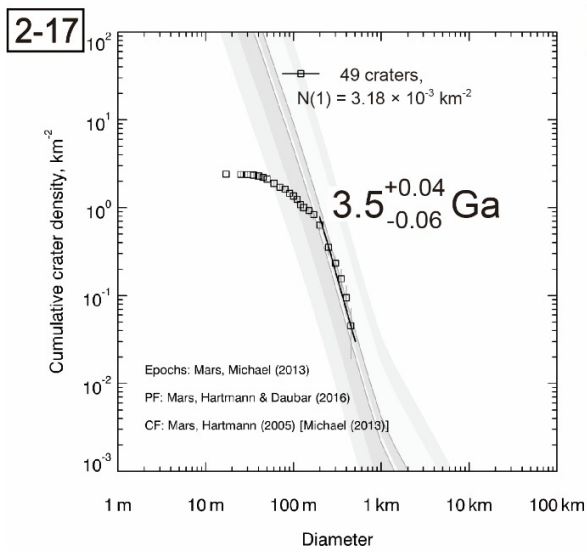
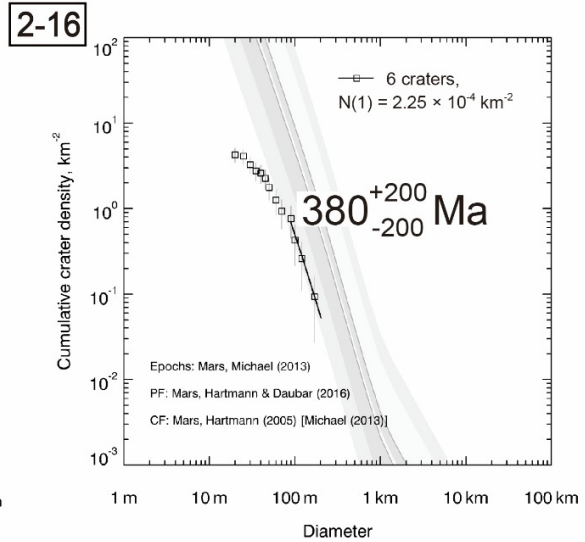
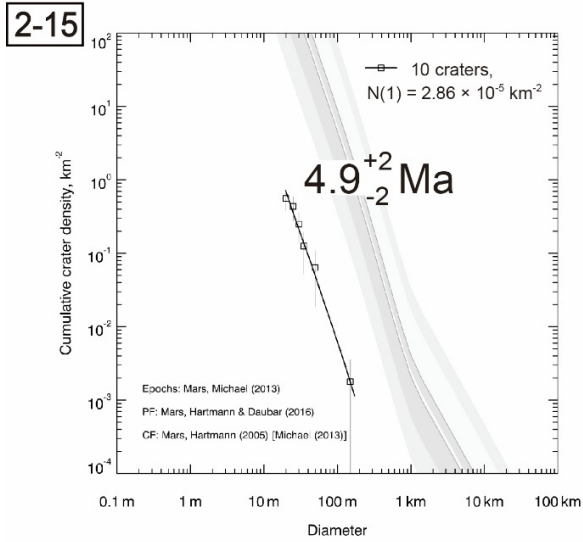
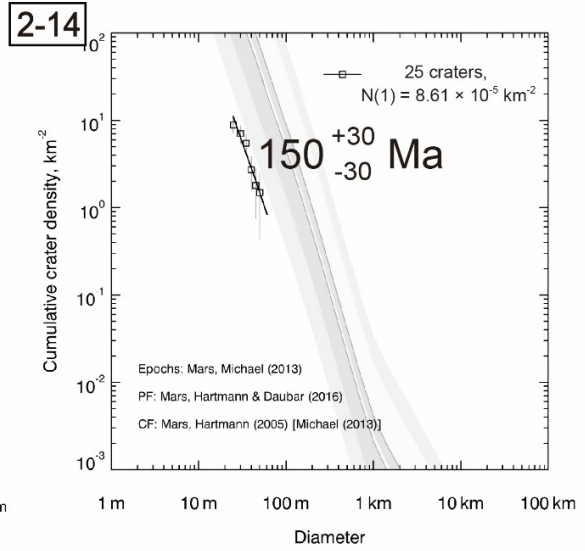
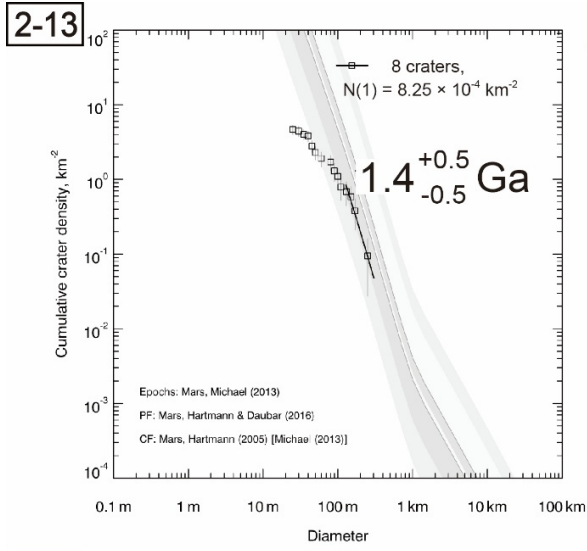


Figure S8 (continued)

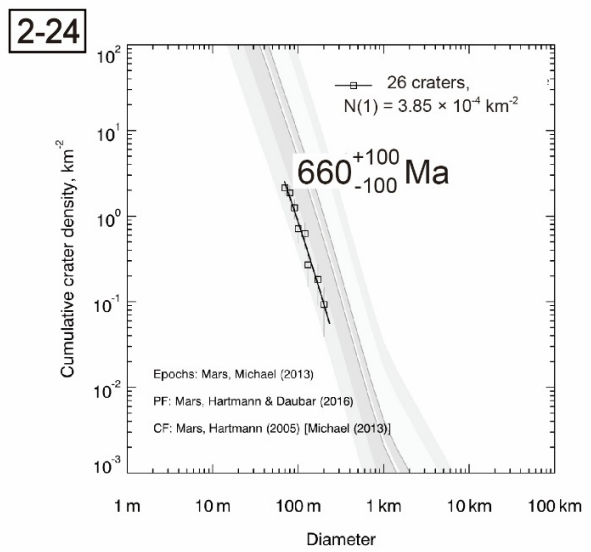
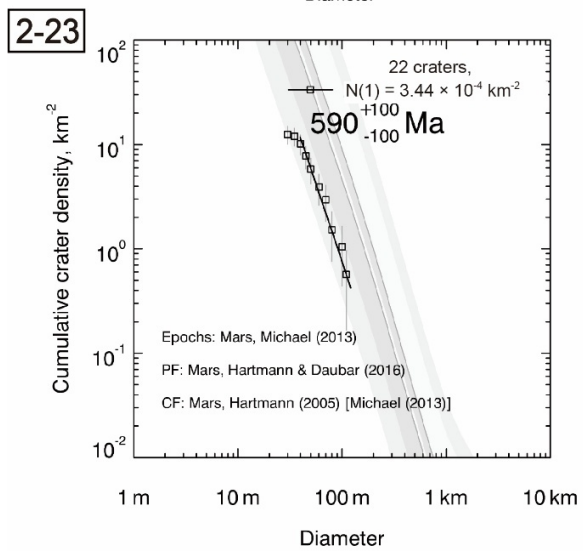
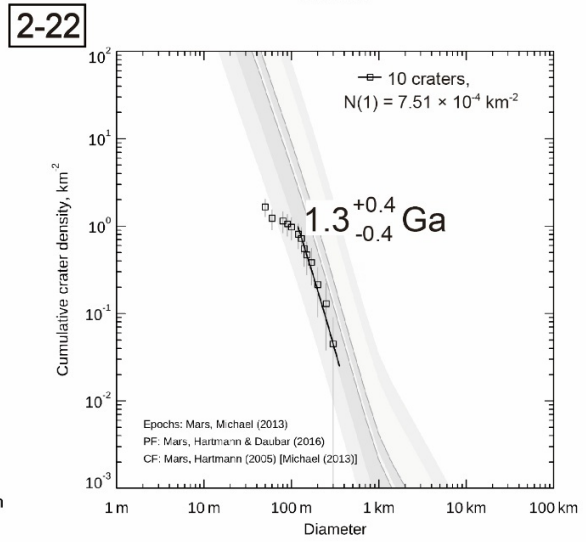
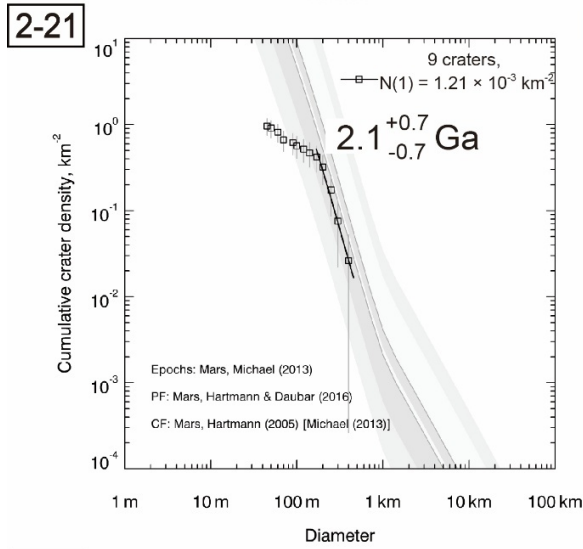
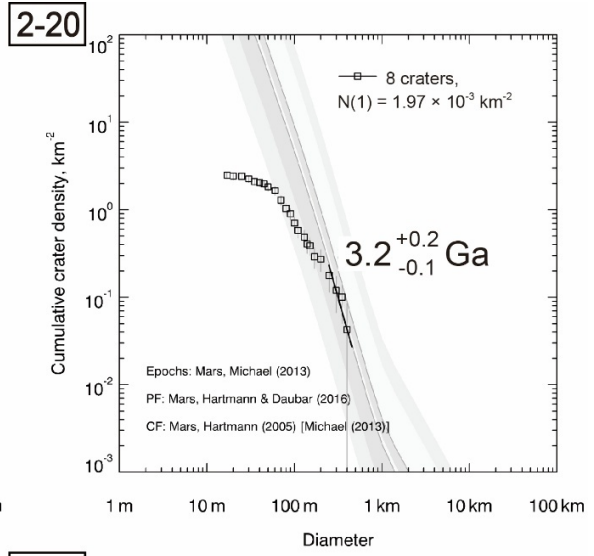
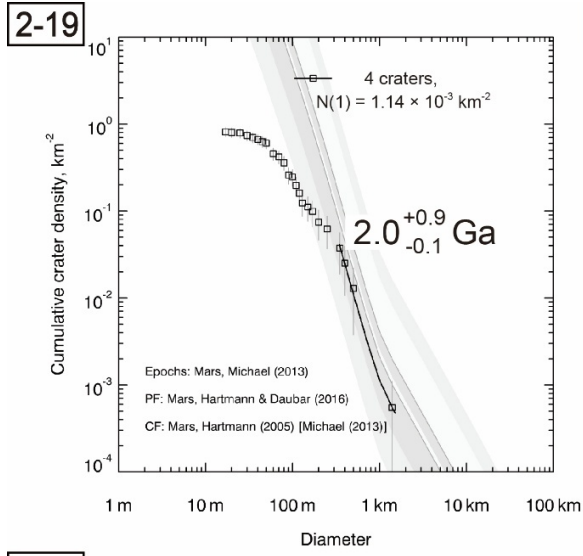


Figure S8 (continued)

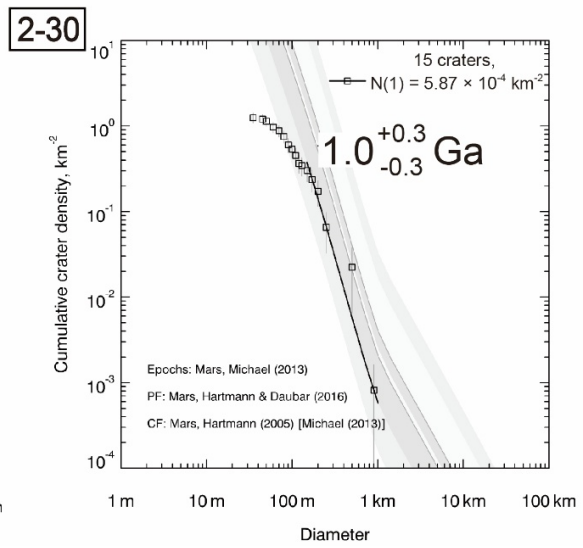
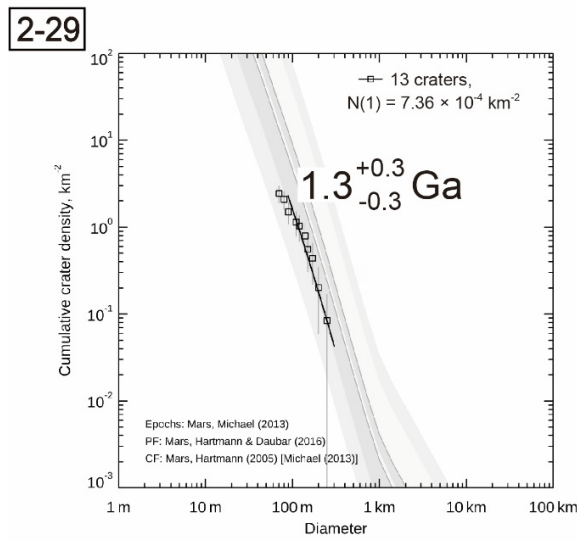
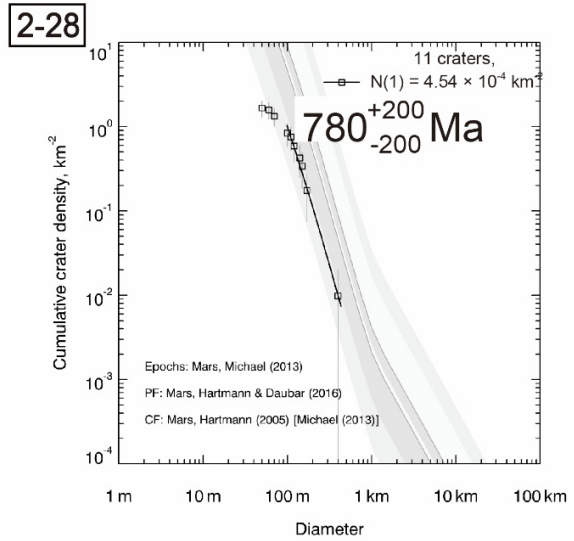
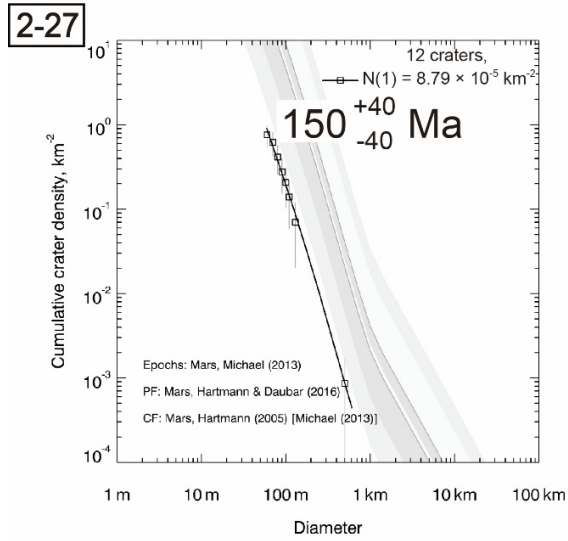
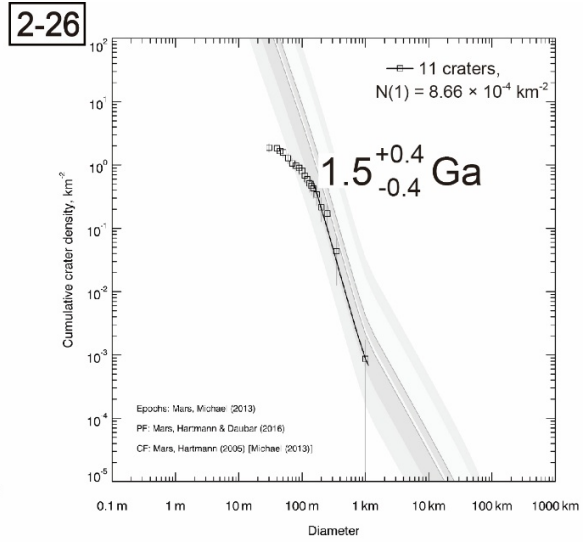
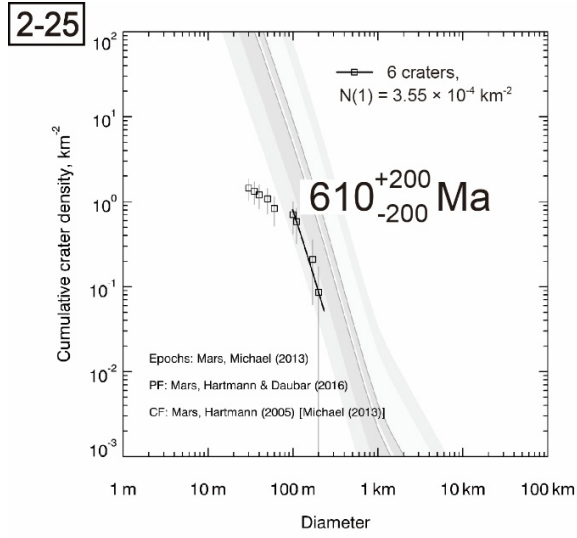


Figure S8 (continued)

Table S3: Location and calculated age of Channelized SFDs in plains on Mars.

ID	Elevation (m)	Longitude (°)	Latitude (°)	Age (Ga)	Age error (Ga)	Delta Area (km²)	Channel length (km)	Basin type	Counted crater numbers
3-1	-2973.99	-23.81	17.81	3.70	+0.06 -0.10	75.93	193.66	Plain	72
3-2	-2534.38	10.04	37.27	3.40	+0.07 -0.10	363.12	116.29	Plain	282
3-3	-2456.98	-47.01	11.66	3.60	+0.08 -0.20	253.24	269.06	Plain	72
3-4	-2090.35	151.06	-6.84	3.40	+0.10 -1.00	2449.22	79.47	Plain	68

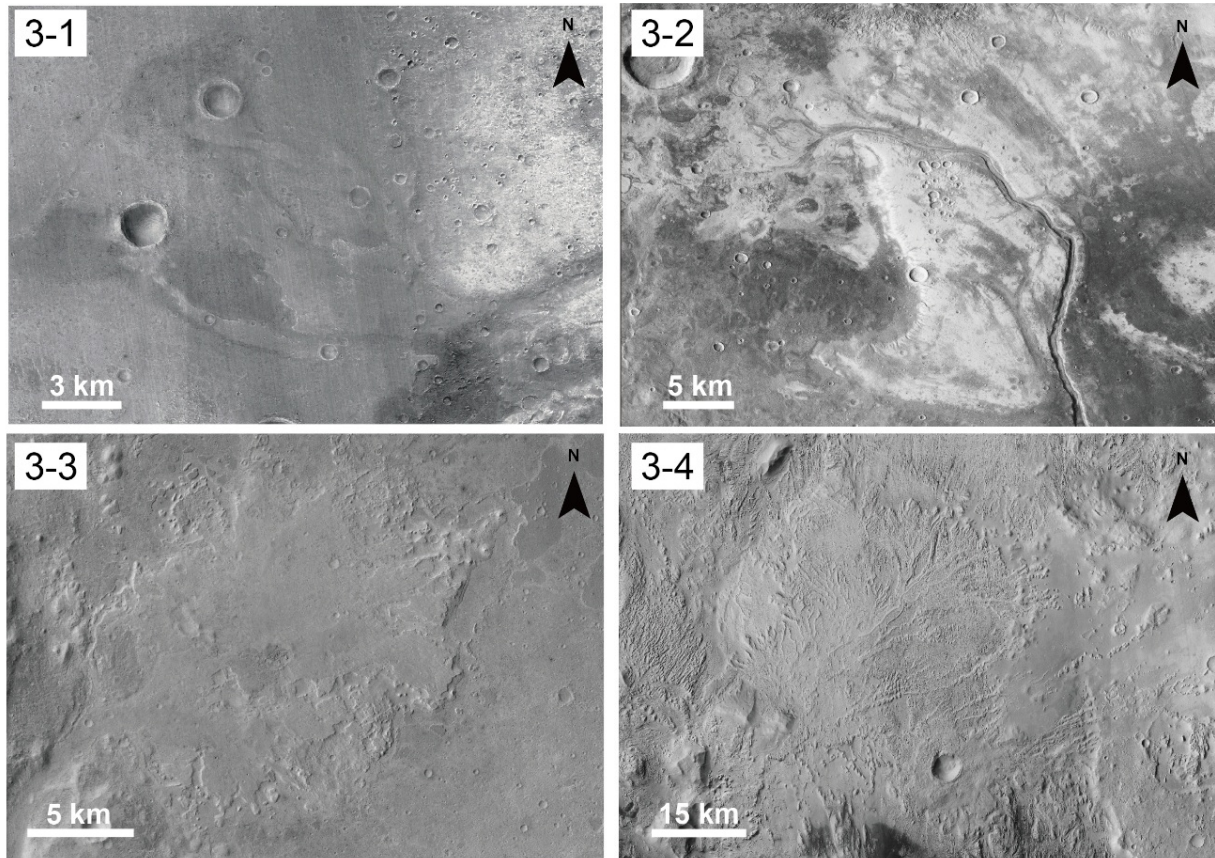


Figure S9: Satellite images of Channelized SFDs in plains on Mars. The numbers at the top left indicate the IDs. CTX⁸¹ images were used.

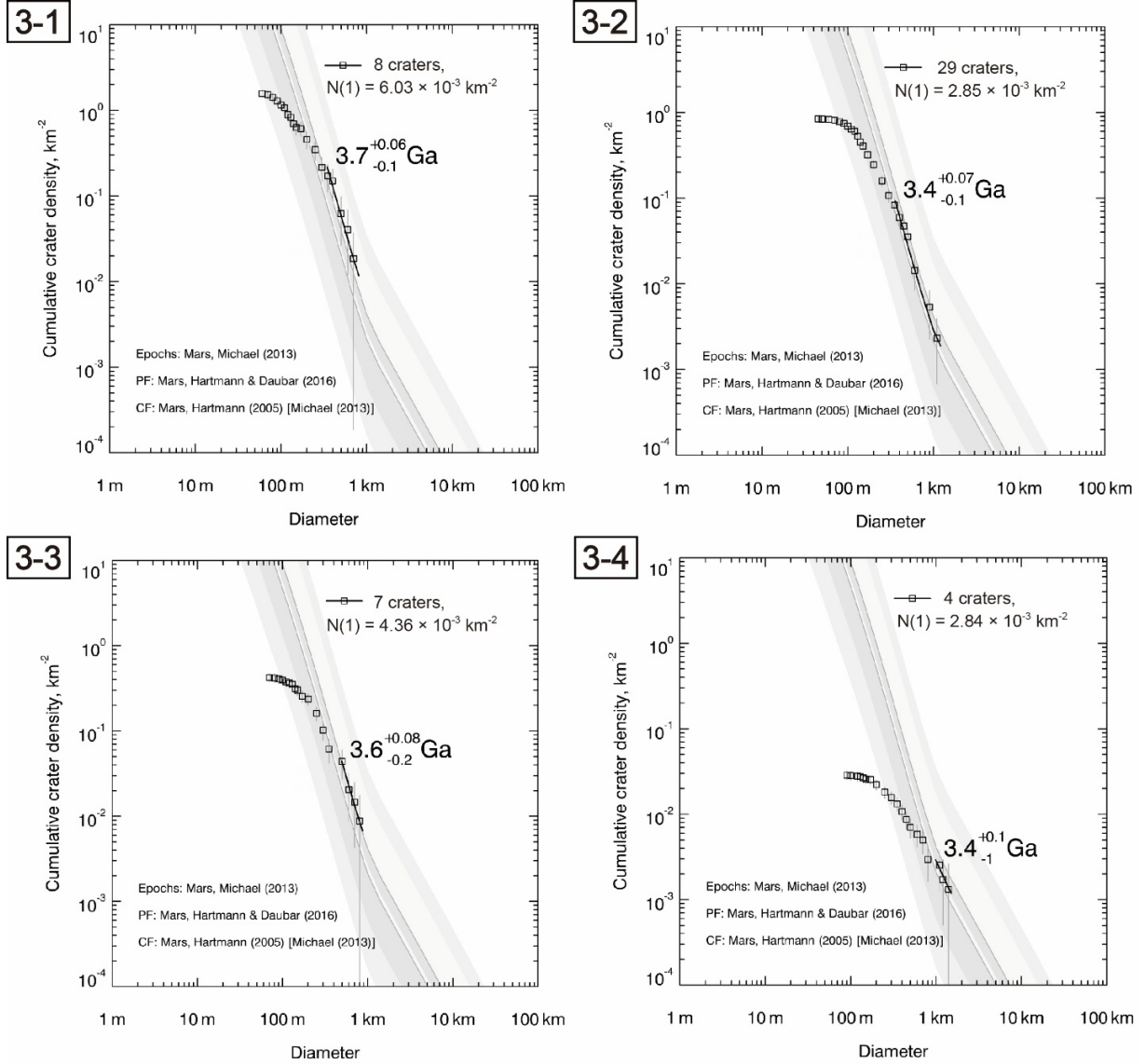


Figure S10: Age plots of Channelized SFDs in plains on Mars. The numbers at the top left indicate the IDs. CSFD and model ages were calculated and plotted by the authors using Craterstats II software developed by G. G. Michael, Freie Universität Berlin^{14,76}.