

Appendix B-1

Description of Granular Experiments

Appendix B. Details on initial experimental set-ups (dimensions and materials used), the evolution of each experimental run, and the final deformation pattern

No	Initial Conditions	Material of base	Experiment evolution, structural development (unit 1-3)	Activity unit 4	Final setting
2	GB (5.6), baryte (8), GB (<200mm) (7.2), sand (>5.6)	GB on table	1-2: glass beads of unit 1 are compressed and squeezed out, 3: a thrust in unit 2 forms, 4+: unit 2 shears off unit 3 on to unit 4	no thrusting	c
3	GB (5.6), baryte (8), GB (7.2), sand (>5.6)	GB on table	1-2: glass beads of unit 1 are compressed and squeezed out, 3: glass beads of unit 3 are squeezed out, 4+: unit 2 shears off unit 3 on to unit 4	no thrusting	c
4	GB (5.6), baryte (8), GB (7.2), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1-2: glass beads of unit 1 are compressed, 3: glass beads of unit 3 are squeezed out, 4+: unit 2 shears off unit 3 on to unit 4	no thrusting	c
5	GB (5.6), baryte (8), GB (1.2), sand (6), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1-2: glass beads of unit 1 are compressed, 4: thrust, but no uplift in unit 3, 5-12: backthrusts in unit 2 and uplift	one thrust: 13	c
6	GB (5.6), baryte (8), sand (3), GB (1.2), sand (3), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1-2: glass beads of unit 1 are compressed, 3: thrusts in unit 3, 6-14: compression and backthrusts in unit 2	one thrust: 15	c
7	sand (3.4), GB (3.4), baryte (6.8), GB (3), sand (3.2), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1-7: uplift in unit 1, 4-11: uplift in unit 3, 5-10: compression in unit 2, 11+: uplift of unit 2	two thrusts: 16, 17	d
8	sand (3.6), GB (2), baryte (8), GB (1.5), sand (5.7), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1-7: uplift in unit 1, 4-11: uplift in unit 3, 5-10: compression in unit 2, 11+: uplift of unit 2	one thrust: 16	d
9	sand (2.8), GB (2.8), baryte (8), GB (2.8), sand (4.4), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1+: uplift unit 1, 3: compression in unit 2, 4: uplift unit 3, 6-14: uplift unit 2	one thrust: 20	d
10	sand (2.8), GB (2.8), baryte (8), GB (2.8), sand (4.4), sand (>5.6)	GB up to 20.8, then sandpaper (<0.4 mm) at 6°	1-8: uplift unit 1, 3-11: uplift unit 3, 5-13: compression and uplift unit 2	one thrust: 17	d
11	sand (4.1), GB (1.5), baryte (8), GB	GB up to 20.8, then	1-5: uplift unit 1, 3-8: uplift unit 3, 7-12: compression and	two thrusts: 13, 15	d

	(1.5), sand (5.7), sand (>5.6)	sandpaper (<0.4 mm) at 6°	uplift unit 2		
12	sand (4.1), GB (1.5), baryte (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil	1-5: uplift unit 1, 4-11: uplift unit 3, 7-12: compression and uplift unit 2	three thrusts: 17, 19, 20	e
13	sand (4.6), GB (1), baryte (9), GB (1), sand (6.2), sand (>5.6)	teflar foil, sand (<0.4 mm) on top	1-4: uplift unit 1, 3-12: compression in unit 2, but no uplift, 5-7: compression in unit 3	four thrusts: 16, 19, 22, 23	a
14	sand (4.1), GB (1.5), baryte (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil, sand (<0.4 mm) on top	1-5: uplift unit 1, 4-12: compression in unit 2, 7: compression in unit 3, 9-19: overridding of unit 2 over unit 3	three thrusts: 20, 24, 25	c
15	sand (4.1), GB (1.5), baryte (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil, on top: viscous gel up to 20.8, then sand	1-4: uplift unit 1, 4-8: compression in unit 2, 4-11: uplift in unit 3	no thrusting	e
16	sand (4.1), GB (1.5), baryte (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil, sand (<0.4 mm) on top	1-3: compression in unit 1, 4: uplift in unit 3, 4-12: unit 2 thrusts over unit 3, subsequent thrusting	three thrusts: 13, 15, 16	a
18	sand (4.1), salt (1.5), baryte (8), salt (1.5), sand (5.7), sand (>5.6)	teflar foil, salt on top	1-2: compression unit 1, 3-4: compression in unit 2, 5-11: unit 2 thrusts over unit 3, subsequent thrusting	two thrusts: 12, 17	c
19	sand (4.1), salt (1.5), rice pudding (8), salt (1.5), sand (5.7), sand (>5.6)	teflar foil, salt on top	1: compression unit 1, 2-7: compression and uplift unit 2, 8-11: unit 2 thrusts over unit 3, subsequent thrusting	three thrusts: 12, 15, 17	b
20	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	teflar foil	1-4: uplift in unit 1, 4-10: compression and uplift unit 2, 7-12: uplift in unit 3	two thrusts: 14, 16	e
21	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	teflar foil, sand (<0.4 mm) beneath unit 2	1-3: uplift unit 1, 4-7: unit 2 is compressed, 4-8: compression in unit 3, 8-13: unit 2 thrusts over unit 3	three thrusts: 17, 20, 21	c
22	sand (3.6), fine sand (2), baryte (8), fine sand (2), sand (5.2), sand (>5.6)	teflar foil, sand (<0.224 mm) on top	1-5: uplift unit 1, 4-9: compression and uplift unit 2, 4-10: uplift unit 3	three thrusts: 12, 15, 18	d

23	sand (4.1), GB (1.5), corn meal (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil	1-3: uplift unit 1, 3-9: uplift unit 2, 10-12: unit 2 thrusts over unit 3, subsequent thrusting	three thrusts: 14, 18, 22	b
25	sand (4.1), GB (1.5), starch (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil	1-3: uplift unit 1, 3-10: uplift unit 2, 11+: subsequent thrusting	four thrusts: 11, 14, 17, 21	b
26	sand (4.1), GB (1.5), corn meal (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil, GB on top	1-3: uplift unit 1, 3-9: uplift unit 2, 7: thrust in unit 3, 10+: unit 2 thrusts over unit 3, subsequent thrusting	four thrusts: 13, 16, 19, 21	b
27	sand (4.1), GB (1.5), starch (8), GB (1.5), sand (5.7), sand (>5.6)	teflar foil, GB on top	1-3: uplift unit 1, 3-8: uplift unit 2, 7-9: uplift in unit 3, 11-12: unit 2 thrusts over unit 3, subsequent thrusting	three thrusts: 13, 17, 19	b
29	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	teflar foil, GB on top	1-5: uplift unit 1, 3-10: uplift of unit 3, 5-9: compression and uplift unit 2	one thrust: 17	d
30	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	no foil, surface of table	1-5: uplift unit 1, 5-10: uplift of unit 3, 6+: compression and uplift unit 2, subsequent thrusting	four thrusts: 16, 18, 19, 22	e
31	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	alcor foil	1-5: uplift unit 1, 5-10: uplift of unit 3, 6+: compression and uplift unit 2, subsequent thrusting	five thrusts: 11, 13, 16, 17, 19	e
32	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	sandpaper (<0.4 mm)	1-5: thrusting in unit 1, 5-10: compression in unit 2, 6-11: thrusts in unit 3, subsequent thrusting	two thrusts: 18, 24	a
33	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	glass beads (<400 mm) paper	1-3: compression unit 1, 4-7: compression unit 2, 8+: compression in unit 3, 14+: whole system is moving	no thrusting	a
34	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	glass beads (<200 mm) paper	1-7: compression unit 1, 8-12: uplift in unit 3, 13-19: overriding of units 1 and 2 over 3, 19+: whole system is moving	no thrusting	a

35	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6)	alcor foil up to 20.8, then sandpaper (<0.4 mm)	1-5: uplift unit 1, 6-12: uplift unit 3, 7-12: compression in unit 2, 13-21: system at same position but further compression, 22+ system has one taper angle and is moving as a whole	no thrusting	first e, then a
36	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6) → erosion	alcor foil	1-7: uplift unit 1, 4-10: uplift unit 3, 5-11: compression unit 2, subsequent thrusting	four thrusts: 12, 13, 16, 19	e
37	sand (2.1), GB (1.4), sand (2.1), baryte (8), sand (2.9), GB (1.4), sand (2.9), sand (>5.6) → detachment in unit 4	alcor foil	1-3: uplift unit 1, 3-12: compression and uplift unit 2, 6-12: uplift unit 3	three thrusts: 10, 14, 18	e
38	sand (2), GB (1), sand (2), baryte (9), sand (4), GB (1.5), sand (4), sand (10+) → detachment in unit 4	alcor foil	1-5: uplift unit 1, 5-10: compression and uplift unit 2, 6-11: uplift unit 3, subsequent thrusts	eight thrusts: 12, 16, 18, 23, 25, 26, 28, 29	e
39	sand (3.5), GB (1), sand (3.5), baryte (6), sand (5.5), GB (1), sand (5.5), sand (10+)	alcor foil	1-5: uplift unit 1, 5+: compression and uplift unit 2, 6-13: uplift unit 3	two thrusts: 15, 17	e
40	sand (3.5), GB (1), sand (3.5), baryte (6), sand (5.5), GB (1), sand (5.5), sand (10+) → height 1.7	alcor foil	1-3: uplift unit 1, 3-7: compression and uplift unit 2, 5-12: uplift unit 3	eight thrusts: 14, 16, 21, 24, 26, 27, 28, 31	e
41	sand (2), GB (1), sand (2), baryte (9), sand (4), GB (1.5), sand (4), sand (10+)	alcor foil, unit 4 at 10°	1-4: uplift unit 1, 5-12: compression and uplift unit 2, 6-16: uplift unit 3	five thrusts: 18, 21, 23, 24, 25	e
42	sand (2), GB (1), sand (2), baryte (9), sand (4), GB (1.5), sand (4), sand (10+) → erosion	alcor foil	1-4: uplift unit 1, 3-13: compression and uplift unit 2, 6-12: uplift unit 3, subsequent thrusting	seven thrusts: 13, 17, 20, 23, 26, 27, 28	e
43	sand (2), GB (1), sand (2), baryte (9), sand (4), GB (1.5), sand (4), sand (10+)	alcor foil up to 47 cm, sandpaper 47+	1-4: uplift unit 1, 5-15: compression and uplift unit 2, 5-17: uplift unit 3 and compression, 17+: system develops one high taper angle and moves as a whole	no thrusting	first e, then a
44	sand (4), GB (2), sand (4), baryte (18), sand (8.5), GB (2), sand (8.5), sand (20+)	alcor foil	1-5: uplift unit 1, 4-11: compression and uplift unit 2, 5-18: compression and uplift unit 3, subsequent thrusting	four thrusts: 19, 24, 27, 30	e

47	sand (5), baryte (8), sand (5), sand (5+)	alcor foil	subsequent thrusting in units 1-4	no differentiation between unit 3 and 4	a
48	GB (5), sand (8), GB (5), GB (5+)	alcor foil	subsequent thrusting in units 1-4	no differentiation between unit 3 and 4	a
49	GB (5), sugar (8), GB (5), GB (5+)	alcor foil	unit 2 is compressed and uplifted, no thrusts	no differentiation between unit 3 and 4	b
50	GB (40-70 μm) (5), GB (8), GB (40-70 μm) (5), GB (5+)	teflar foil	1: thrust in unit 1, 2-5: thrusts in unit 2, 6+: more thrusts in unit 3 and 4	no differentiation between unit 3 and 4	a
51	GB (5), Z-lights (8), GB (5), GB (5+)	teflar foil	1: uplift in unit 1, 2-7: uplift unit 2, no subsequent thrusts visible as they are immediately covered by slope sediments from unit 2	-	b
52	GB (5), sand (8), GB (5), GB (5+)	teflar foil	1-4: uplift unit 1, 5-7: compression unit 2, 5-13: uplift unit 3	two thrusts: 15, 19	d
53	sand	teflar foil	No differentiation in units: thrusts at: 4, 8, 10, 16, 21, 25	-	a
54	GB	teflar foil	No differentiation in units: taper angle constantly increases, no thrusts visible as they are immediately covered by slope sediments	-	a
55	sand (5), sugar (8), sand (5), sand (5+)	teflar foil	1-2: uplift unit 1, 4-9: uplift in unit 2, 5-14: uplift in unit 3	one thrust: 16	b

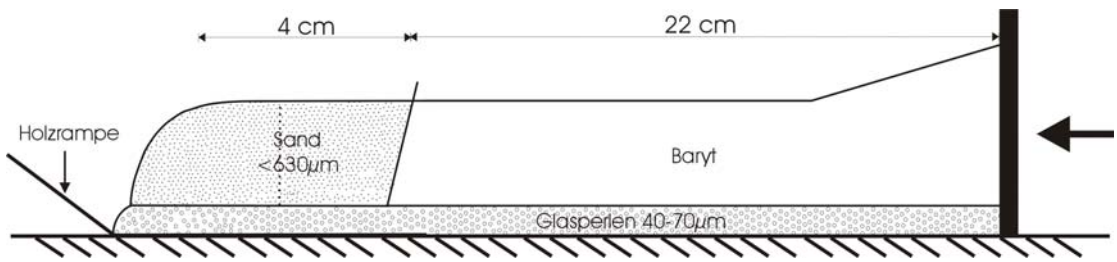
Annotations:

- 1) GB stands for glass beads;
- 2) Numbers in brackets in the column "initial conditions" specify the width of units in centimetres;
- 3) Numbers under "structural evolution development" and "activity in unit 4" indicate the centimetre of convergence at which a certain development has taken place.

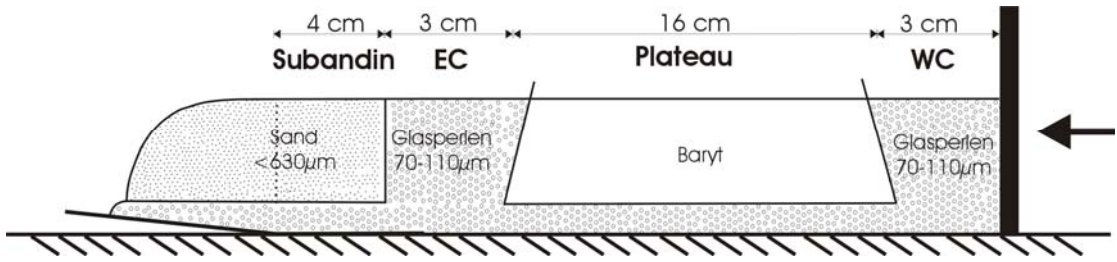
Appendix B-2

Set-up Sketches (Granular Experiments)

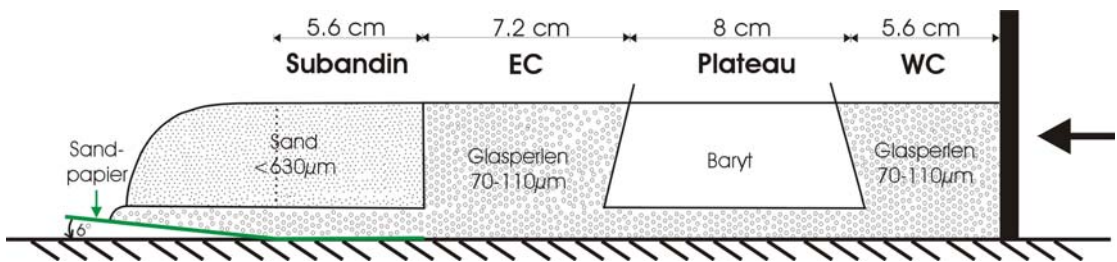
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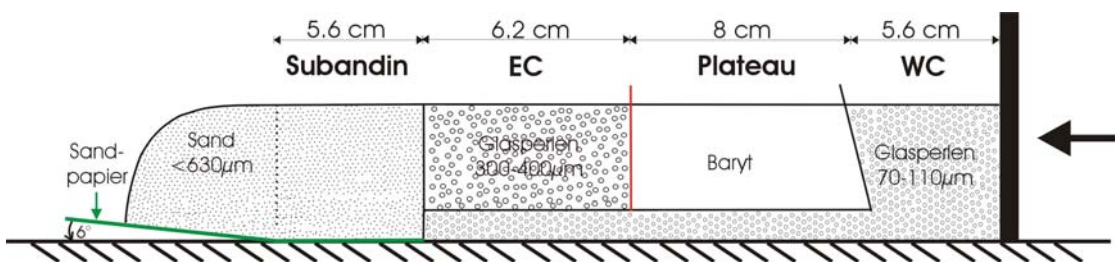
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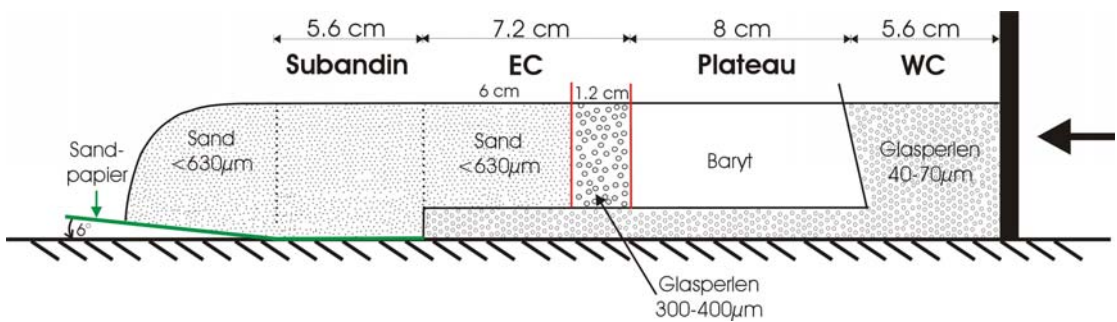
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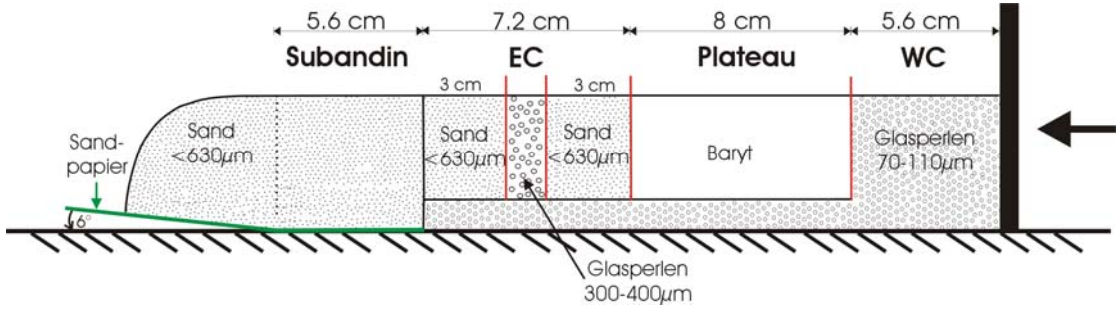
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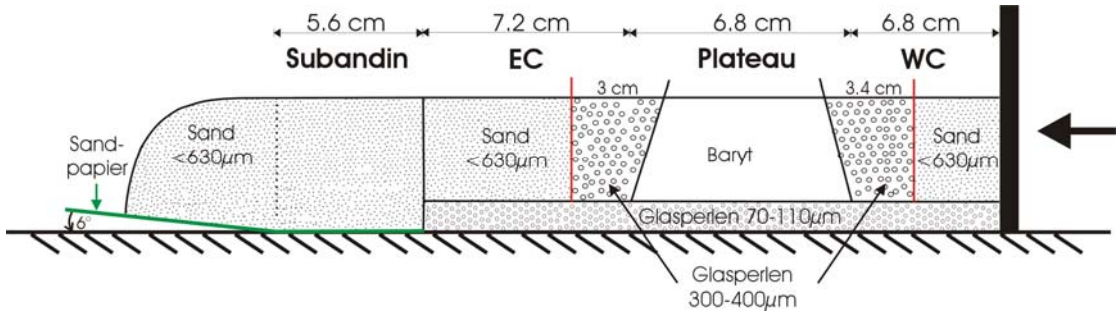
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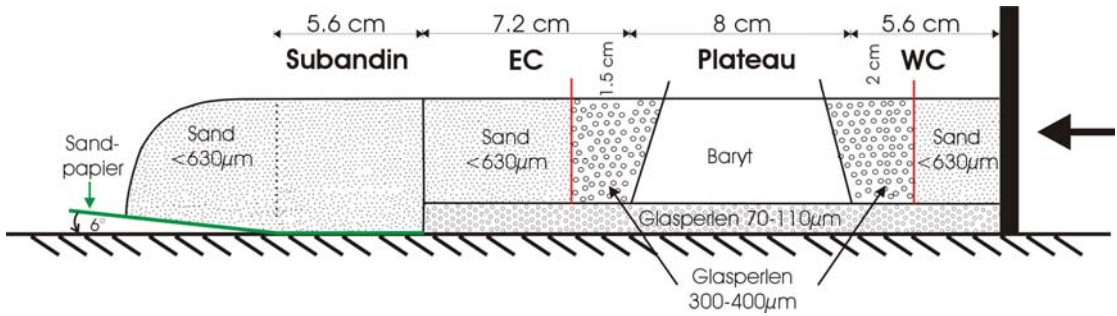
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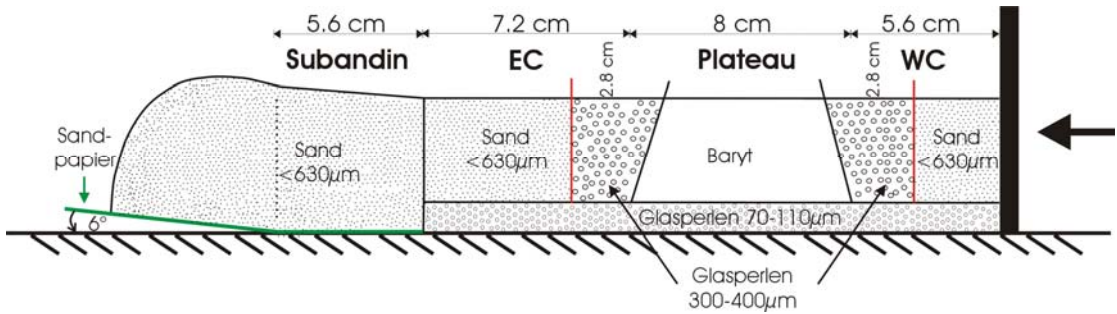
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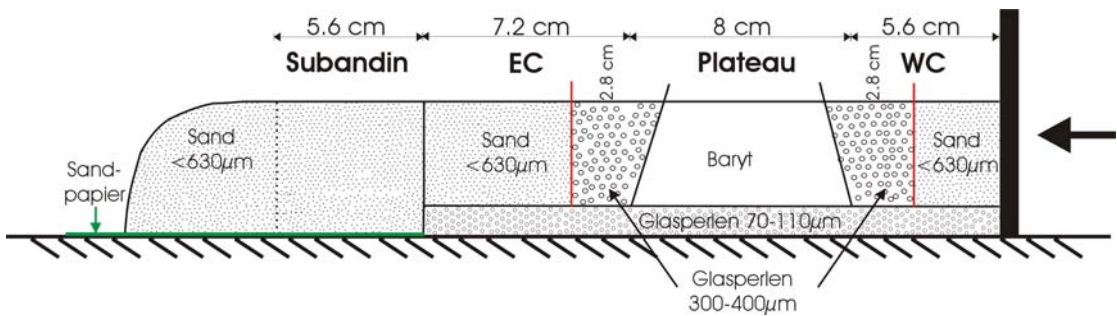
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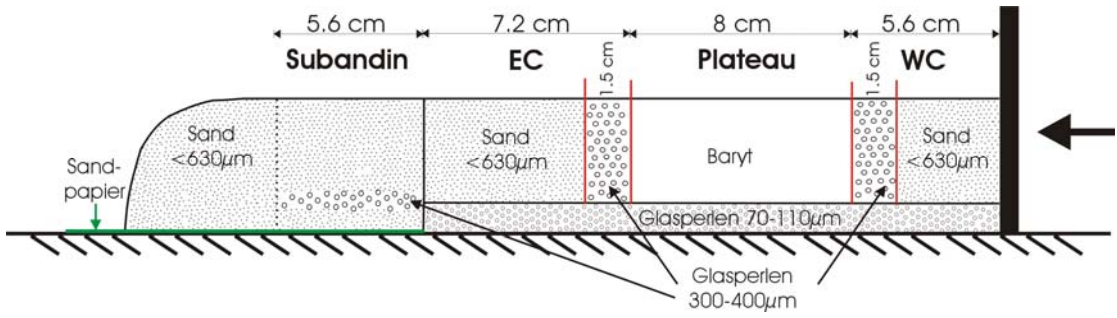
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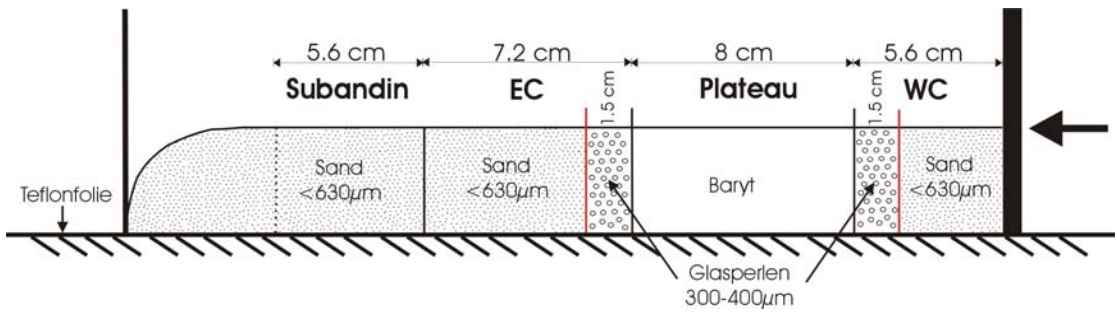
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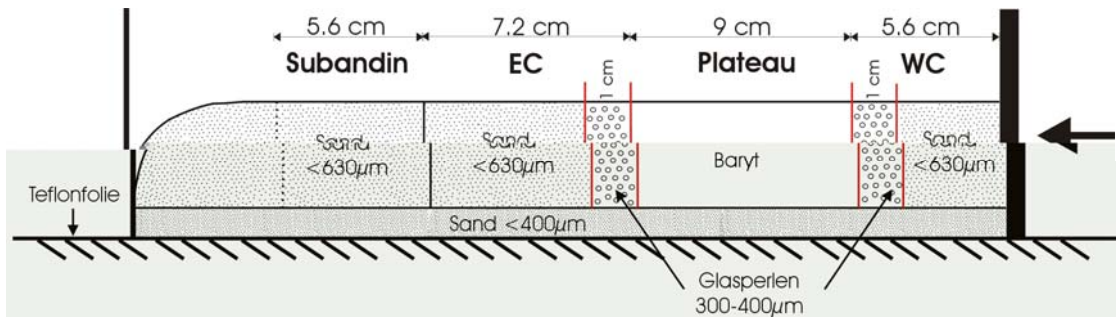
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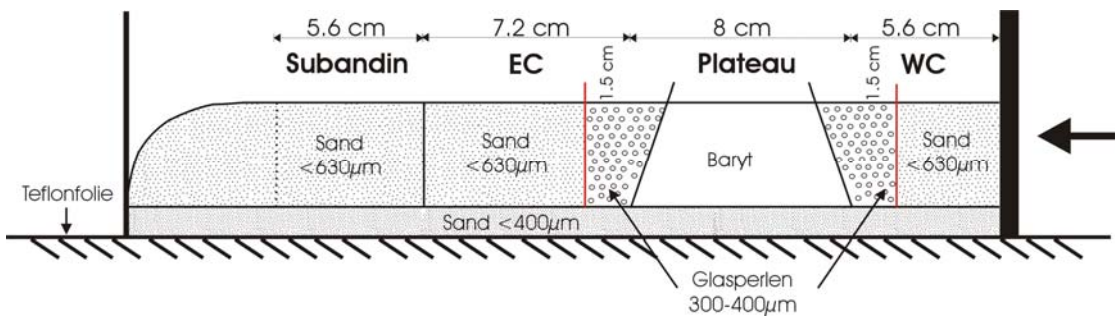
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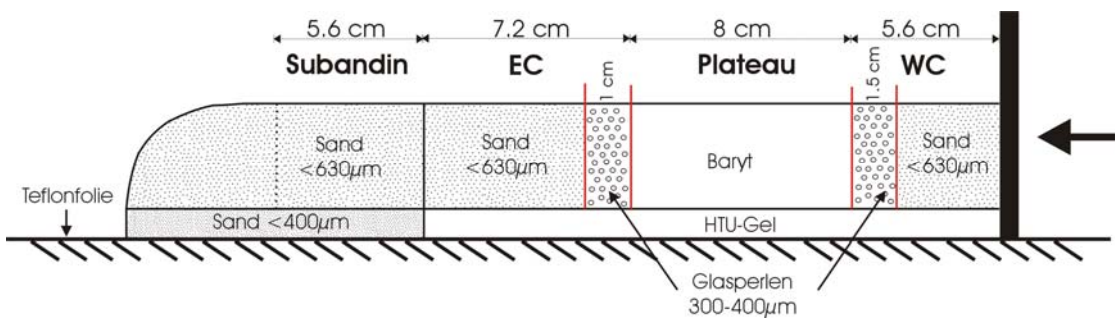
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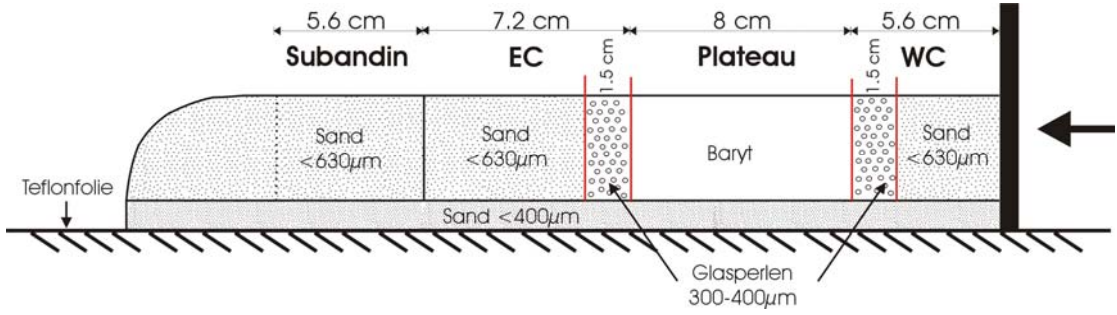
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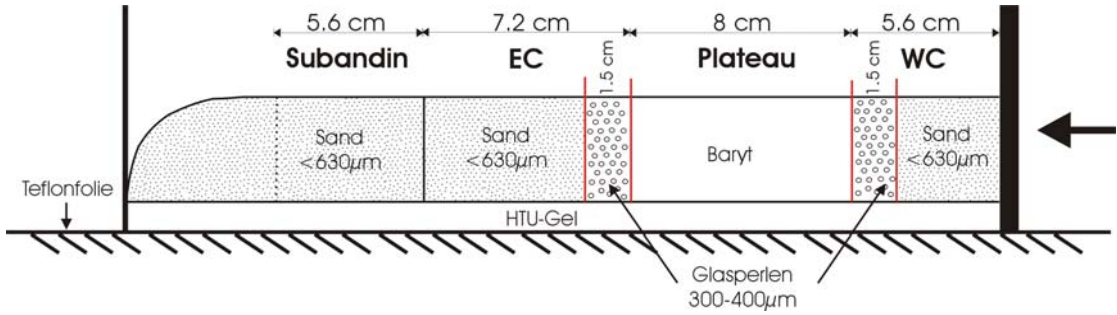
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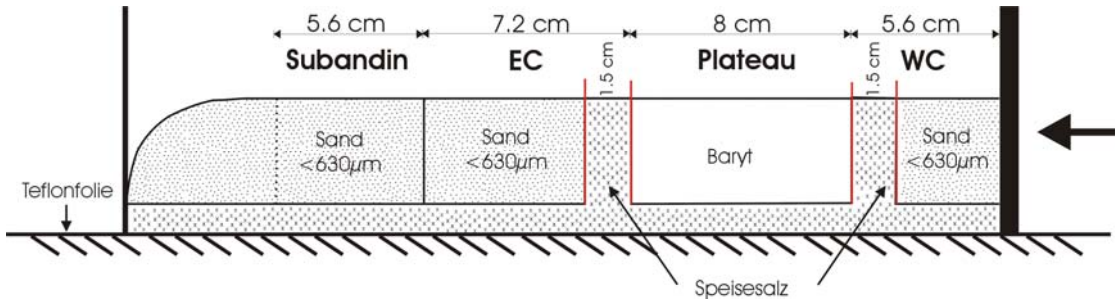
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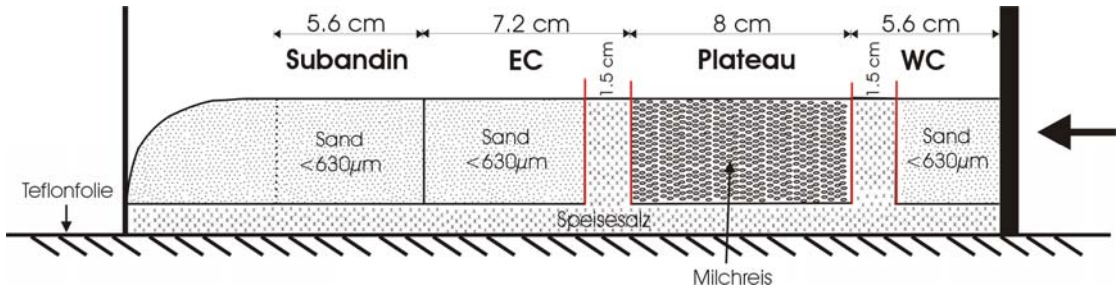
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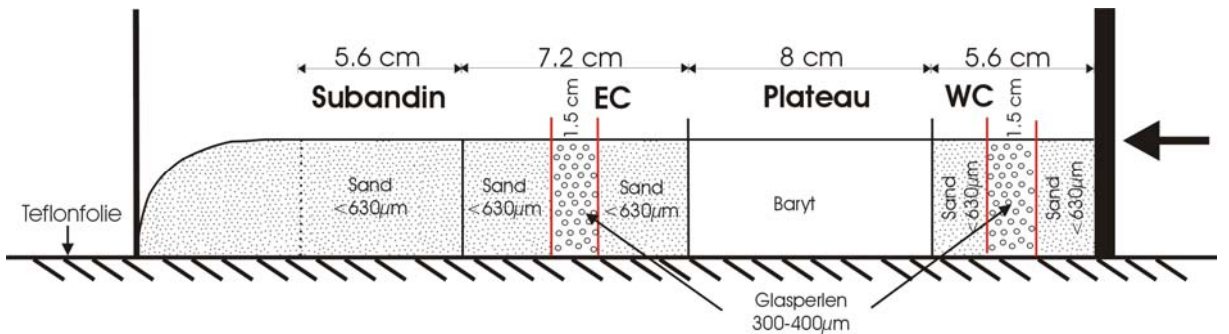
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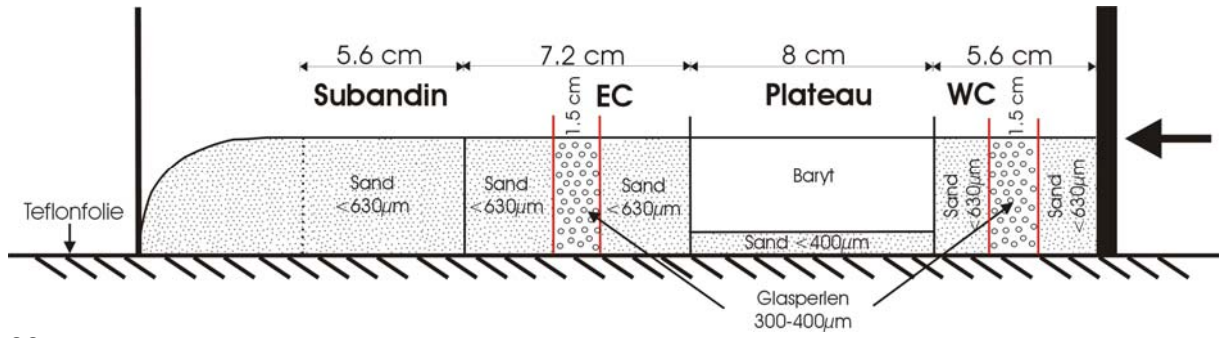
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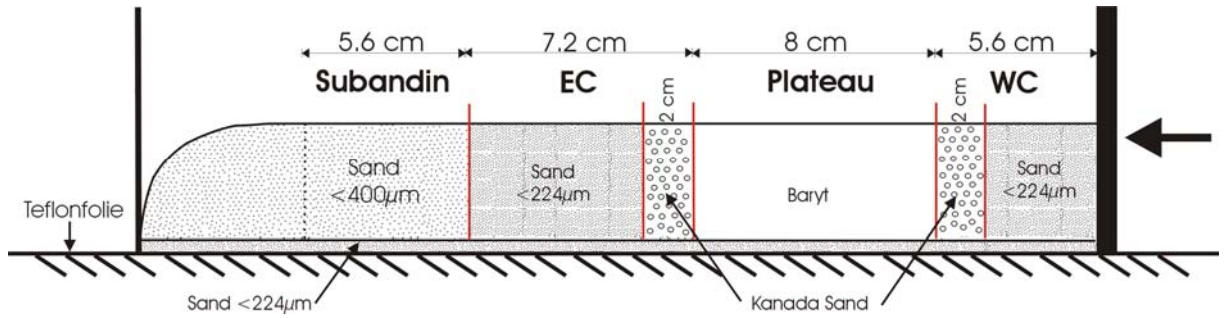
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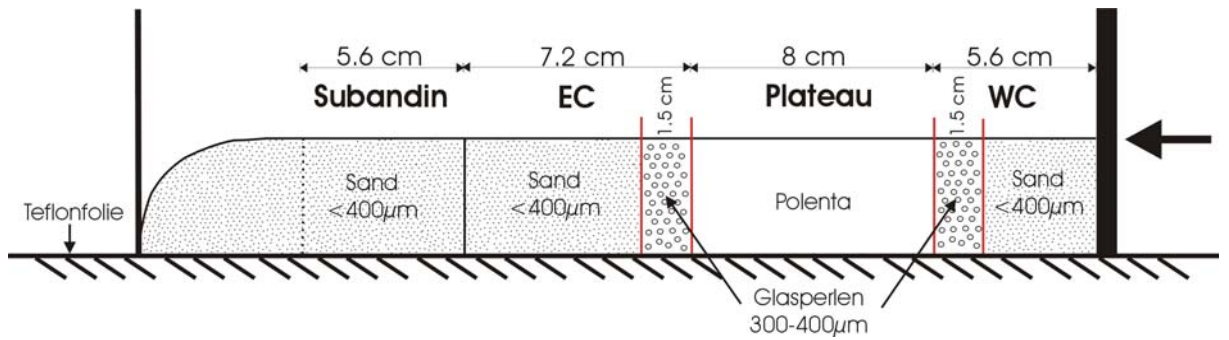
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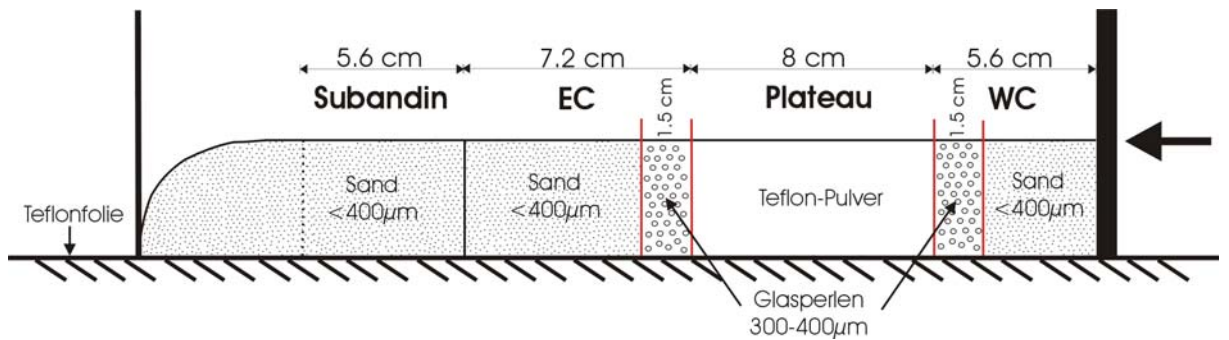
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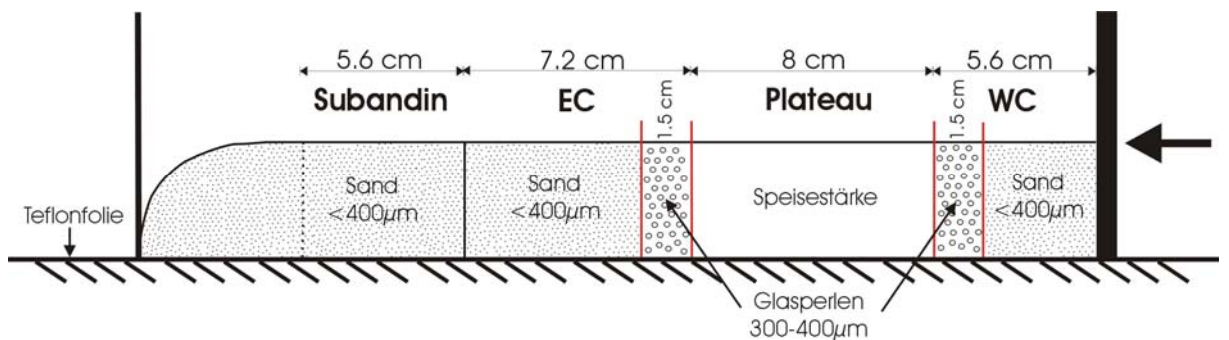
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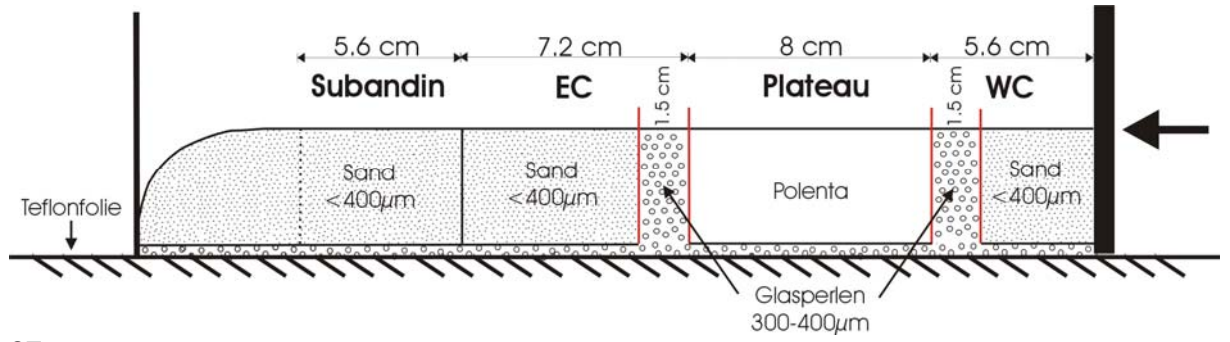
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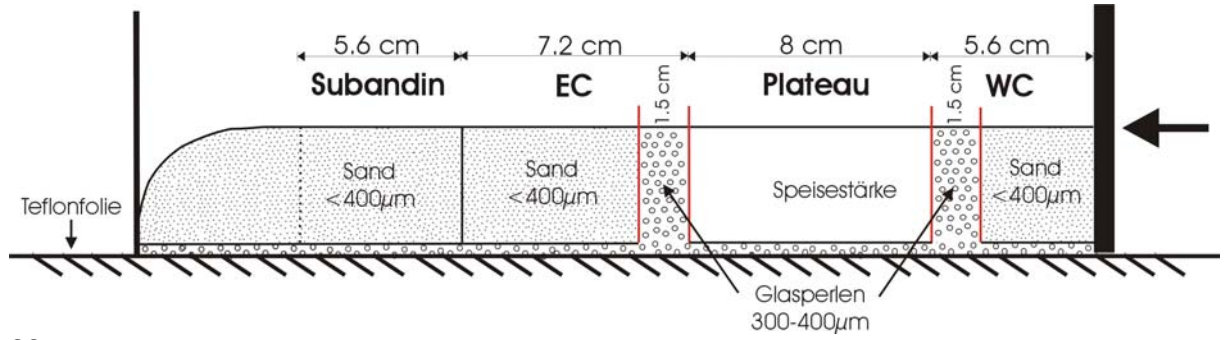
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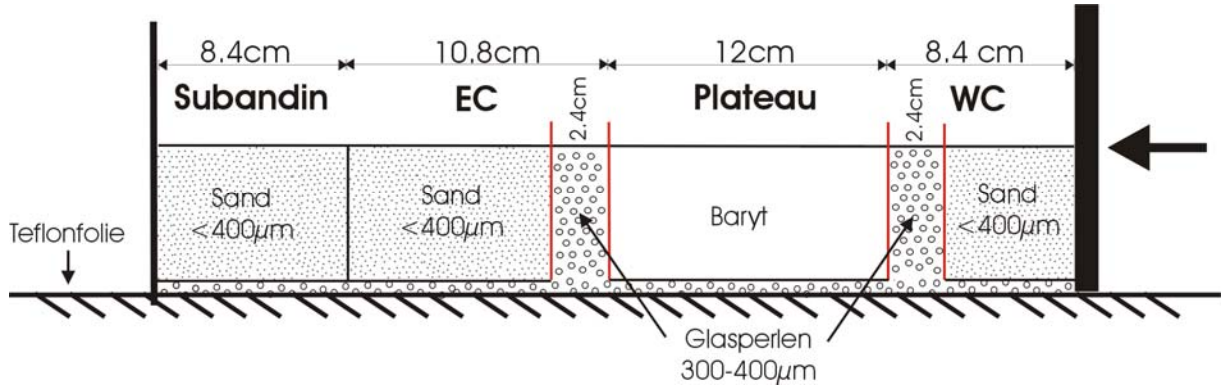
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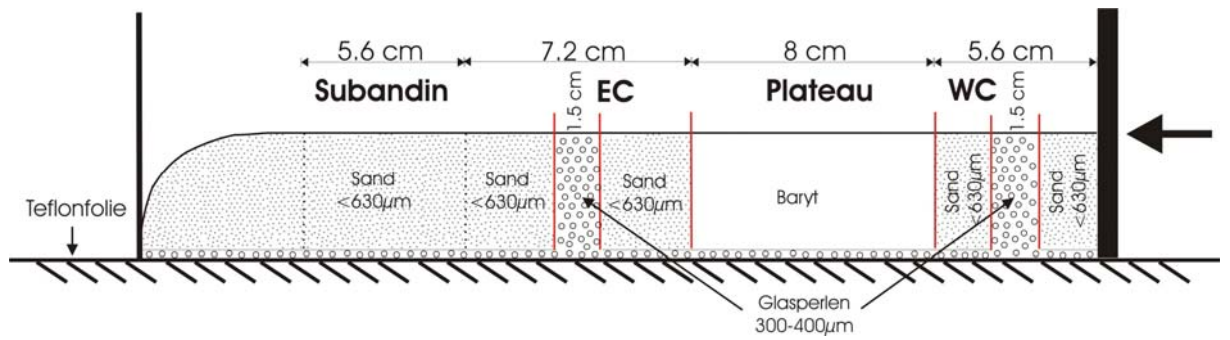
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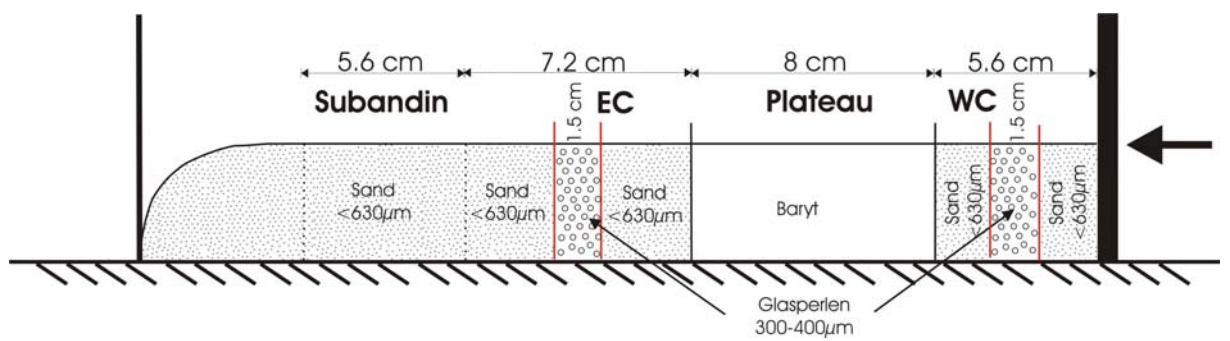
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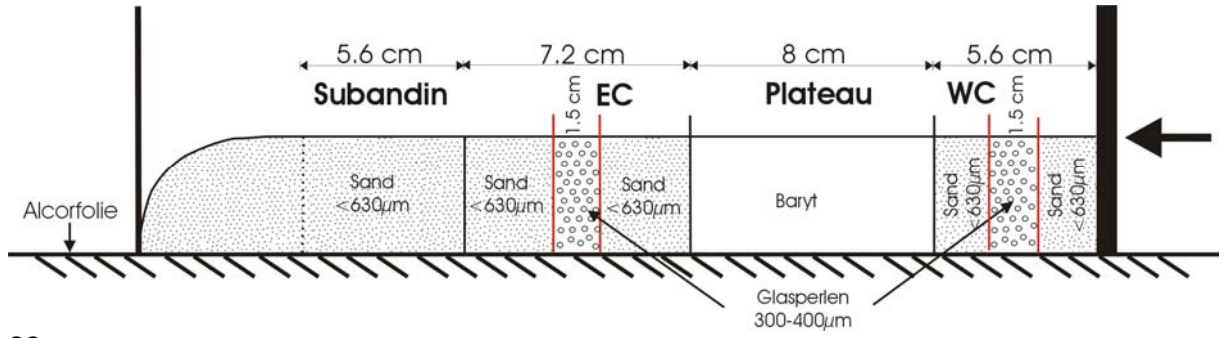
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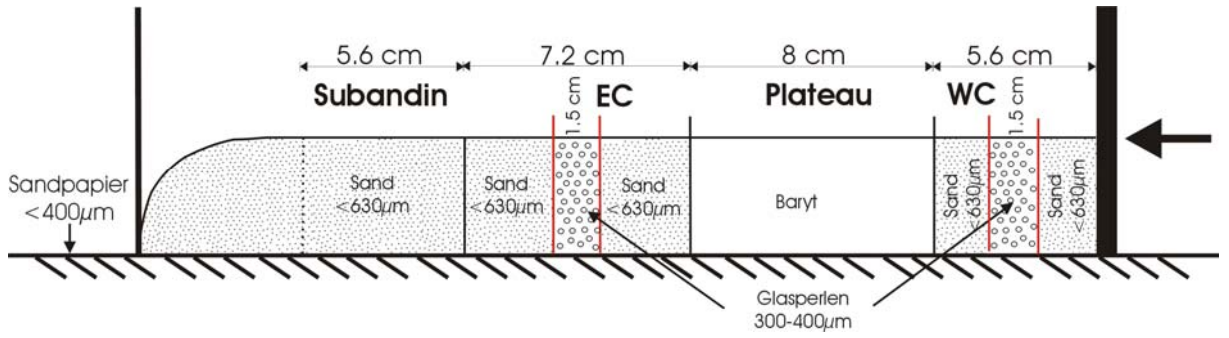
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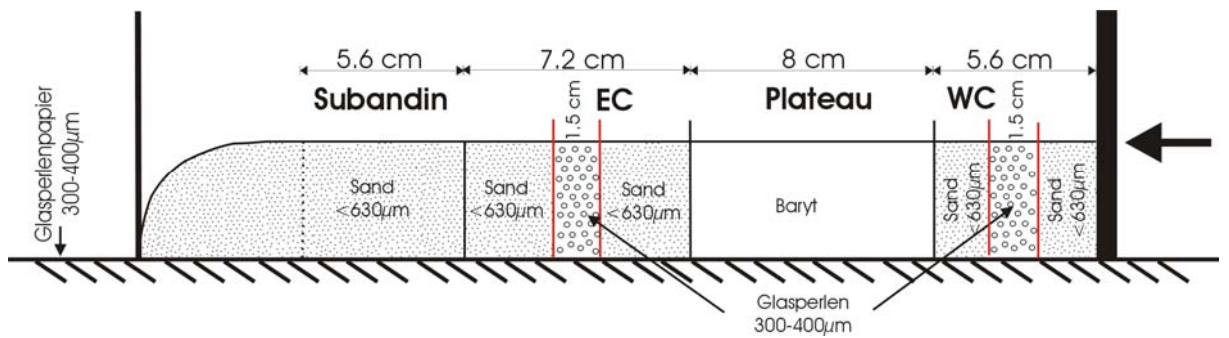
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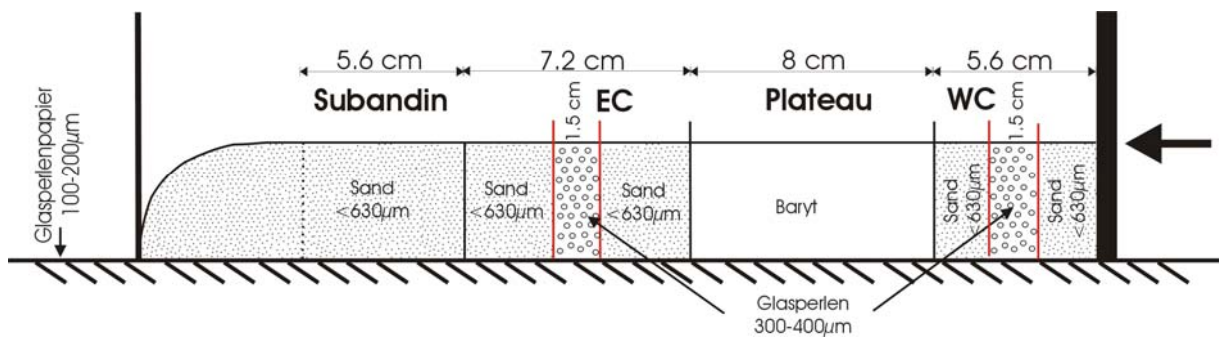
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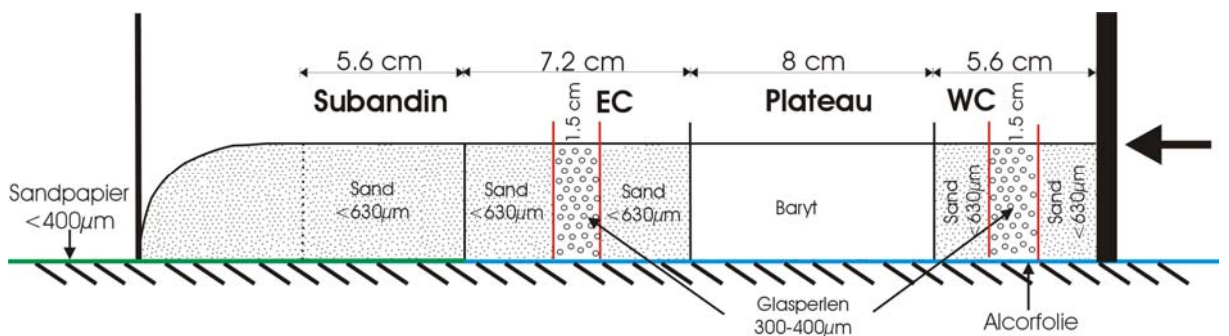
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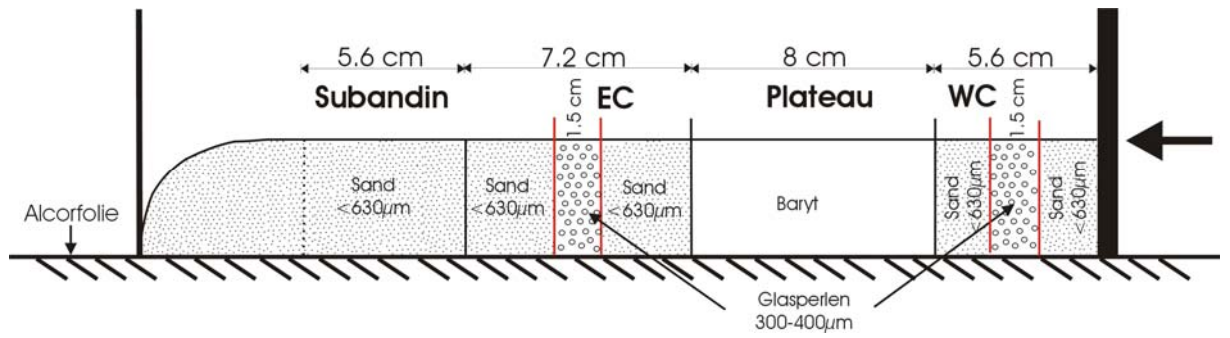
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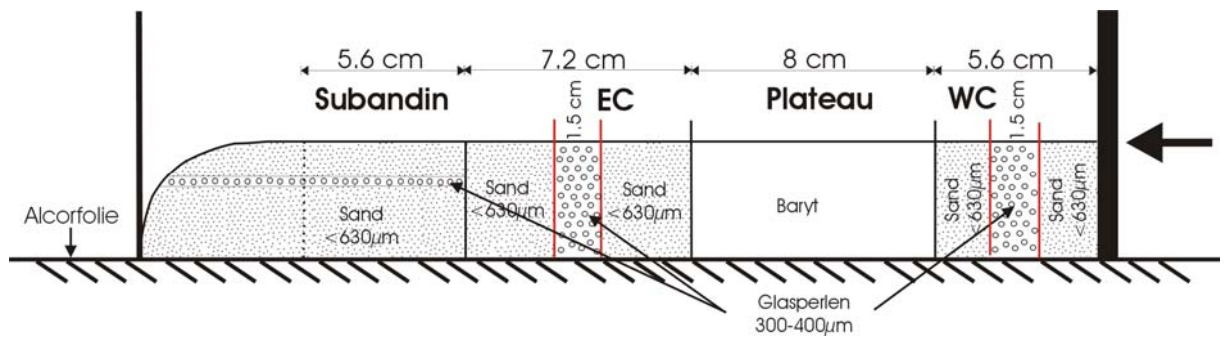
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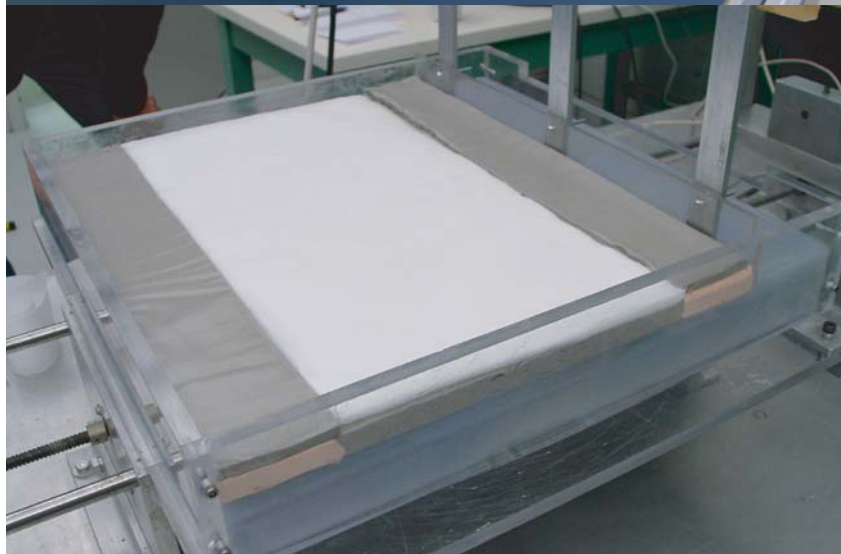
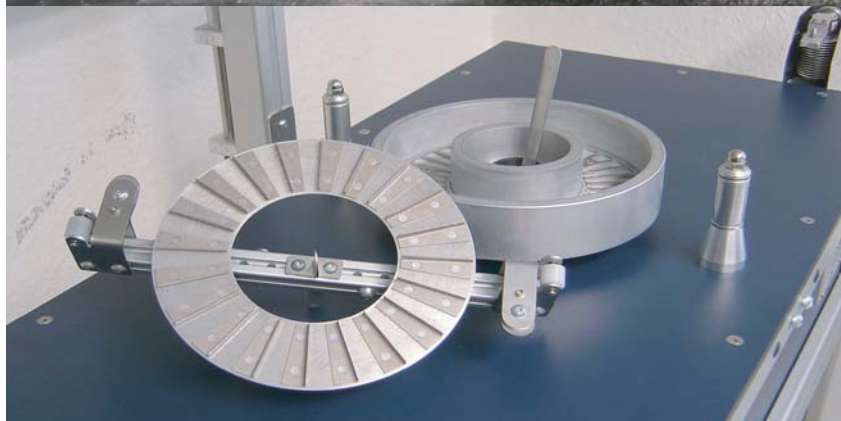
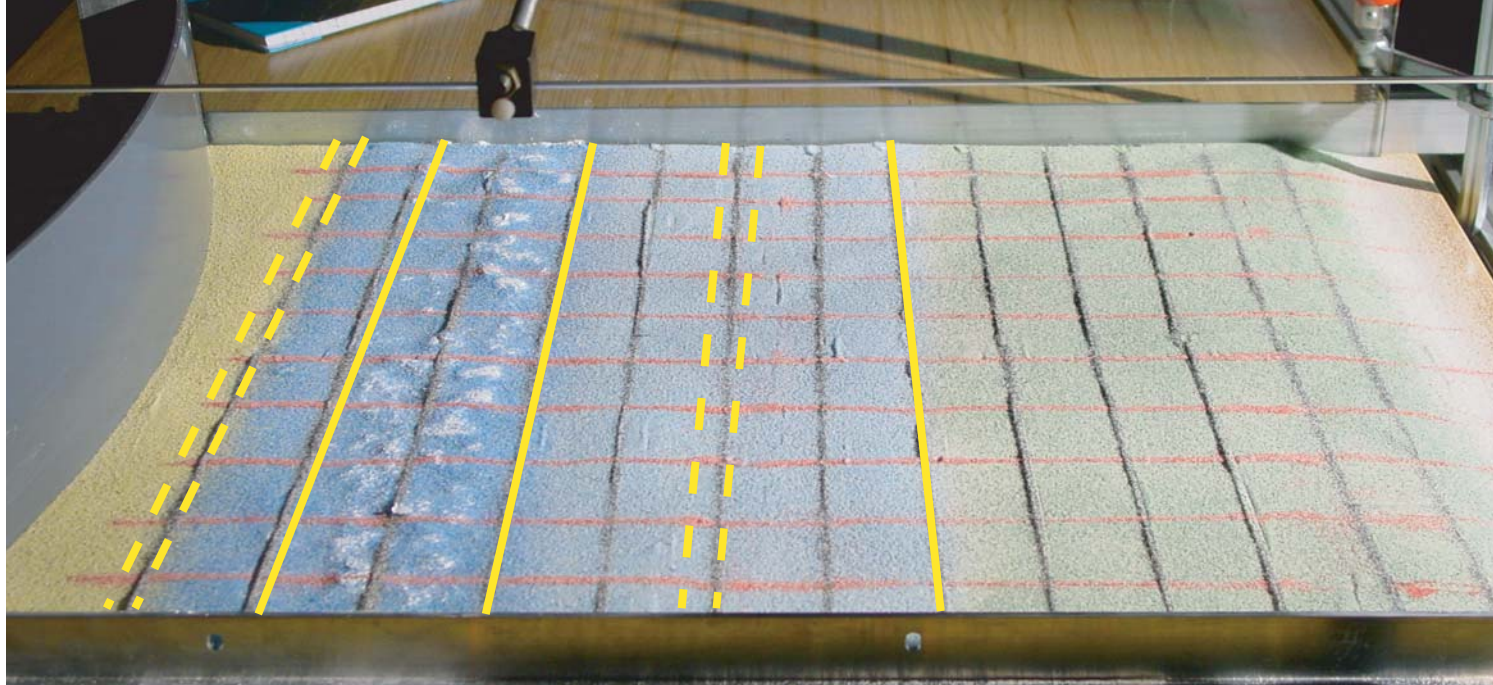
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Experiments 38-44 have a similar set-up than Experiment 37, but with different dimensions (confer Appendix B, Details on initial experimental set-ups).

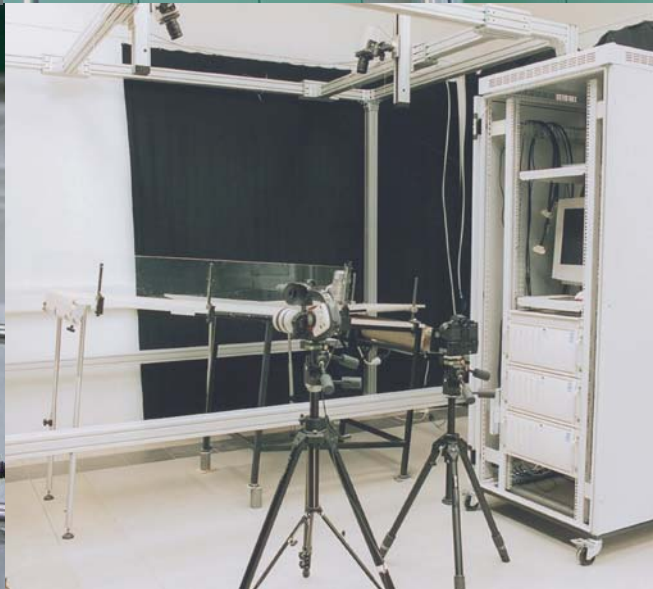
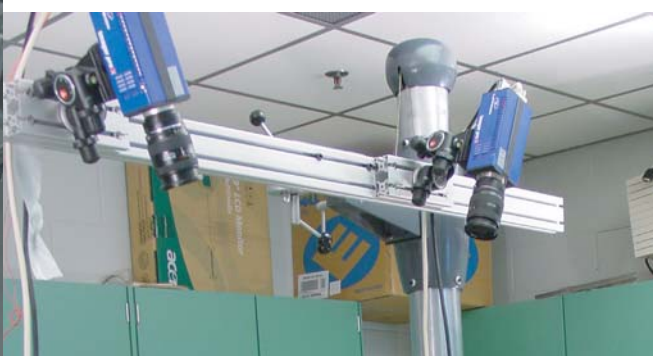
Appendix B-3

Photographs of Analogue Devices



Analogue devices

top: Granular experimental set-up
left (second from top): ring shear device
left (third from top): viscous layers in tank
left (bottom): vise model (here with viscous asthenosphere)
below: PIV cameras in stereoscopic view
bottom (right): PIV rack with PIV cameras (background), PIV computer (right), and digital cameras (front)



Appendix B-4

Material Parameters for Vise Experiments

Appendix B-5

Material mixtures for Vise Experiments

	upper crust	strong lower crust (for one vice)	strong mantle lithosphere (for one vice)	weak lower crust	weak mantle lithosphere	mantle
Mixtures						
Vice a	514,24 g sand 269 g Z-lights	176,5 g PDMS 18 g black plasticene 37,5 g Z-lights	152 g pink putty 412 g PDMS 45,5 g Z-lights	8,16 g PDMS 24 g 3M glass bubbles S 46,5 g low-viscosity silicone	1922,15 g reused PDMS 186,9 g black plasticene 234,3 g Z-lights	reused PDMS
Exp. 1	514,24 g sand 269 g Z-lights	194 g PDMS 20,5 g black plasticene 25 g Z-lights	158 g pink putty 446,4 g PDMS 19,5 g Z-lights	750,7 g PDMS 4,2 g 3M glass bubbles S 67,3 g low-viscosity silicone	2381,4 g reused PDMS (27 cm frame)	water
Exp. 2	413,45 g sand 175,8 g Z-lights	194 g PDMS 20,5 g black plasticene 25 g Z-lights	158 g pink putty 446,4 g PDMS 19,5 g Z-lights	566,2 g PDMS 70 g glass bubbles S 55 g low-viscosity silicone of this 345,6 g and 76,8 PDMS 32 g 3M glass bubbles S 245,7 g low-viscosity silicone	1190,7 reused PDMS (24 cm frame)	water
Exp. 3	370 g sand 129 g Z-lights	for both vices 350 g PDMS 39 g black plasticene 47 g Z-lights	for both vices 393 g pink putty 665 g PDMS 78 g Z-lights	566,2 g PDMS 70 g glass bubbles S 55 g low-viscosity silicone of this 336,7 g and 76,8 g glass bubbles S 32 g 3M glass bubbles S 245,7 g low-viscosity silicone	1058,4 g reused PDMS (will be cut smaller)	water
vice b	370 g sand 129 g Z-lights	for both vices 350 g PDMS 39 g black plasticene 47 g Z-lights	548,5 g recovered 203,2 g pink putty 343,7 g PDMS 40,6 g Z-lights	328,7 g PDMS 248,9 g low-viscosity silicone 102,6 g iron filler 67,6 g 3M glass bubbles S	944,64 g reused PDMS	water
Exp. 4	370 g sand 129 g Z-lights	for both vices 350 g PDMS 39 g black plasticene 47 g Z-lights	847,8 g recovered 99,7 g pink putty 168,6 g PDMS 19,9 g Z-lights	328,7 g PDMS 248,9 g low-viscosity silicone 106,3 g barium sulphate filler 63,9 g 3M glass bubbles S	944,64 g reused PDMS	water
Exp. 5	370 g sand 129 g Z-lights	for both vices 370 g PDMS 31 g blue plasticene 36 g Z-lights	910,4 g recovered 78,2 g pink putty 132,2 g PDMS 15,6 g Z-lights	328,7 g PDMS 248,9 g low-viscosity silicone 106,3 g barium sulphate filler 63,9 g 3M glass bubbles S <i>low-viscosity silicone for LVZ</i>	944,64 g reused PDMS	water
Exp. 6	370 g sand 129 g Z-lights	for both vices 370 g PDMS 31 g blue plasticene	797 g recovered 117,3 g pink putty 198,3 g PDMS	304,1 g PDMS 230,3 g low-viscosity silicone 87,1 g barium sulphate filler	1889,3 g reused PDMS	water

Exp. 7	370 g sand 129 g Z-lights	36 g Z-lights	23,4 g Z-lights	63,1 g 3M glass bubbles S	944,64 g reused PDMS 150,92 g reused PDMS extra	water
	319,2 g from this: for both vices 370 g PDMS 31 g blue plasticene 36 g Z-lights	831,6 g recovered		383,9 PDMS 133,34 calcium sulphate 290,7g low-viscosity silicone 65,45 g 3M glass bubbles S		
Exp. 8	370 g sand 129 g Z-lights	287,6 g PDMS 24,1 g blue plasticene 28 g Z-lights	242 g recovered 222,5 g pink putty 376,2 g PDMS 44,4 g Z-lights	397,86 g PDMS 301,1 g low-viscosity silicone 138,2 g calcium sulphate 67,8 g 3M glass bubbles S	1167,18 g reused PDMS	water
Exp. 9	370 g sand 129 g Z-lights	117,8 g left from vice 9 270,3 g PDMS 22,6 g blue plasticene 26,3 g Z-lights	for both vices 393 g pink putty 665 g PDMS 78 g Z-lights	buoyant part (10 cm wide) 136,6 g PDMS 25,4 g 3M glass bubbles S 0,15 g calcium sulphate 103,4 g low-viscosity silicone non-buoyant part (2*7cm wide) 191,74 g PDMS 145,2 g low-viscosity silicone 66,6 g calcium sulphate 32,7 g 3M glass bubbles S	944,64 g reused PDMS	water