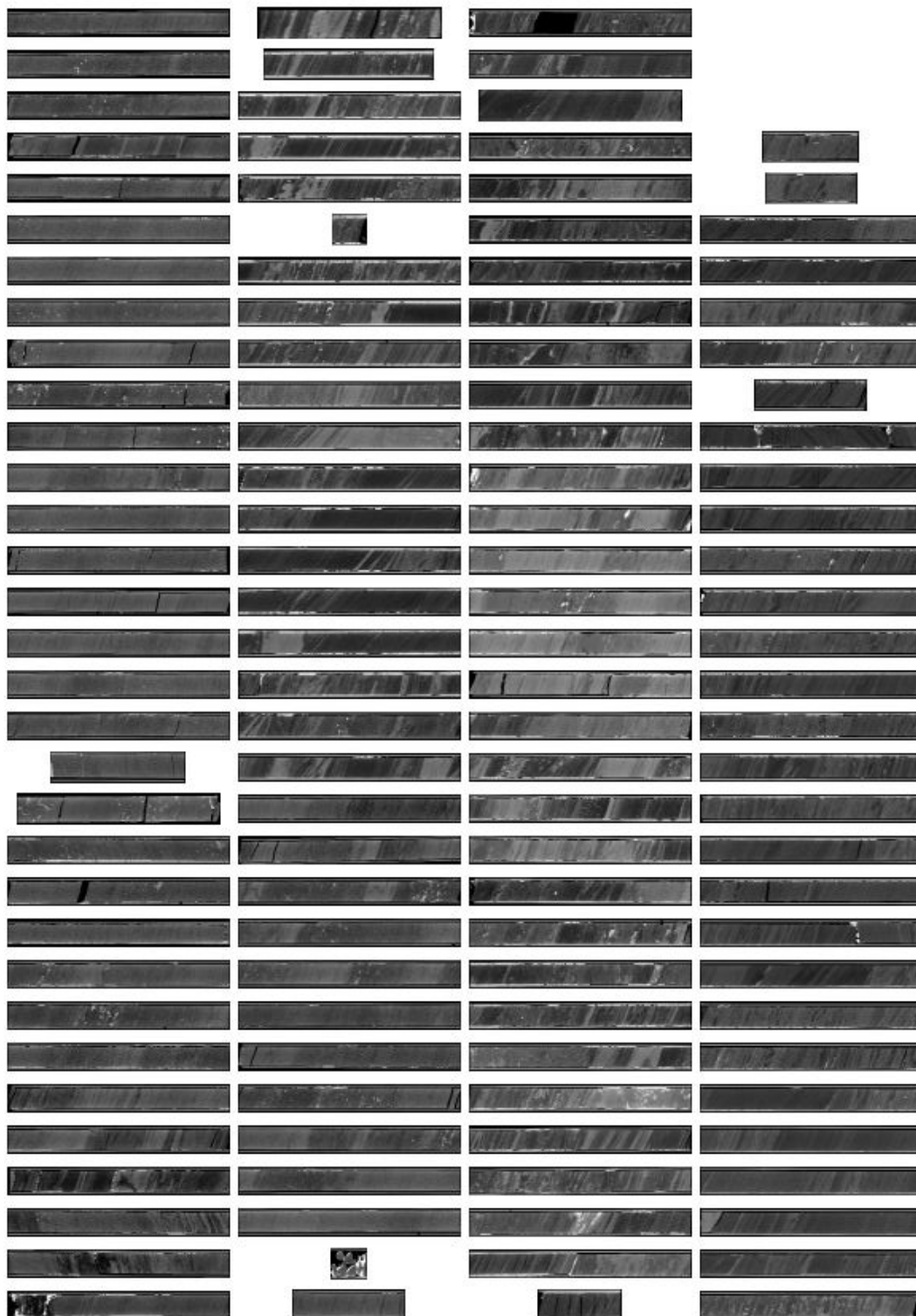
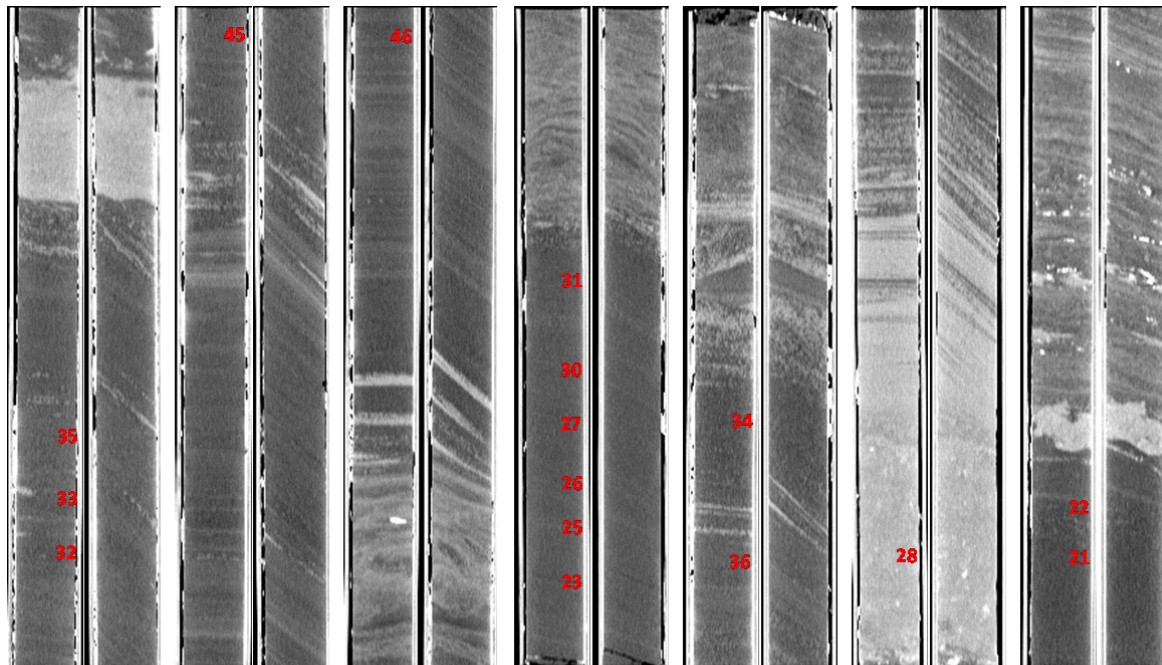


Appendix 1. CT-scans of the core in the barrels



Appendix 2. Selected sampling horizons

A2.1. Selected plug locations indicated in CT-scans of core material in barrels



Box 50

Box 51

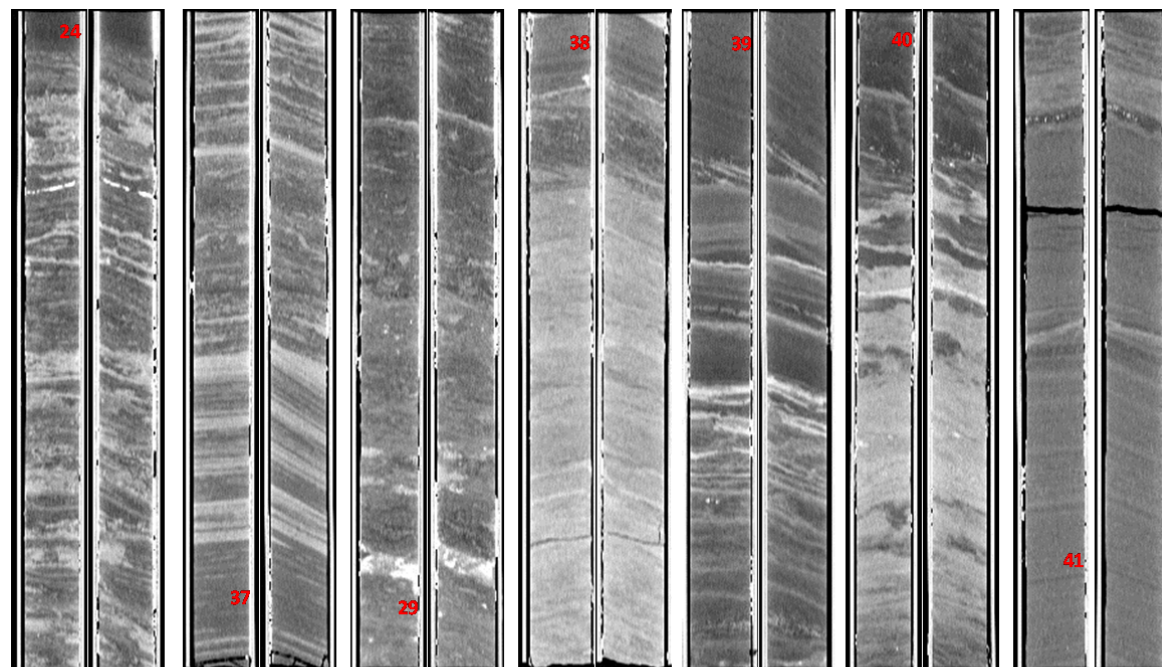
Box 52

Box 53

Box 54

Box 55

Box 58



Box 59

Box 69

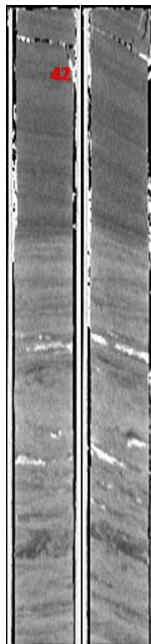
Box 73

Box 79

Box 87

Box 92

Box 107



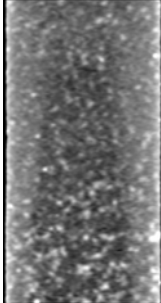

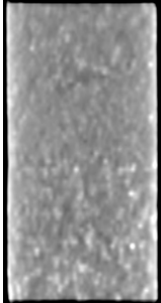

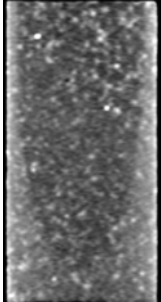

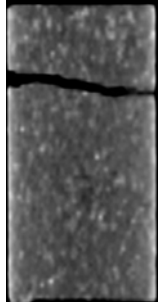

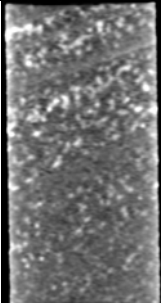

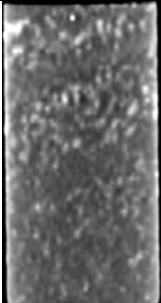

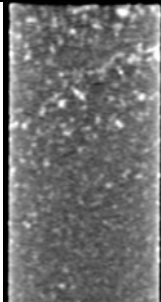

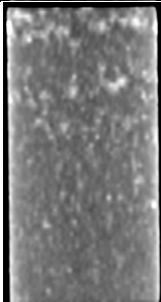

Box 120

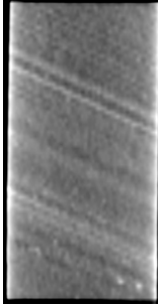

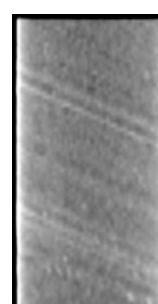


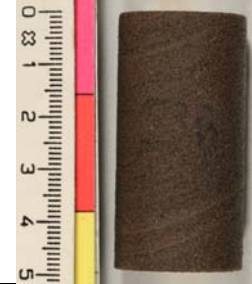


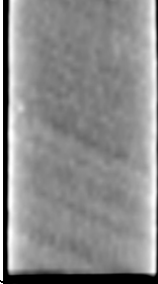



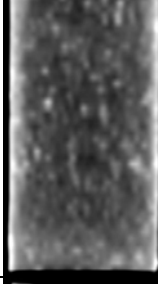



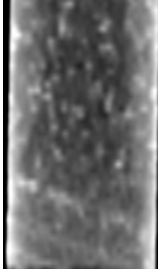



A2.2. Core box number, depth and core length

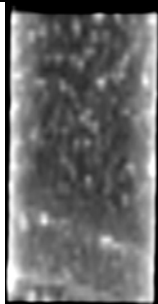


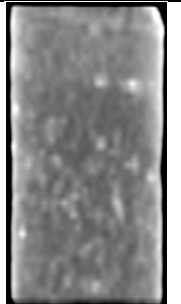

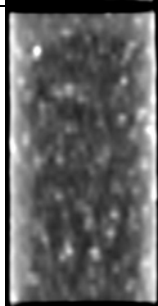





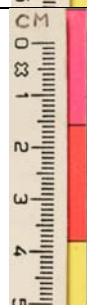



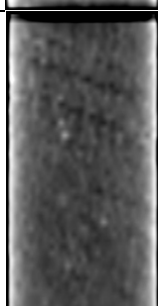


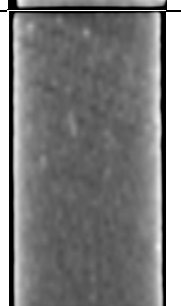






Core Number	Box Number	Top Depth (m)	Bottom Depth (m)	Length (m)
#3	50	3819.16	3820.07	0.91
#3	51	3820.07	3820.96	0.89
#3	52	3820.96	3821.86	0.90
#3	53	3821.86	3822.81	0.95
#3	54	3822.81	3823.73	0.92
#3	55	3823.73	3824.63	0.90
#3	58	3826.43	3827.33	0.90
#3	59	3827.33	3828.42	1.09
#4	69	3835.42	3836.39	0.97
#4	73	3839.19	3840.12	0.93
#4	79	3844.66	3845.54	0.88
#4	87	3851.88	3852.78	0.90
#4	92	3856.62	3857.62	1.00
#5	107	3870.67	3871.58	0.91
#5	120	3881.87	3882.76	0.89

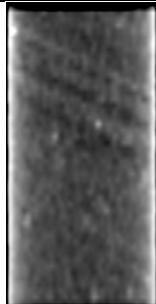




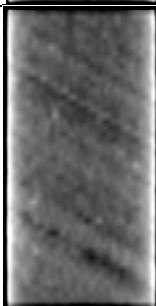


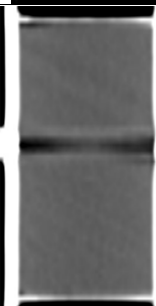




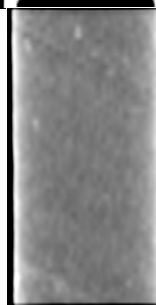

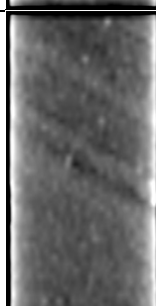


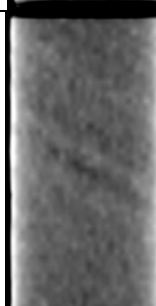

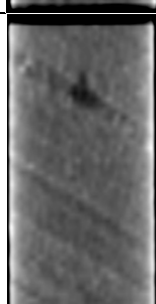




Appendix 3. CT-scans and white light photos of the tested samples

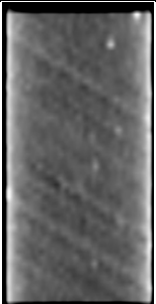




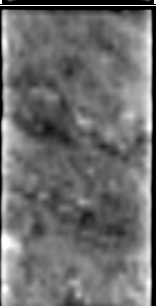


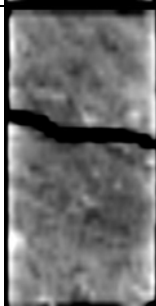

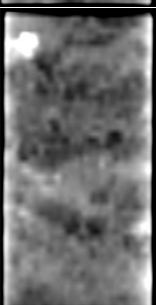


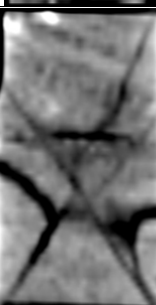

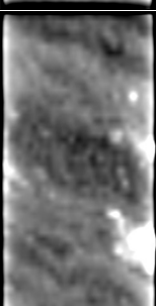


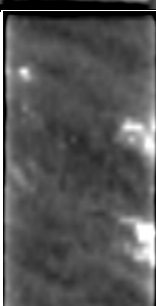

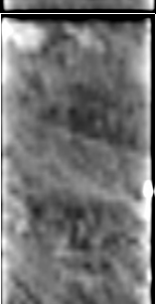


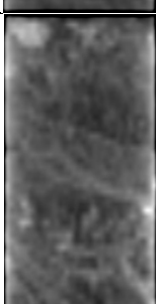

Pre and post CT-scans and daylight photos of the samples as used in the various experiments. The CT-scans given are 90° oriented to the bedding plane. The pre-test photos also display a ruler in cm.

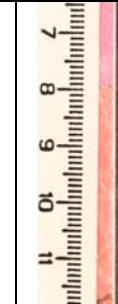

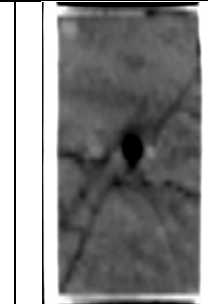

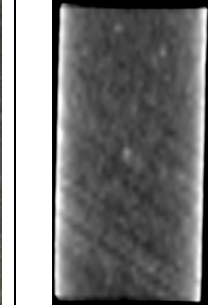

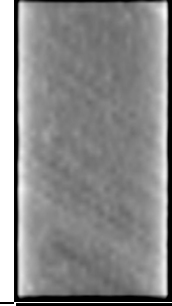



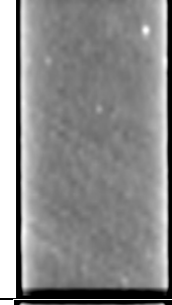

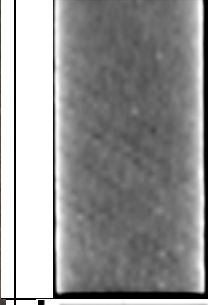


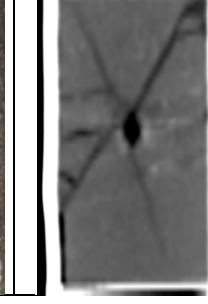
Sample	Pre 90° CT-scan	Pre Daylight photo	Post 90° CT-scan	Post 90° Daylight photo	Test*
21A					A
21B					A
22A					A
22B					A

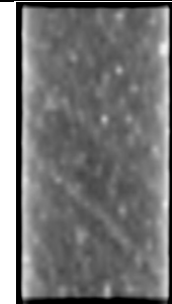


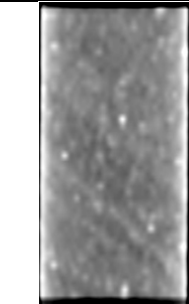




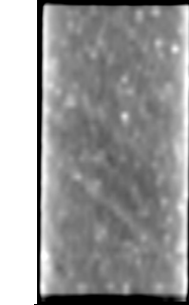

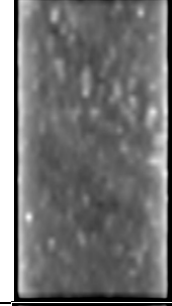


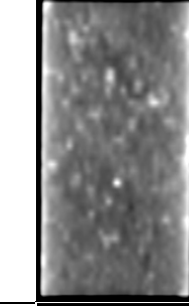




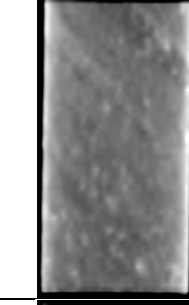






23A					A
23B					A
23D					A
24A					E
24B					E

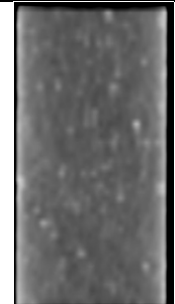


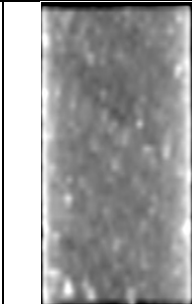

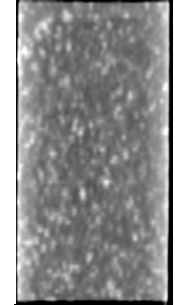


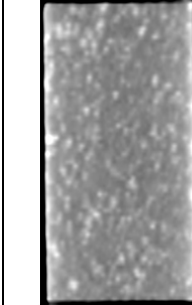

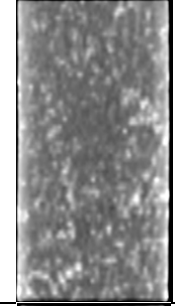


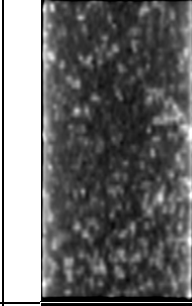

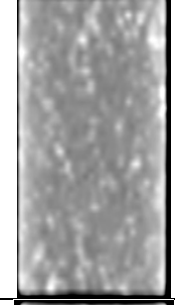
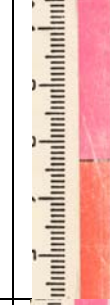

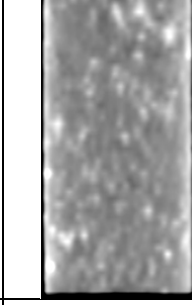

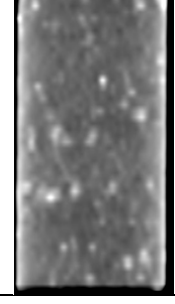
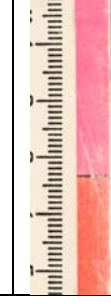



24C						A
24D						E
24E						E
25B						A
25C						A

25D						A
26C						B
26D						B
26E						A
27C						B

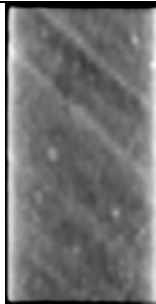


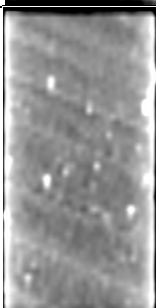


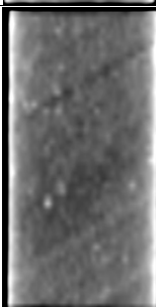





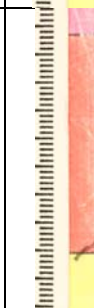






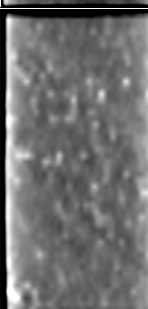

27D						A
29A						E
29B						E
29C						A
29D						C

29E						E
30B						C
30D						A
30E					not available	A
31C						E

32A						C
32B						A
32D						A
33B						A
33C						A

33D						A
34A						A
34B						A
34C						C
35A						F

35B						E
35D						D
35E						D
36B						E
39B				not available	not available	E

39E				not available	not available	A
41B				not available	not available	A
42B						A
45A						A
45E						A

Appendix 4. Porosity and permeability data for plugged intervals

Sample depth (meter):	sample orientation with respect to core axis		Porosity ambient [Hg ~ CO3H] [%]	Grain density [g/ml]	permeability -to-air [400 psi] (mD)	permeability - Klinkenberg corrected Kk (mD)	Bulk density [g/ml]	Hg bulk volume [ml]	Grain volume [ml]	Core length [cm]	Core diameter [cm]	V pore [ml]	Remarks
	ID	V											
3822.58	MG13_26GSA	V	23.8%	2.655	10.7	8.18	2.023	9.917	7.558			2.359	False means not measured
3822.66	MG13_25E	V	22.5%	2.646	17	13	2.050	21.553	16.695	4.480	2.496	4.857	rock piece next to sample; on post-test geomech plug
3822.66	MG13_25GSA	V	22.8%	2.649			2.045	19.909	15.371			4.538	rock piece next to sample
3822.66	MG13_25A	V	22.6%	2.650	16.7	13.2	2.050	24.284	18.787	5.005	2.511	5.497	
3822.71	MG13_23BT	V	21.7%	2.647	4.6	3.1	2.072	16.191	12.677	3.394	2.489		trim end
3822.71	MG13_23GSA	V	23.1%	2.652			2.039	11.198	8.611			2.588	rock piece next to sample
3827.18	MG13_22GSA	V	25.1%	2.655	409	383	1.989	22.165	16.608			5.558	rock piece next to sample; on post-test geomech plug
3827.28	MG13_21GSA	V	26.9%	2.654	392	366	1.941	24.265	17.744			6.521	rock piece next to sample; on post-test geomech plug
3827.37	MG13_24D	V	26.5%	2.654	290	269	1.950	24.030	17.659	4.982	2.491		
3827.37	MG13_24GSA	V	26.1%	2.662			1.966	24.462	18.066			6.396	rock piece next to sample
3822.50	MG13_27BT	V	23.7%	2.648	19.1	15.3	2.020	11.779	8.987	2.497	2.471	2.793	trim end
3824.57	MG13_28AT	V	3.2%	2.704	<0.01	<0.01	2.619	18.117	17.546	3.657	2.506	0.571	trim end
3840.09	MG13_29BT	V	13.3%	2.684	0.5	0.2	2.328	12.383	10.742	2.508	2.511	1.641	trim end
3822.50	MG13_27GSA	V	24.3%	2.655	15.6	12.3	2.010	23.000	17.412			5.588	rock piece next to sample; on post-test geomech plug
3824.57	MG13_28GSA	V	2.9%	2.699			2.621	24.301	23.602			0.699	rock piece next to sample; dense spots in the sample
3840.09	MG13_29GSA	V	14.0%	2.682	0.21	0.11	2.307	24.227	20.839			3.388	rock piece next to sample; on post-test geomech plug
3823.40	MG13_34CT	V	23.5%	2.649	184	167	2.026	19.583	14.980	4.181	2.478	4.603	trim end
3819.84	MG13_35DT	V	18.6%	2.639	192	175	2.148	12.060	9.813	2.461	2.512		
3822.41	MG13_30GSA	V	23.4%	2.648			2.027	25.534	19.548			5.986	rock piece next to sample
3822.33	MG13_31GSA	V	22.3%	2.645			2.055	22.926	17.816			5.110	rock piece next to sample
3820.01	MG13_32GSA	V	17.8%	2.641			2.170	21.559	17.717			4.342	rock piece next to sample
3819.92	MG13_33GSA	V	19.4%	2.645			2.133	22.431	18.088			4.747	rock piece next to sample
3819.84	MG13_35GSA	V	18.2%	2.641			2.161	26.135	21.389			3.864	trim end
3823.67	MG13_36CT	V	20.2%	2.657	35.3	29.6	2.119	19.090	15.226	3.995	2.512		
3836.34	MG13_37BT	V	17.4%	2.672	2.81	1.78	2.208	12.082	9.980	2.460	2.527	2.101	trim end
3844.71	MG13_38AT	V	16.4%	2.671	1.30	0.71	2.232	11.468	9.583	2.386	2.521	1.884	trim end
3851.93	MG13_39AT	V	23.2%	2.658	20.9	16.9	2.042	13.694	10.518	2.880	2.501	3.176	trim end
3856.67	MG13_40AT	V	26.0%	2.651	534	501	1.961	11.746	8.687	2.500	2.488	3.059	trim end
3871.54	MG13_41AT	V	17.1%	2.651	1.08	0.56	2.197	11.367	9.419	2.354	2.528	1.948	trim end
3881.99	MG13_42ET	V	22.3%	2.649	7.01	5.06	2.059	13.033	10.131	2.668	2.526	2.902	trim end
3783.36	MG13_43ET	V	4.3%	2.735	<0.01	<0.01	2.618	13.030	12.474	2.586	2.536	0.556	trim end
3781.58	MG13_44ET	V	5.5%	2.746	<0.01	<0.01	2.595	14.347	13.560	2.866	2.529	0.786	trim end
3820.11	MG13_45AT	V	19.1%	2.645	209	192	2.141	10.652	8.622	2.160	2.536	2.030	trim end
3821.01	MG13_46CT	V	21.8%	2.642	15.8	12.5	2.066	15.218	11.897	3.235	2.482	3.321	trim end
3827.28	MG13_21A post test	V			392	366				7.568	3.790		on post-test geomech plug
3822.71	MG13_22A post test	V			409	383				7.593	3.795		on post-test geomech plug
3822.58	MG13_28E post test	V			10.7	8.2				4.980	2.510		on post-test geomech plug
3822.50	MG13_27D post test	V			15.6	12.3				4.993	2.486		on post-test geomech plug
3840.09	MG13_29D post test	V			0.21	0.11				5.025	2.516		on post-test geomech plug

Appendix 5. Mechanical data

sample info		routine analysis					pore fluid	temperature	pressure			test			
sample	depth	porosity (Hg)	permeability (Klink corr.)	grain density	grain size				S _{axial}	P _{pore}	P _{radial}	type			
	[m]	[frac.]	[mD]	[g/ml]	mean	ln(width)			[Mpa]	[Mpa]	[Mpa]				
					[μm]		[°C]								
21A	3827.3	0.269	-	2.654	253.23	0.4654	wetting	20	80	57	67	A			
21B								100				A			
22A	3827.2	0.251	-	2.655	259.60	0.3716	non-wetting	20	80	57	67	A			
22B								60				A			
23A	3822.7	0.231	3.1	2.652	244.84	0.2949	wetting	60	80	57	67	A			
23B								20				A			
23D								100				G			
24A								20				-	-	-	F
24B	3827.4	0.261	274	2.662	228.60	0.3685	wetting	20	80	57	67	F			
24C								20				-	-	-	F
24D								20				-	-	-	F
24E								20				-	-	-	F
25B								100				A			
25C	3822.7	0.228	13	2.649	270.89	0.3958	wetting	60	80	57	67	A			
25D								20				A			
26C	3822.6	0.238	-	2.655	257.93	0.4693	wetting	60	75	52	62	B			
26D								60				85	62	72	B
26E								60				80	57	67	A
27A	3822.5	0.243	15.3	2.655	247.10	0.2941	non-wetting	60	80	57	67	A			
27C								60				A			
27D								60				A			
29A	3840.1	0.140	0.2	2.682	336.46	0.6172	wetting	20	80	57	67	F			
29B								20				-	-	-	F
29C								60				80	57	67	A
29D								60				80	57	67	C
29E								20				-	-	-	F
30B	3822.4	0.234	-	2.648	248.33	0.3247	wetting	60	80	57	67	C			
30D								100				A			
30E								60				A			
31C	3822.3	0.223	-	2.645			non-wetting	20	-	-	-	F			
32A	3820.0	0.178	-	2.641	359.39	0.4105	non-wetting	60	80	57	67	G			
32B								60				80	57	67	A
32D								60				80	57	67	C
33B	3819.9	0.194	-	2.645	308.10	0.4358	wetting	100	80	57	67	A			
33C								60				80	57	67	C
33D								60				80	57	67	A
34A	3823.4	0.235	167	2.649	335.12	0.3314	wetting	20	80	57	67	A			
34B								20				80	57	67	A
34C								60				80	57	67	C
35A	3819.8	0.182	-	2.641			wetting	20	80	57	67	F			
35B								20				-	-	-	F
35D								20				80	57	67	D
35E								60				80	57	67	D
36B								3823.7				0.202	29.6	2.657	
39B	3851.9	0.232	16.9	2.658			wetting	20	80	57	67	E			
39E								20				A			
41B	3871.5	0.171	0.56	2.651			wetting	20	80	57	67	A			
42B	3882.0	0.223	5.06	2.649			wetting	20	80	57	67	A			
45A	3820.11	0.191	200	2.645			non-wetting	60	80	57	67	A			
45E								60				H			

The following index indicates the type of test performed on the sample:

A: Uniaxial Pore Pressure Depletion (UPPD) – Section 3.3.2

B: UPPD at lower of higher in-situ stresses – Section 3.3.3

C: One-step UPPD – Section 3.3.3

D: Oedometric loading at various rates – Section 3.3.4

E: Stress-free strain pore pressure depletion (SSPPD) – Section 3.3.5

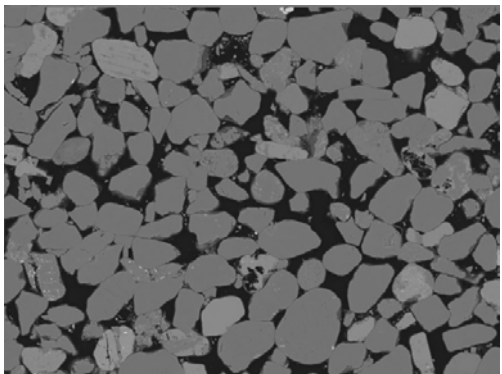

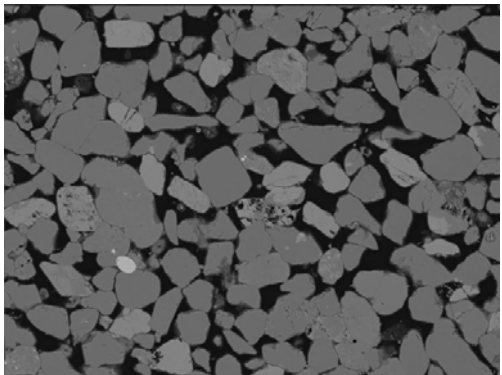
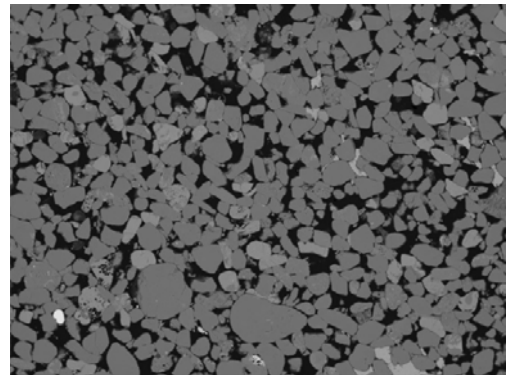
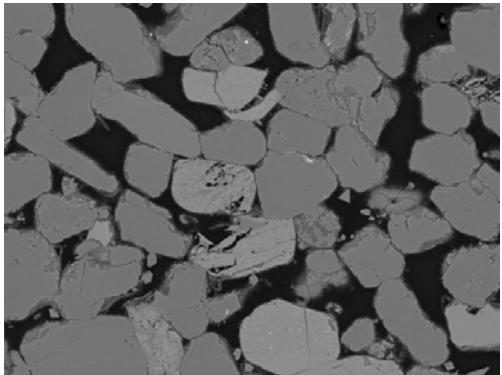
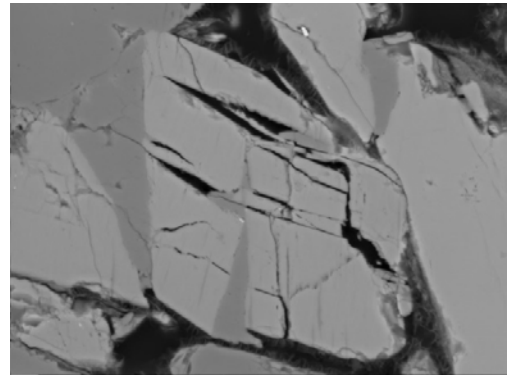
F: Triaxial compressive strength – Section 3.3.6

G: Triaxial pore pressure depletion at fixed depletion constant – Section 3.3.3

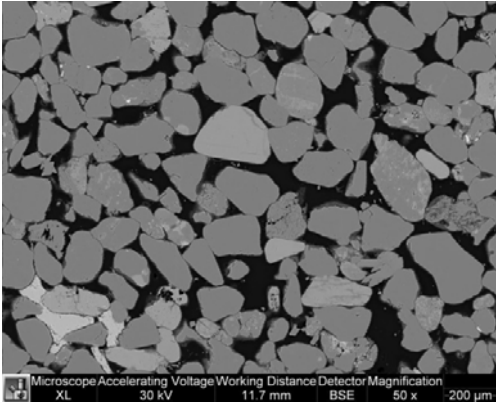
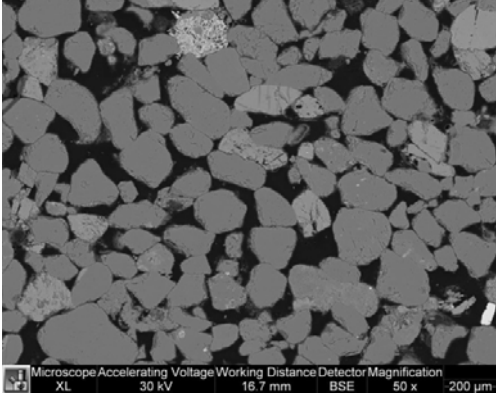
H: Step-and-Hold Uniaxial pore pressure depletion (UPPD) – Section 3.3.3

Appendix 6. SEM images

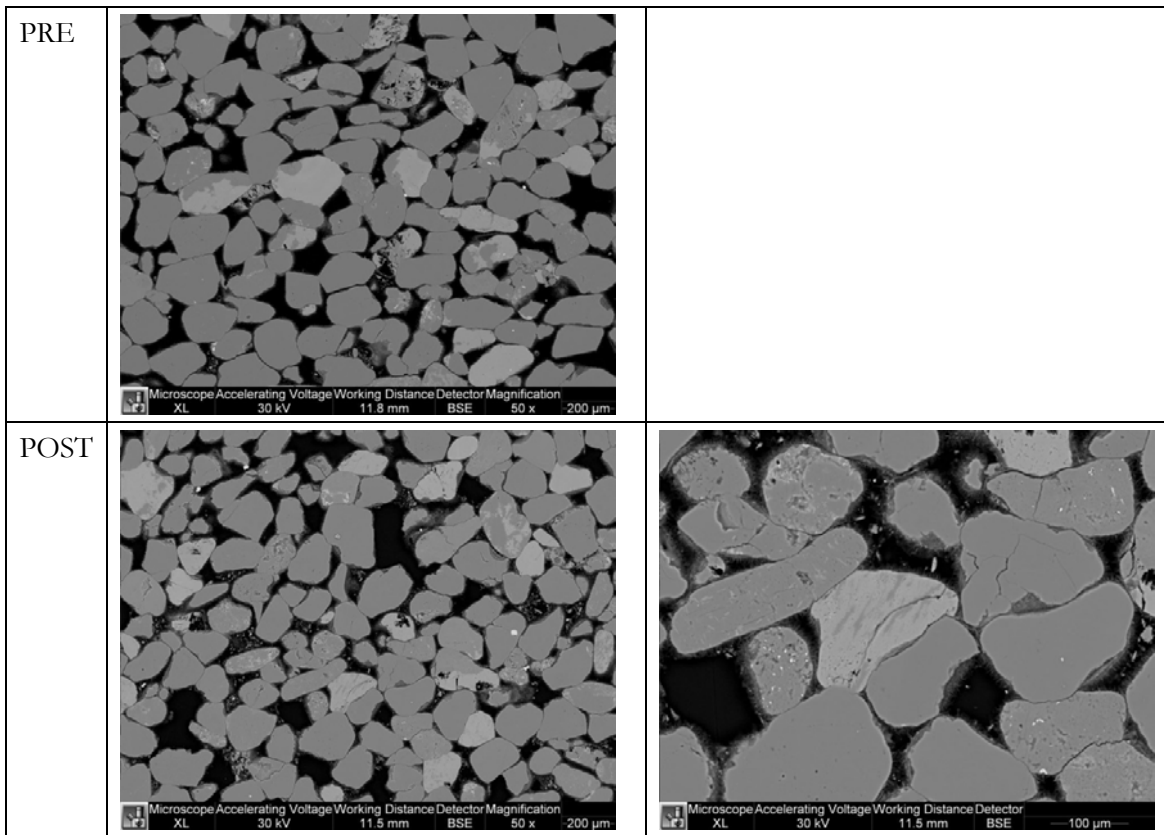
A6.1. Sample 21 (pre) and 21A (post)

PRE	 <p>Microscope Accelerating Voltage Working Distance Detector Magnification XL 30 kV 11.2 mm BSE 50 x 200 μm</p>	
POST	 <p>Microscope Accelerating Voltage Working Distance Detector Magnification XL 30 kV 16.3 mm BSE 50 x 200 μm</p>	 <p>Microscope Accelerating Voltage Working Distance Detector XL 30 kV 16.2 mm BSE 500 μm</p>
POST	 <p>Microscope Accelerating Voltage Working Distance Detector XL 30 kV 16.2 mm BSE 200 μm</p>	 <p>Microscope Accelerating Voltage Working Distance Detector XL 30 kV 16.2 mm BSE 50 μm</p>

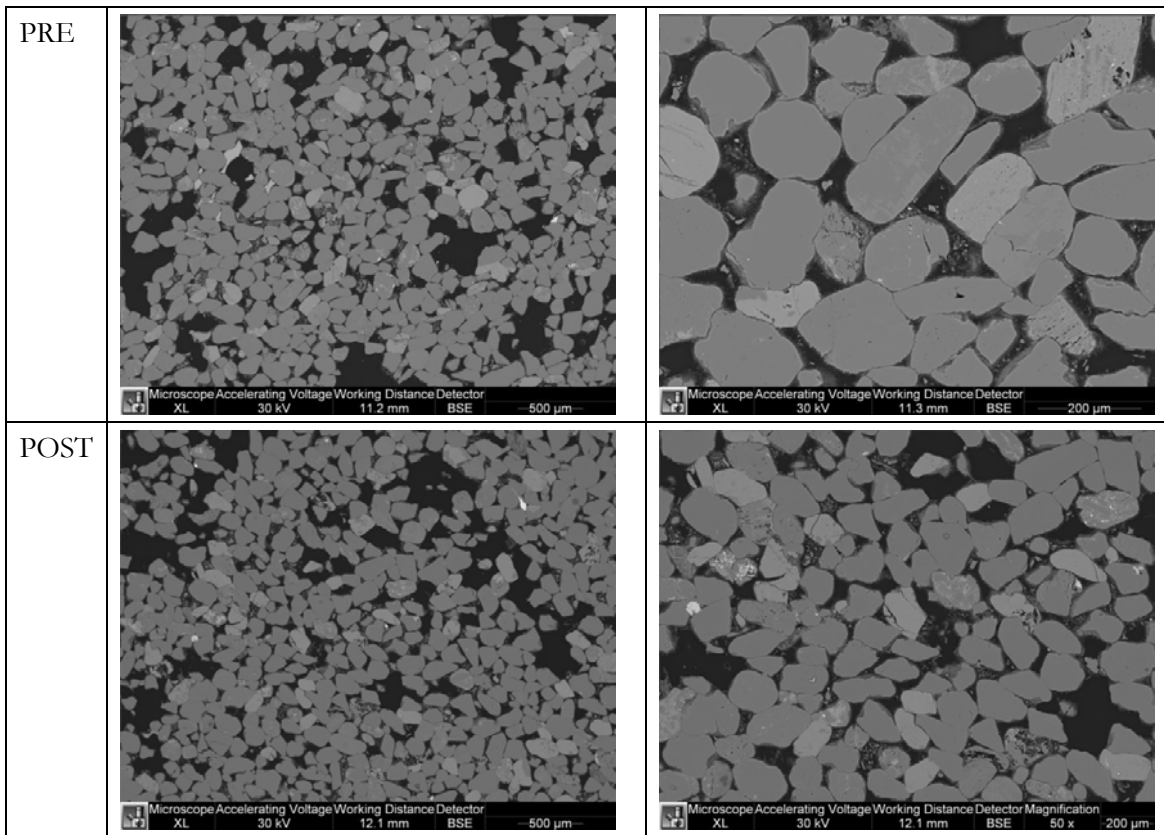
A6.2. Sample 22 (pre) and 22A (post)

PRE		
POST		

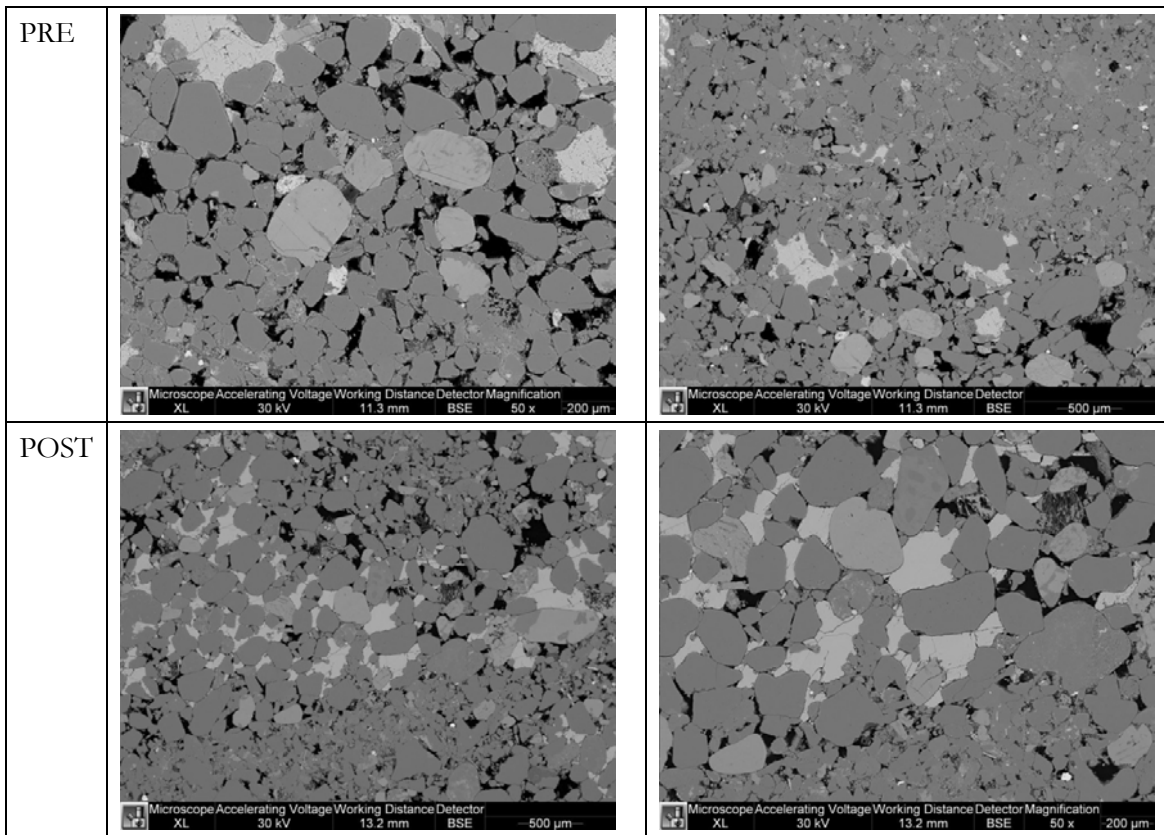
A6.3. Sample 26 (pre) and 26E (post)



A6.4. Sample 27 (pre) and 27D (post)



A6.5. Sample 29 (pre) and 29D (post)



Bibliographic information

Classification	Restricted
Report Number	SR.15.11614
Title	Mechanical characterization of Permian reservoir sandstone from the Moddergat-3 well in the Dutch Wadden Area
Author(s)	S. Hol (PTI/RF) A.J. van der Linden (PTI/RF) P.M.M. Zuiderwijk (PTI/RF) F.H.M. Marcelis (PTI/RF) A.H. Coorn (PTI/RF)
Keywords	Geomechanics, Moddergat-3, Nes, Permian sandstone, Wadden, Groningen, gas, experiments, compaction, compression, subsidence, constitutive behaviour, poroelasticity, friction angle, cohesion, shear strength, uniaxial, depletion
Date of Issue	July 2015
US Export Control	Non US - Non Controlled
Reviewed by	A.H. Makurat (PTI/RF)
Approved by	H. de Jong (PTI/RF)
Sponsoring Company / Customer	NAM
Issuing Company	Shell Global Solutions International B.V. P.O. Box 60 2280 AB Rijswijk The Netherlands

Report distribution

Electronic distribution (PDF)

Name, Company, Ref. Ind.

PT Information Services, PTT/TIKE, PT-Information-Services@Shell.com

Baehr, Hermann NAM-PTU/E/G

Bierman, Stijn M GSNL-PTD/TASE

van den Bogert, Peter AJ GSNL-PTU/E/Q

van Boom, Ruud, NAM-UIO/T/DL

Bourne, Stephen J GSNL-PTI/RC

Doornhof, Dirk NAM-PTU/E/Q

Dudley, John W SIEP-PTI/RF

van Eijs, Rob MHE NAM-PTU/E/Q

Hoogerduijn-Strating, Eilard H NAM-UIO/T/DL

Jansen, Jeroen M NAM-UIO/T/H

de Jong, H SIEP-PTI/RF

Kole, Pepijn R NAM-PTU/E/Q

Kraaijeveld, Famke GSNL-PTI/RC

Makurat, Axel H GSNL-PTI/RF

Mossop, Anthony P GSNL-PTI/RC

Park, Timothy A GSUK-PTD/TASE

Post, Alice D PTIN-PTU/I/S

Schutjens, Peter GSNL-PTU/E/Q

van der Veen, Wim NAM-PTU/E/G

van der Wal, Onno NAM-PTU/E/Q

Wentinck, Rick M GSNL-PTI/RC

Wong, Sau-Wai SIEP-PTI/U

The copyright of this document is vested in Shell. All rights reserved.

Neither the whole nor any part of this document may be reproduced, stored in any retrieval system or transmitted in any form or by any means (electronic, mechanical, reprographic, recording or otherwise) without the prior written consent of the copyright owner.