

Supplementary Material to the paper:

”Structural analysis of clastic dikes using Structure from Motion–Multi-View Stereo: a case-study in the Paraná Basin, southeastern Brazil“

by Camila D. Viana¹, Carlos H. Grohmann², Mariana S.T. Busarello¹ and Guilherme P.B. Garcia¹

¹ - Institute of Geosciences, University of São Paulo, Brazil

² - Institute of Energy and Environment, University of São Paulo, Brazil

1. Location

Location of study area in Google Maps: <https://goo.gl/maps/UdkNeZfSbvQ2>

2. Figures

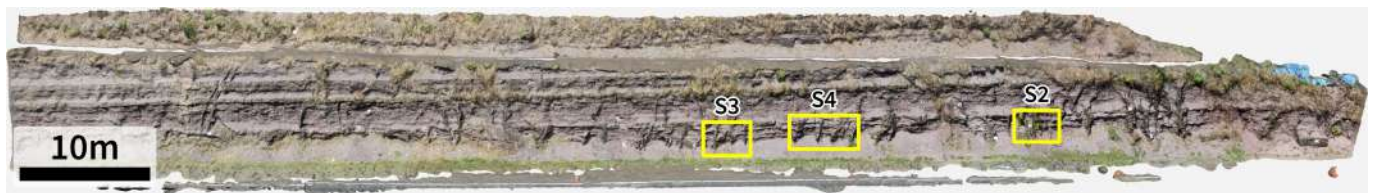


Figure S1. Location of figures S2, S3 and S4.



Figure S2. Example of distortion and artifacts generated on the DOM. The surface sampling was not performed on these areas as the surface distortion would significantly affect measurements.

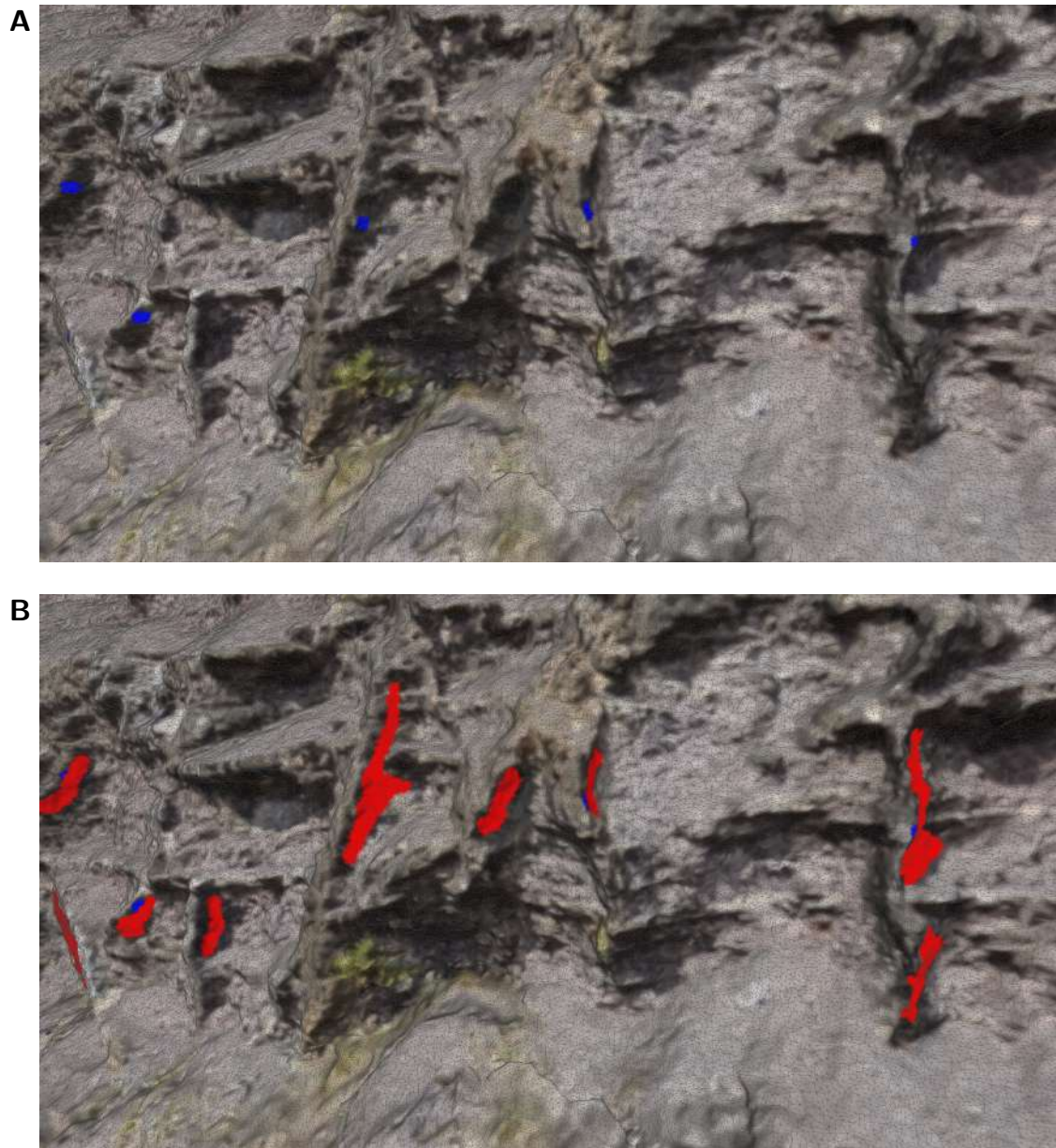


Figure S3. Example of different sample techniques performed on DOM using MeshLab. A) Punctual sampling (blue) was made using a 7 pixel circular brush to simulate field measures. B) Surface sampling (red) was made selecting the whole visible surface of the dikes.

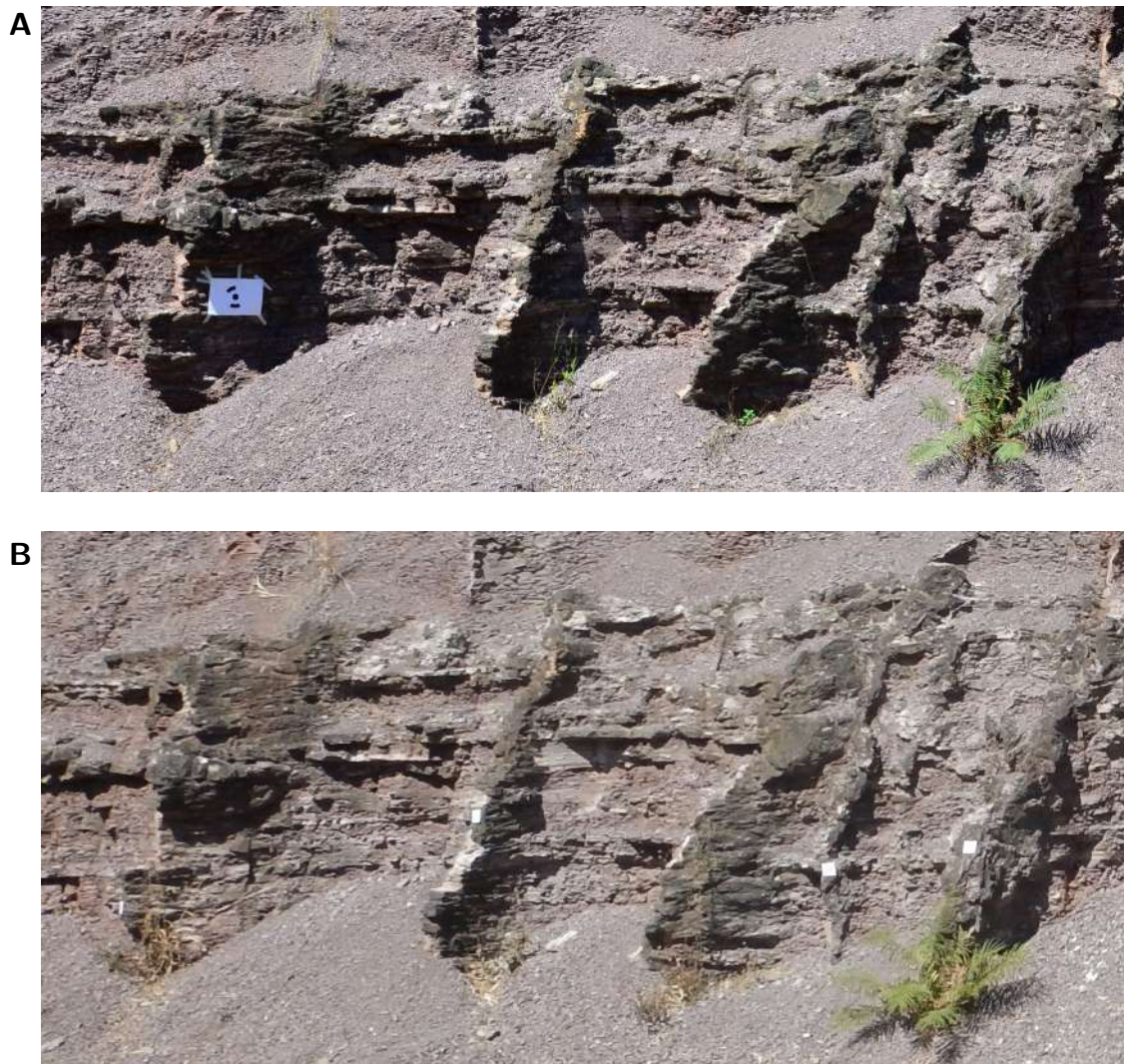


Figure S4. Shadowing effect on pictures taken at different moments. A) Image acquired on 09-05-2017 at 12:36 (GMT -3); solar illumination at N346.0° with inclination of 60.1°. B) Image acquired on 11-07-2017 at 13:45 (GMT -3); solar illumination at N294.6° with inclination of 76.5°. Solar positioning was determined with The Photographer's Ephemeris App (<https://www.photoephemeris.com>).



Figure S5. Generated digital outcrop model (DOM) with camera positions (in blue) and GCPs (flags)

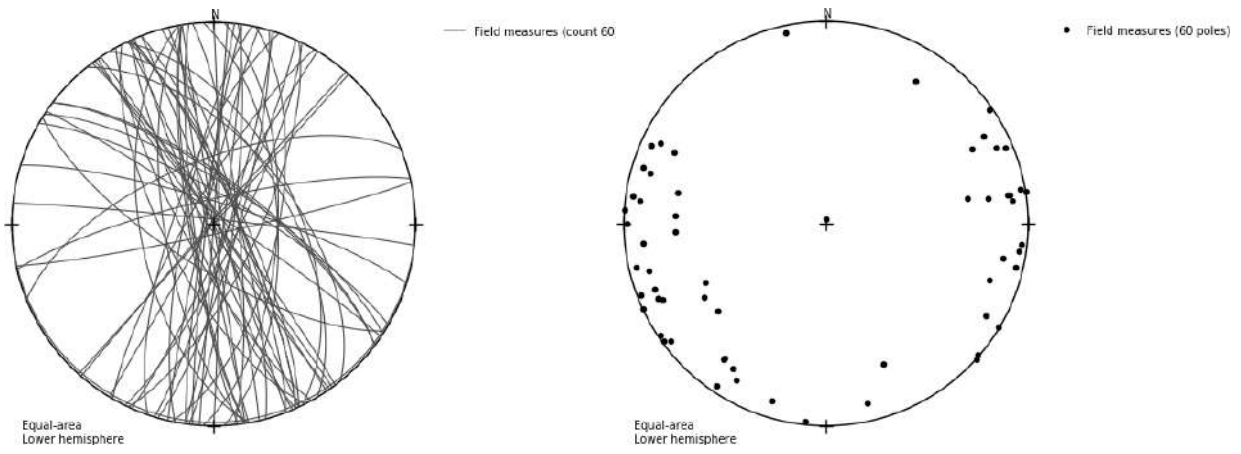


Figure S6. Stereograms of field measures.

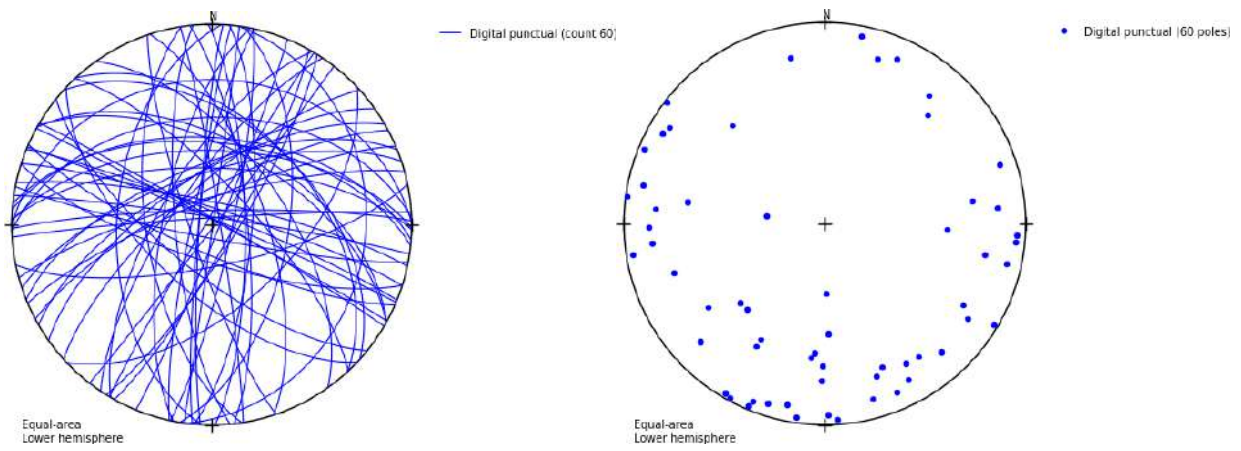


Figure S7. Stereograms of digital punctual measures.

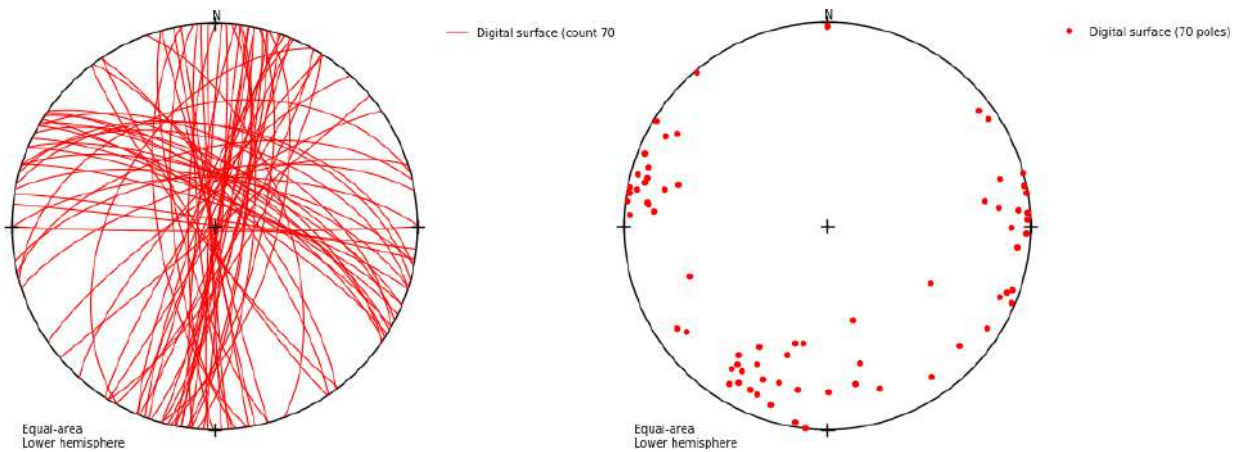


Figure S8. Stereograms of digital surface measures.

3. Table

Table S1. Traditional field measurements and digital punctual measurements obtained for 60 dikes. The angular difference between dip directions and dips are also shown.

Dike ID	Field measures		Digital punctual		Difference	
	dipdir	dip	dipdir	dip	dipdir	dip
1	53	86	83.7	75.5	30.7	10.5
2	84	80	272.9	50.8	171.1	29.2
3	241	78	12.0	80.8	131.0	2.8
4	181	2	358.1	45.5	177.1	43.5
5	235	88	275.6	84.8	40.6	3.2
6	37	72	223.3	63.3	173.7	8.7
7	66	80	46.9	74.3	19.1	5.7
8	347	80	330.0	69.2	17.0	10.8
9	66	80	344.6	79.2	81.4	0.8
10	102	64	95.0	73.6	7.0	9.6
11	90	88	54.5	60.7	35.5	27.3
12	6	88	1.5	66.9	4.5	21.1
13	33	74	17.7	83.3	15.3	9.3
14	75	80	22.1	84.8	52.9	4.8
15	30	78	331.9	76.6	58.1	1.4
16	65	78	29.2	55.6	35.8	22.4
17	260	60	4.4	54.2	104.4	5.8
18	64	56	29.3	58.9	34.7	2.9
19	97	82	121.9	80.0	24.9	2.0
20	54	89	197.6	75.1	143.6	13.9
21	87	64	112.3	86.9	25.3	22.9
22	98	86	336.9	80.0	121.1	6.0
23	114	84	119.1	81.6	5.1	2.4
24	281	78	101.9	81.6	179.1	3.6
25	168	86	356.4	87.2	171.6	1.2
26	116	80	300.8	87.7	175.2	7.7
27	300	80	42.2	48.2	102.2	31.8
28	34	86	28.8	88.2	5.2	2.2
29	107	84	89.0	76.5	18.0	7.5
30	260	87	261.3	63.1	1.3	23.9
31	94	90	98.0	89.6	4.0	0.4
32	106	80	1.0	59.6	105.0	20.4
33	59	60	282.3	81.9	136.7	21.9
34	283	86	303.7	74.4	20.7	11.6
35	301	89	136.6	56.9	164.4	32.1
36	278	86	281.1	70.0	3.1	16.0
37	311	89	127.7	88.9	176.7	0.1
38	65	90	317.8	74.9	107.2	15.1
39	261	81	99.2	58.4	161.8	22.6
40	115	72	324.6	69.9	150.4	2.1
41	246	81	97.4	24.0	148.6	57.0
42	312	90	191.0	84.5	121.0	5.5
43	261	80	300.3	68.6	39.3	11.4
44	93	64	273.2	84.9	179.8	20.9
45	56	89	30.5	87.5	25.5	1.5
46	338	64	338.0	65.6	0.0	1.6
47	69	80	80.9	86.6	11.9	6.6
48	263	82	358.9	84.2	95.9	2.2
49	276	87	8.4	86.9	92.4	0.1
50	37	73	359.5	28.5	37.5	44.5
51	77	86	218.9	70.7	141.9	15.3
52	51	58	6.0	56.2	45.0	1.8
53	247	86	251.3	81.1	4.3	4.9
54	69	88	264.7	75.1	164.3	12.9
55	261	90	341.5	68.9	80.5	21.1
56	261	70	47.1	47.9	146.1	22.1
57	17	81	22.8	87.7	5.8	6.7
58	212	72	203.6	78.3	8.4	6.3
59	243	70	71.9	67.9	171.1	2.1
60	289	74	168.4	73.1	120.6	0.9

4. Photoscan processing report

Diques clásticos 23072018

Processing Report

23 July 2018



Survey Data

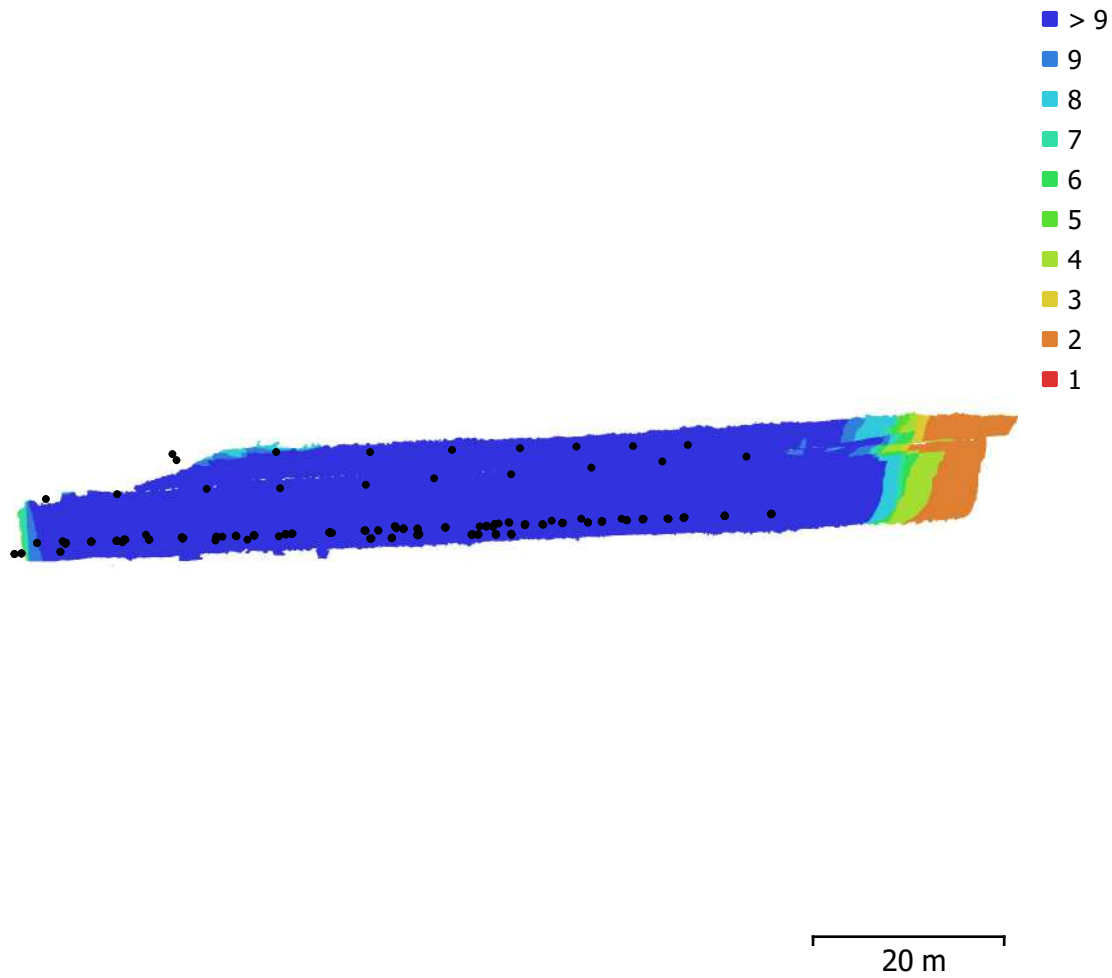


Fig. 1. Camera locations and image overlap.

Number of images:	473	Camera stations:	238
Flying altitude:	23.6 m	Tie points:	86,768
Ground resolution:	2.3 mm/pix	Projections:	440,852
Coverage area:	1.04e+03 m ²	Reprojection error:	1.61 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
NIKON D7000 (35 mm)	4928 x 3264	35 mm	4.93 x 4.93 μm	No
COOLPIX AW130 (7.8 mm)	4608 x 3456	7.8 mm	1.33 x 1.33 μm	No
COOLPIX AW130 (6.1 mm)	4608 x 3456	6.1 mm	1.35 x 1.35 μm	No
COOLPIX AW130 (11mm)	4608 x 3456	11 mm	1.35 x 1.35 μm	No
COOLPIX AW130 (12mm)	4608 x 3456	12 mm	1.35 x 1.35 μm	No

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
COOLPIX AW130 (4.3mm)	4608 x 3456	4.3 mm	1.35 x 1.35 μm	No
NIKON D7000 (250mm)	4928 x 3264	250 mm	4.88 x 4.88 μm	No

Table 1. Cameras.

Camera Calibration

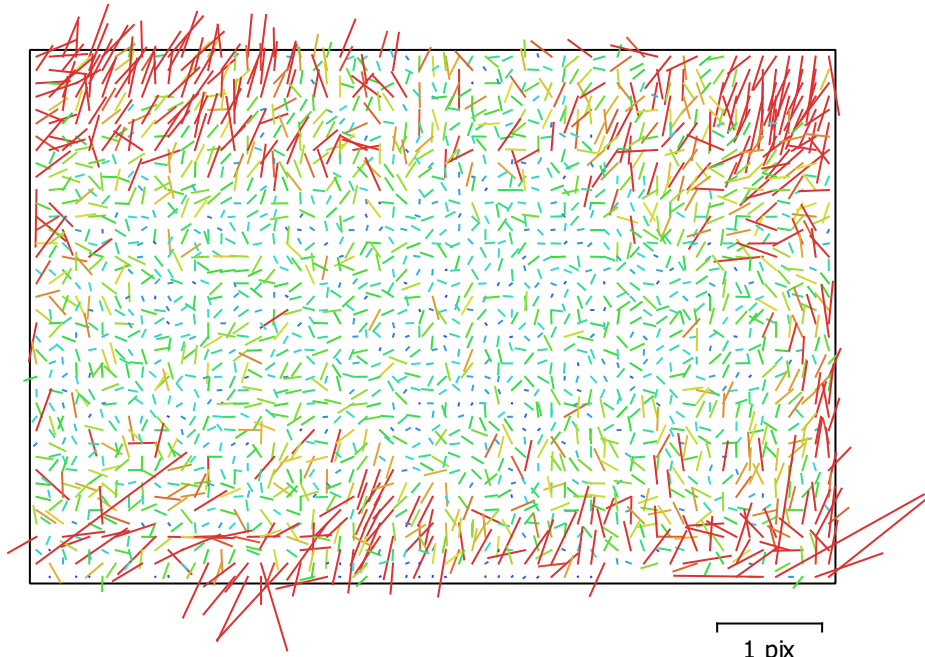


Fig. 2. Image residuals for NIKON D7000 (35 mm).

NIKON D7000 (35 mm)

130 images

Type	Resolution	Focal Length	Pixel Size
Frame	4928 x 3264	35 mm	4.93 x 4.93 μm
F:	7487.66		
Cx:	22.81	B1:	0
Cy:	56.646	B2:	0
K1:	0.148017	P1:	0
K2:	0.468523	P2:	0
K3:	1.06061	P3:	0
K4:	0	P4:	0

Camera Calibration

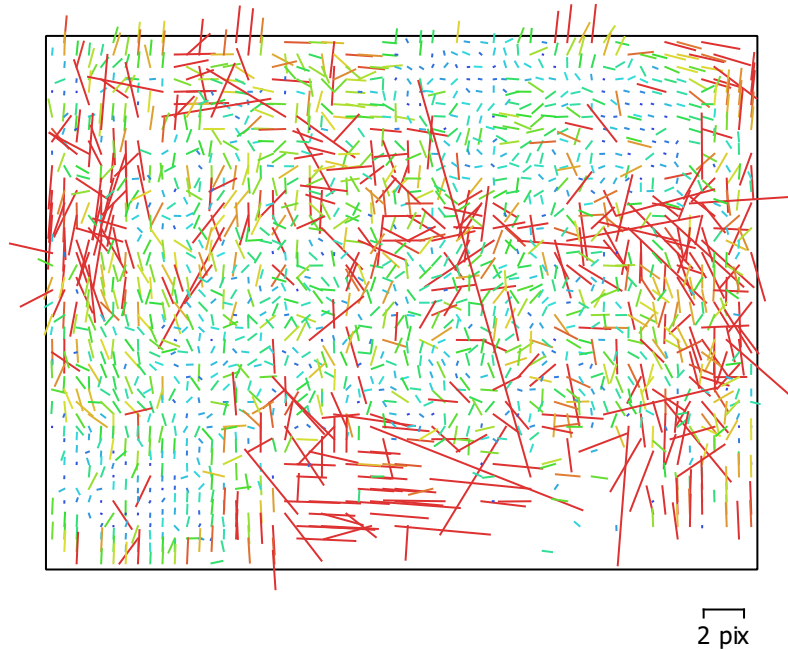


Fig. 3. Image residuals for COOLPIX AW130 (7.8 mm).

COOLPIX AW130 (7.8 mm)

59 images

Type Frame	Resolution 4608 x 3456	Focal Length 7.8 mm	Pixel Size 1.33 x 1.33 μm
F:	5838.28		
Cx:	-11.0779	B1:	0
Cy:	58.5073	B2:	0
K1:	-0.0188349	P1:	0
K2:	0.29681	P2:	0
K3:	-0.836469	P3:	0
K4:	0	P4:	0

Camera Calibration

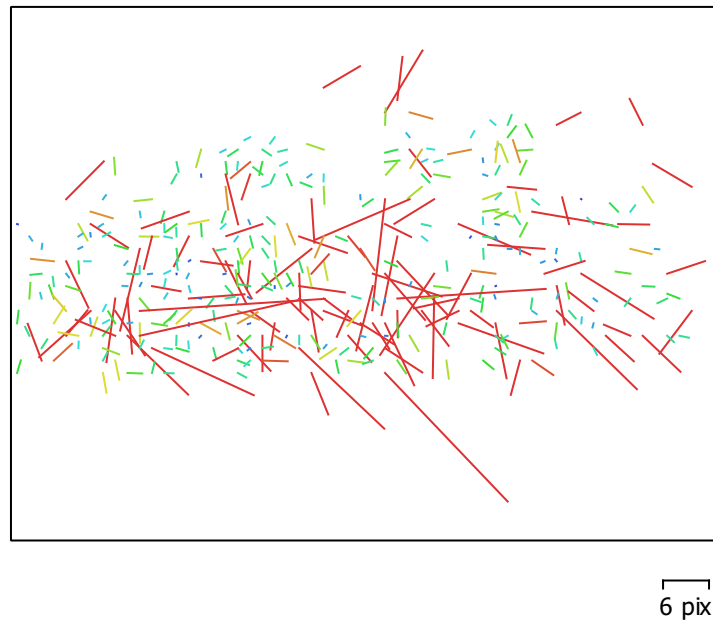


Fig. 4. Image residuals for COOLPIX AW130 (6.1 mm).

COOLPIX AW130 (6.1 mm)

3 images

Type Frame	Resolution 4608 x 3456	Focal Length 6.1 mm	Pixel Size 1.35 x 1.35 μm
F:	4572.81		
Cx:	-7.99922	B1:	0
Cy:	13.1444	B2:	0
K1:	0.0352835	P1:	0
K2:	-0.252861	P2:	0
K3:	0.674622	P3:	0
K4:	0	P4:	0

Camera Calibration

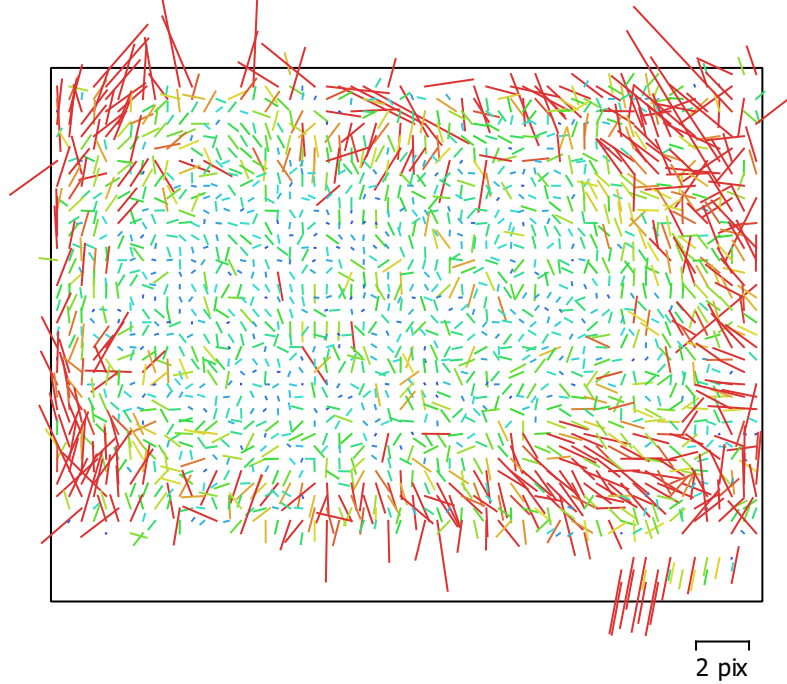


Fig. 5. Image residuals for COOLPIX AW130 (11mm).

COOLPIX AW130 (11mm)

10 images

Type	Resolution	Focal Length	Pixel Size
Frame	4608 x 3456	11 mm	1.35 x 1.35 μm

	Value	Error	P1	P2
F	8120.81			
P1	0.00502538	8.3e-05	1.00	0.01
P2	0.00744112	9e-05		1.00

Table 2. Calibration coefficients and correlation matrix.

Camera Calibration

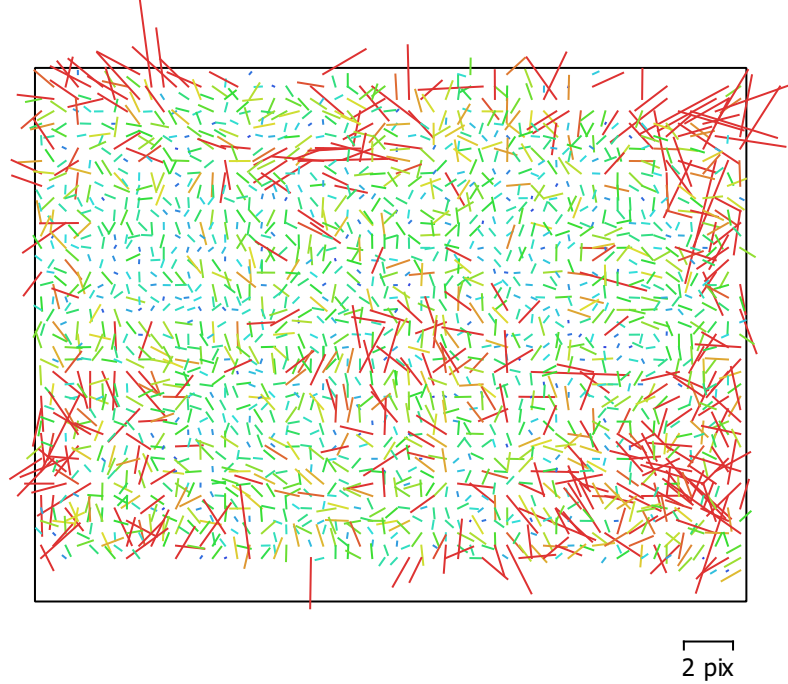


Fig. 6. Image residuals for COOLPIX AW130 (12mm).

COOLPIX AW130 (12mm)

9 images

Type	Resolution	Focal Length	Pixel Size
Frame	4608 x 3456	12 mm	1.35 x 1.35 μm

	Value	Error	P1	P2
F	8919.58			
P1	0.00548246	8.8e-05	1.00	-0.06
P2	0.00710298	9.7e-05		1.00

Table 3. Calibration coefficients and correlation matrix.

Camera Calibration

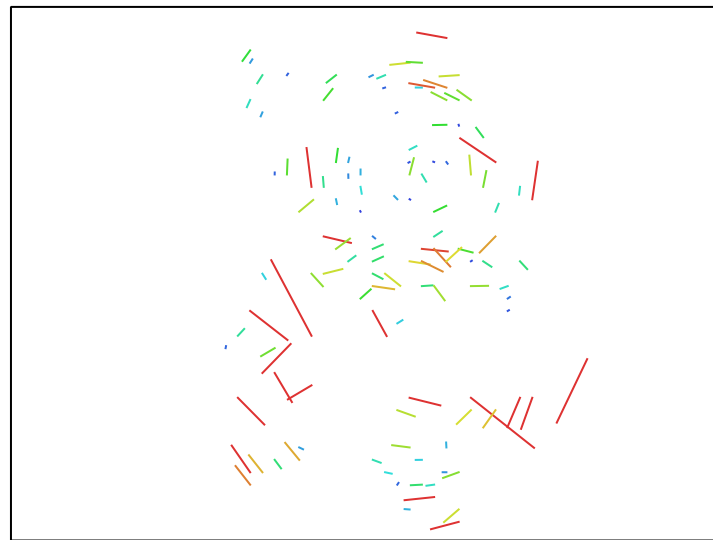


Fig. 7. Image residuals for COOLPIX AW130 (4.3mm). 10 pix

COOLPIX AW130 (4.3mm)

18 images

Type	Resolution	Focal Length	Pixel Size
Frame	4608 x 3456	4.3 mm	1.35 x 1.35 μm
F:	3195.07		
Cx:	0	B1:	0
Cy:	0	B2:	0
K1:	0	P1:	0
K2:	0	P2:	0
K3:	0	P3:	0
K4:	0	P4:	0

Camera Calibration

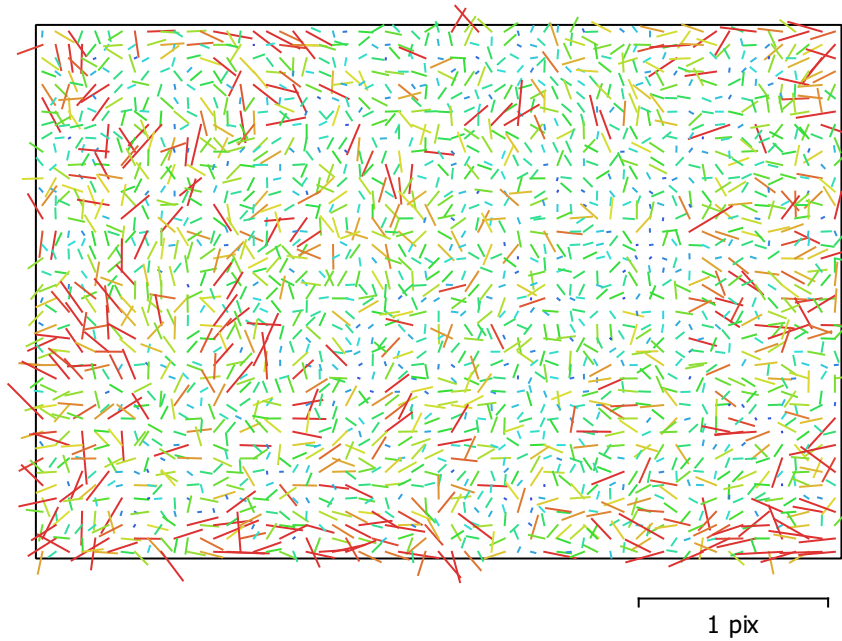


Fig. 8. Image residuals for NIKON D7000 (250mm).

NIKON D7000 (250mm)

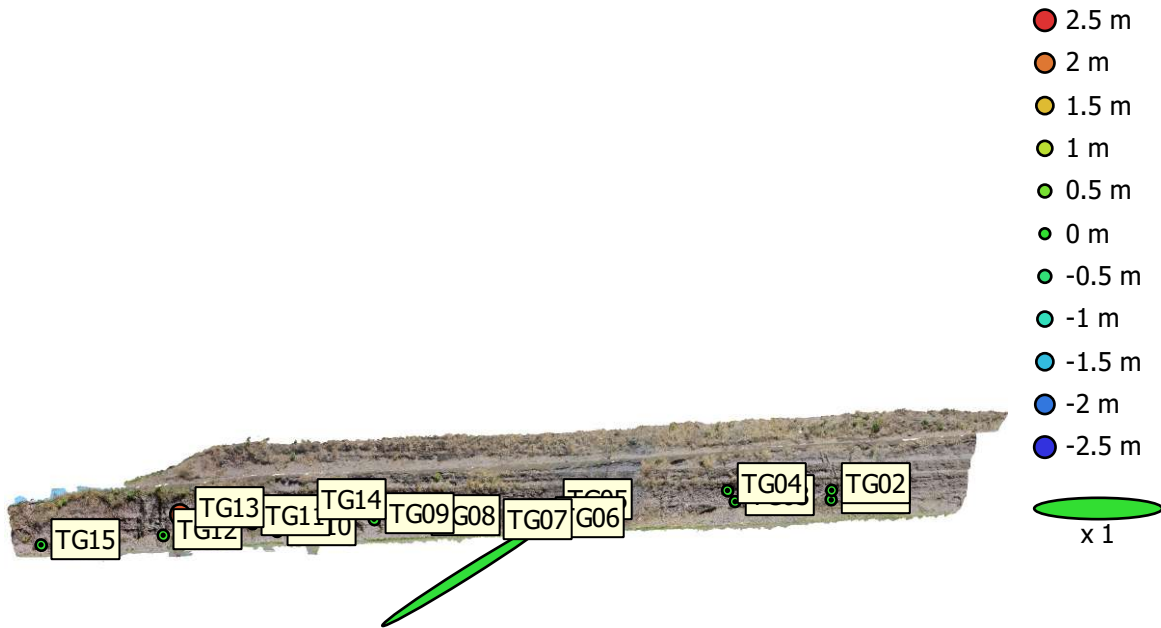
244 images

Type	Resolution	Focal Length	Pixel Size
Frame	4928 x 3264	250 mm	4.88 x 4.88 μm

	Value	Error	K1
F	51231		
K1	1.78458	0.0045	1.00

Table 4. Calibration coefficients and correlation matrix.

Ground Control Points



● Control points ✕ Check points 20 m

Fig. 9. GCP locations and error estimates.

Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.

Estimated GCP locations are marked with a dot or crossing.

Count	X error (m)	Y error (m)	Z error (m)	XY error (m)	Total (m)
10	0.0492242	0.0792006	0.0263485	0.093251	0.096902

Table 5. Control points RMSE.

X - Easting, Y - Northing, Z - Altitude.

Count	X error (m)	Y error (m)	Z error (m)	XY error (m)	Total (m)
5	7.4073	4.8533	0.994945	8.85566	8.91138

Table 6. Check points RMSE.

X - Easting, Y - Northing, Z - Altitude.

Label	X error (m)	Y error (m)	Z error (m)	Total (m)	Image (pix)
TG01	0.0260845	-0.0409131	-0.0268104	0.0554353	0.067 (8)
TG02	-0.00257653	0.0221083	0.0159551	0.0273858	0.124 (8)
TG03	0.00755593	-0.0227303	0.00485075	0.0244395	0.101 (18)
TG04	-0.0402797	0.0524281	0.0139953	0.0675797	0.085 (18)
TG08	-0.0157943	0.0202469	-0.0270374	0.0372883	0.024 (20)
TG09	-0.0395914	0.0627898	-0.00901643	0.0747753	0.035 (16)
TG10	-0.0151761	0.0224365	-0.0174475	0.0322199	0.018 (16)
TG11	0.135191	-0.217386	0.0358244	0.258489	0.038 (17)
TG12	-0.0258678	0.0465005	0.0454771	0.0699972	0.022 (18)
TG15	-0.0295072	0.0549932	-0.0357965	0.0719466	0.038 (9)
Total	0.0492242	0.0792006	0.0263485	0.096902	0.061

Table 7. Control points.
 X - Easting, Y - Northing, Z - Altitude.

Label	X error (m)	Y error (m)	Z error (m)	Total (m)	Image (pix)
TG05	-0.0428253	0.0641011	-0.00190013	0.077114	0.076 (16)
TG06	16.5576	10.3914	-0.0529306	19.5483	0.063 (16)
TG07	0.0190837	-0.0359619	-0.0683202	0.0795304	0.022 (16)
TG13	-0.0652882	0.153329	2.22204	2.22829	0.026 (21)
TG14	-0.425775	3.12457	-0.0679427	3.15417	0.041 (20)
Total	7.4073	4.8533	0.994945	8.91138	0.049

Table 8. Check points.
 X - Easting, Y - Northing, Z - Altitude.

Digital Elevation Model

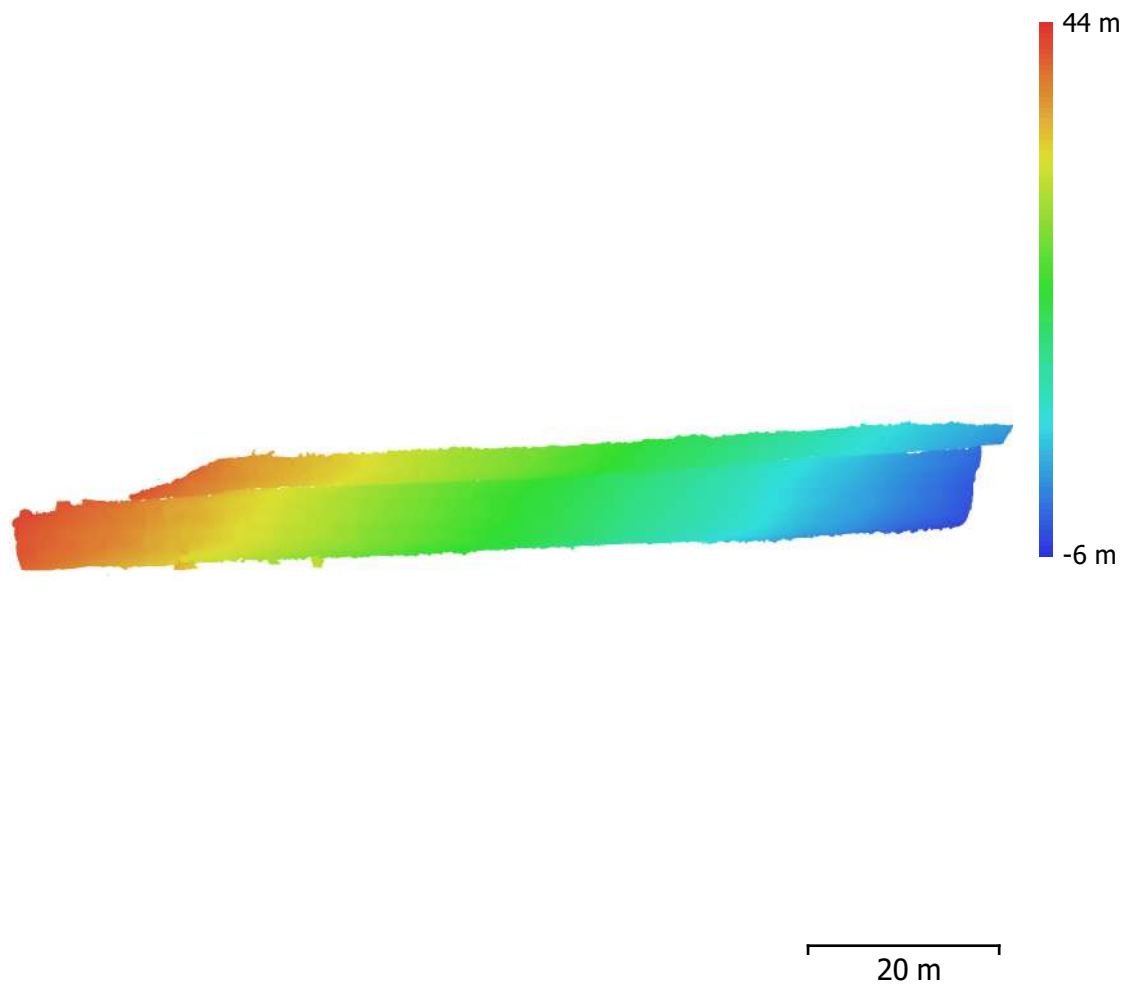


Fig. 10. Reconstructed digital elevation model.

Resolution: 4.59 mm/pix
Point density: 474 points/cm²

Processing Parameters

General

Cameras	473
Aligned cameras	238
Markers	15
Coordinate system	WGS 84 / UTM zone 23S (EPSG::32723)
Rotation angles	Yaw, Pitch, Roll

Point Cloud

Points	86,768 of 498,370
RMS reprojection error	0.168131 (1.61477 pix)
Max reprojection error	0.530962 (74.7361 pix)
Mean key point size	6.73439 pix
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	3.53911

Alignment parameters

Accuracy	Medium
Generic preselection	Yes
Key point limit	40,000
Tie point limit	4,000
Filter points by mask	No
Mask tie points	No
Matching time	2 minutes 57 seconds
Alignment time	32 seconds

Dense Point Cloud

Points	51,314,241
Point colors	3 bands, uint8

Reconstruction parameters

Quality	High
Depth filtering	Aggressive
Depth maps generation time	1 hours 35 minutes
Dense cloud generation time	25 minutes 49 seconds

Model

Faces	14,999,999
Vertices	7,524,684
Vertex colors	3 bands, uint8
Texture	4,096 x 4,096 x 3, 4 bands, uint8

Reconstruction parameters

Surface type	Arbitrary
Source data	Dense
Interpolation	Enabled
Quality	High
Depth filtering	Aggressive
Face count	15,000,000
Processing time	25 minutes 53 seconds

Texturing parameters

Mapping mode	Generic
Blending mode	Mosaic
Texture size	4,096 x 4,096
Enable hole filling	Yes
Enable ghosting filter	Yes
UV mapping time	2 minutes 1 seconds
Blending time	10 minutes 7 seconds

Software

Version	1.4.2 build 6205
Platform	Windows 64