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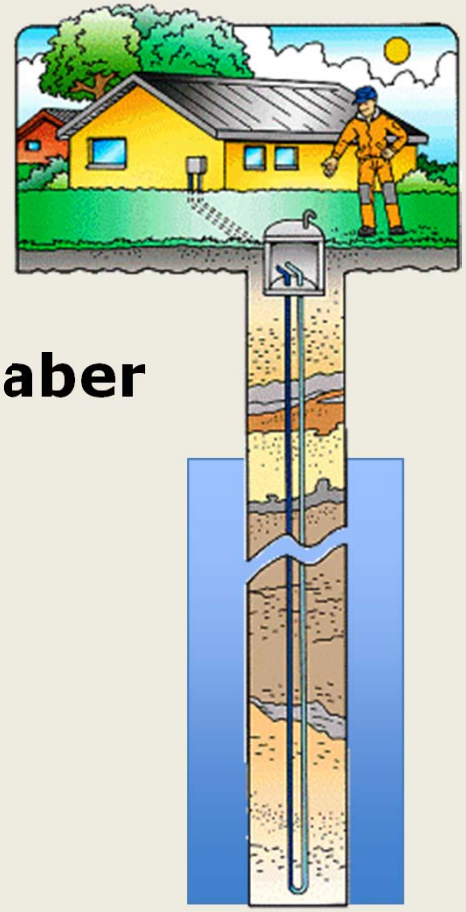


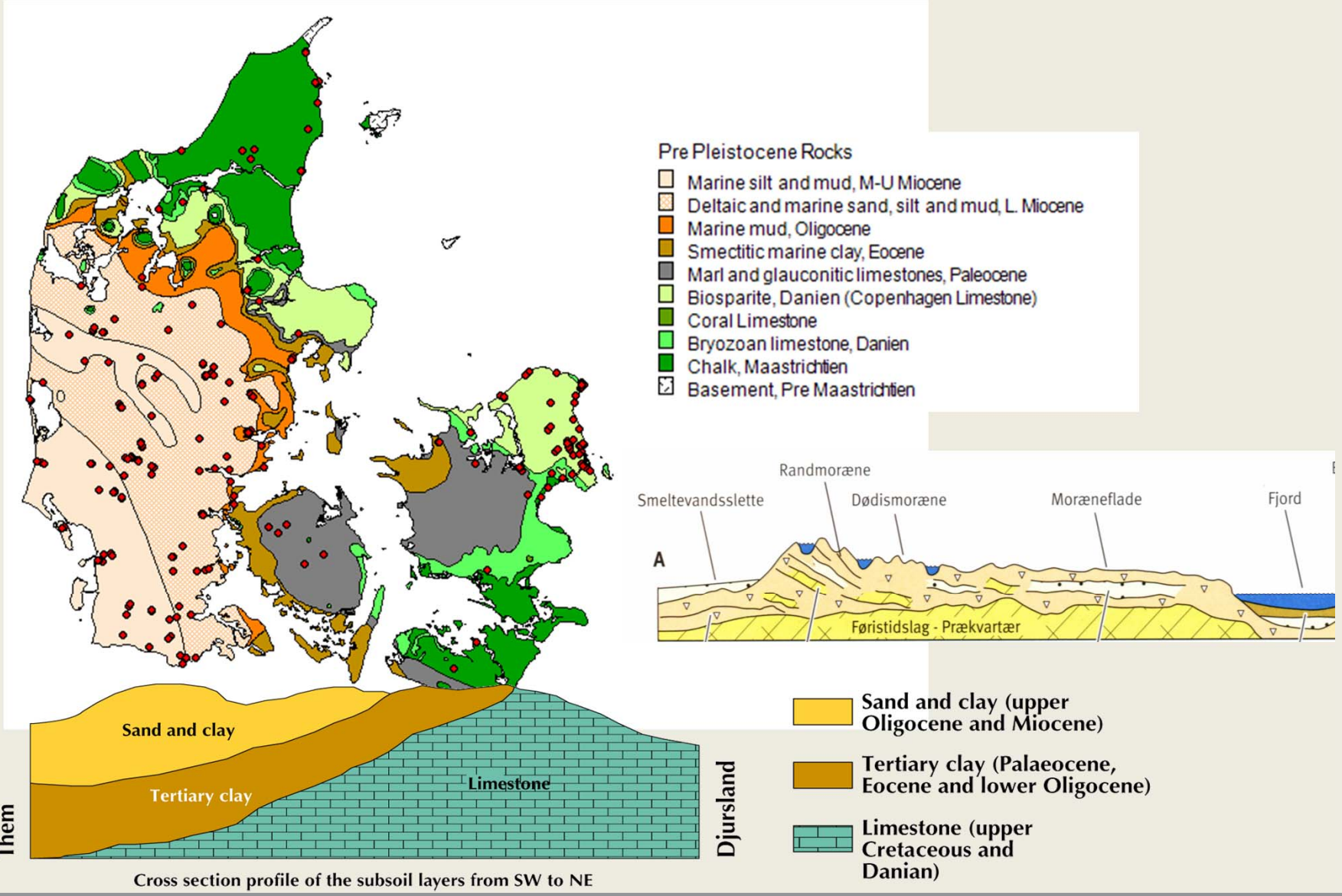
Måling af jordarters termiske egenskaber
WP2

VIA UNIVERSITY COLLEGE

Claus Ditlefsen

EUDP
Energiteknologisk udvikling og demonstration

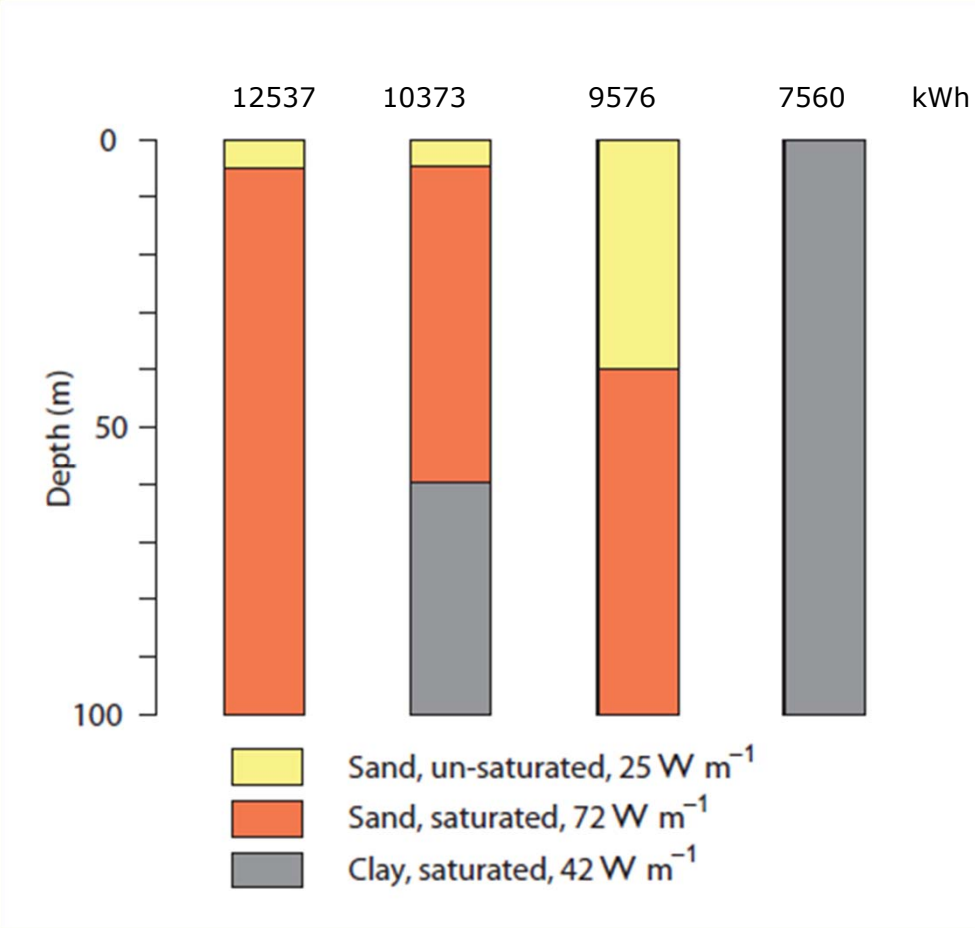
–Beliggenhed af jordvarmeboringer



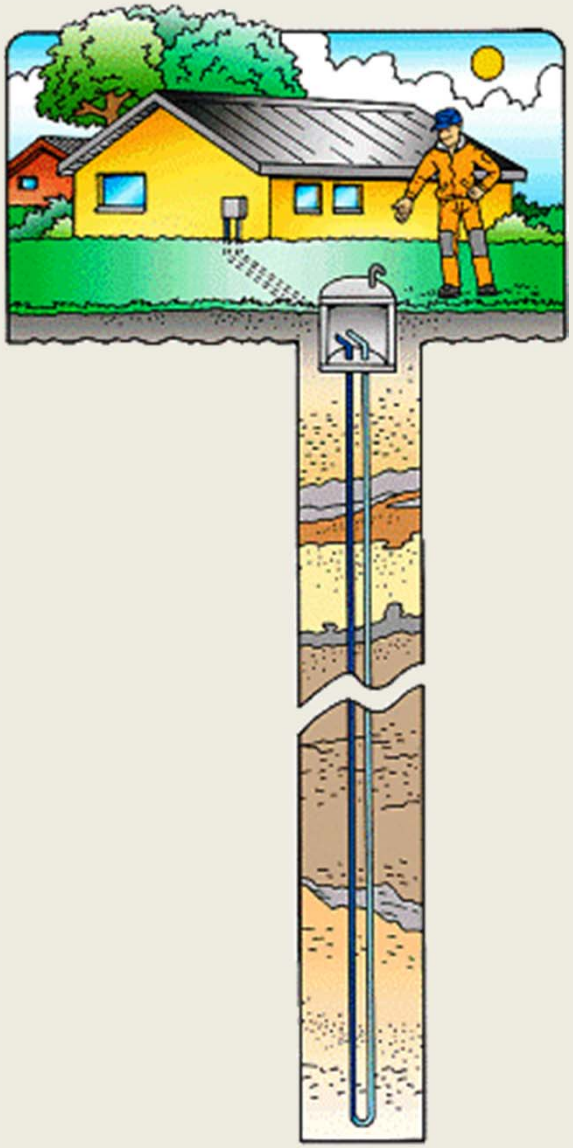
Cross section profile of the subsoil layers from SW to NE

–Anslået årlig udbytte

–Standard design, 1800 timers produktion



–Specific heat extraction rates from VDI (2001)



Fourier's lov:

$$\dot{Q} = k A \frac{\Delta T}{\Delta x}$$

where:
k = thermal conductivity (property)
A = cross-sectional area
ΔT = temperature difference
Δx = thickness

Termiske egenskaber
Internationale tabelværdier

Mineral	Varmeledningsevne W/mK	Specifik varmekapacitet MJ/m^3K
Kvarts	7,7	1,9-2,0
Feldspat	1,5-2,5	1,6-2,2
Glimmer	2,0-2,3	2,2-2,3
Calsit	3,6	2,2
Stensalt	5,9-6,5	1,98
Vand (10° C)	0,6	4,15
Luft (1 atm.)	0,024	0,0013

Fra Banks (2008)

Types of Soil	Thermal Conductivity W / (mK)
Saturated Soil	0.15 - 4
Sand perfectly dry	0.15 – 0.25
Sand moist	0.25 - 2
Sand saturated	2 - 4
Clay dry to moist	0.15 – 1.8
Clay saturated	0.6 – 2.5
Soil with organic matter	0.15 - 2
Solid Rocks	2 - 7
Tuff (porous volcanic rock)	0.5 to 2.5
Water	0.6
Air	0.001

Fra www.Huxeflux.com

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–Varmeledningsevne i danske sedimenter

–Publicerede værdier

Sediment	Reference	λmin W/mK	λmax W/mK	λavg W/mK
SAND	B	1,95	2,004	1,97
SAND, fine silty	B	1,704	1,713	1,71
SAND, fine, silty	B	1,943	2,122	1,94
SAND, medium grainsize	B	1,89	1,9	1,9
Clay Till	B	2,18	2,21	2,21
Clay Till, sandy	B	2	2,09	2,06
Clay Till, very sandy	B	2,2	2,31	2,27
Marine clay, Oligocene Viborg 5, 215 m	A			1.39
Marine clay, Oligocene Vinding 1, 340 m	A			1.48
Marine clay, Eocæn-Paleocene Viborg 5, 243-312 m	A	1,34	1,40	1.38
Marine clay, Eocæn-Paleocene Viborg 1, 434 m	A			1.56
Chalk Gasum 1 (136-267 m)	A	1,7	1,86	1,8
Chalk Rønnebjerg 1 (171-283m)	A	1,55	1,67	1,61
Chalk Svenstrup (124-198 m)	A	1.45	1.52	1,49
Chalk Vemb 1 (127 m) Geoteknisk	A			1,57
A: Geoteknisk Institut (1986)				
B: Balling et al. (1981)				

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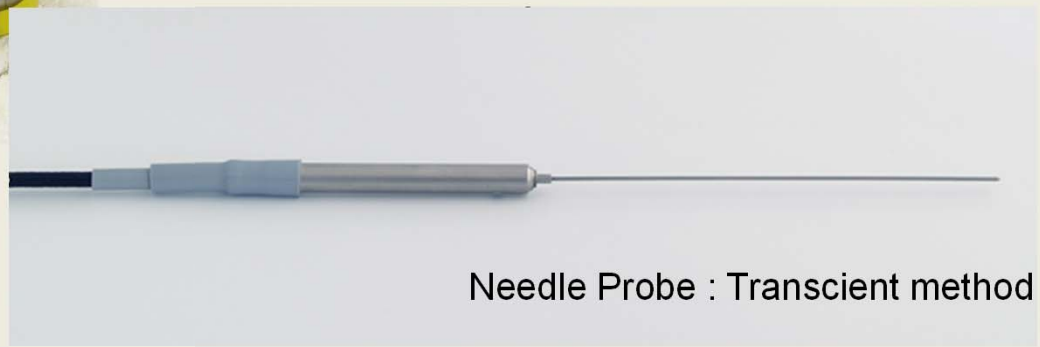
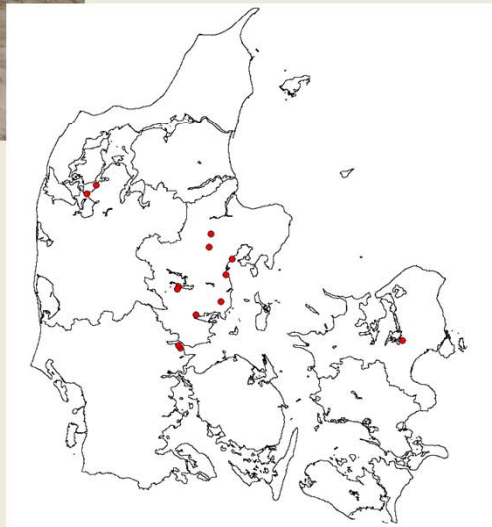
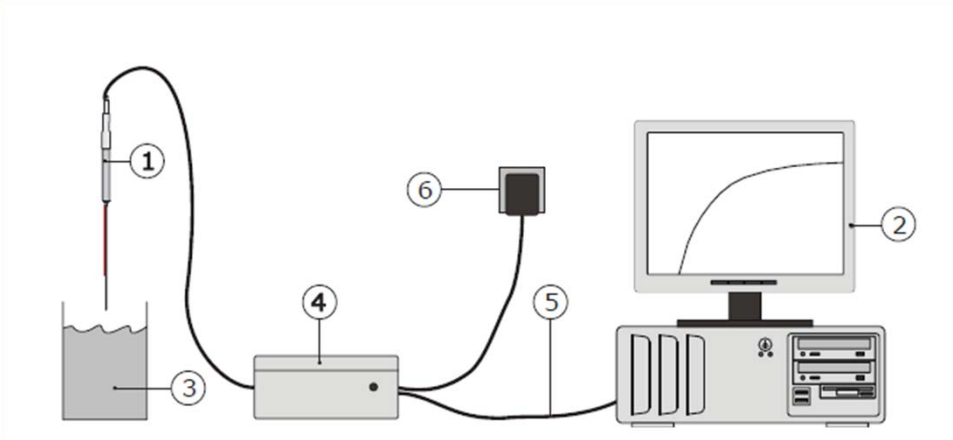
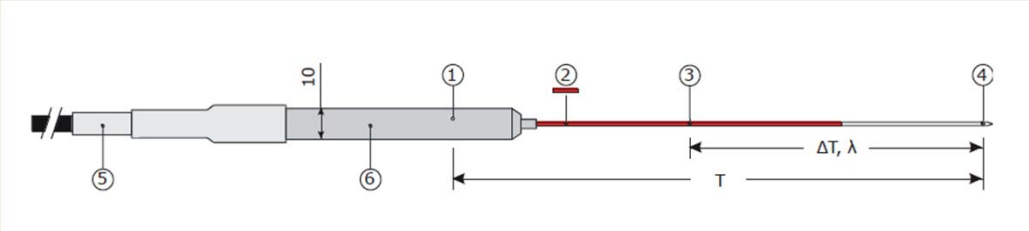
–Måling af termiske ledningsevne



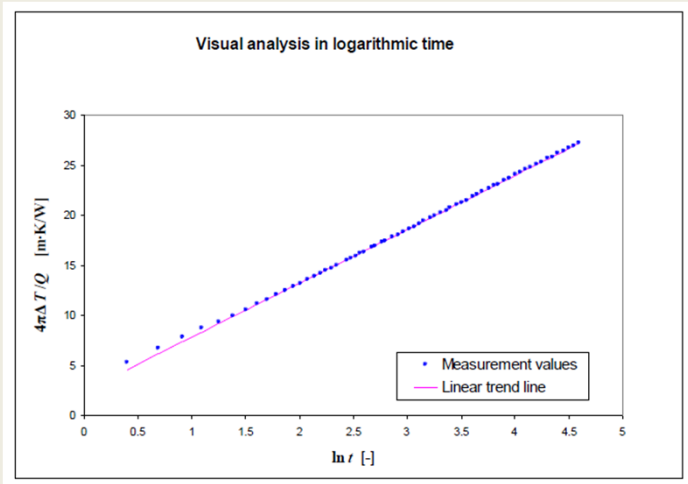






Varmeledning i linieformet legme

$$\Delta T = (Q / 4 \pi \lambda) (\ln t + B)$$



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–Måling af termiske ledningsevne

–Vandmættede sedimenter

–(foreløbige resultater)

Sediment	λavg W/mK
Postglacialt marint gytje	0,65
Smeltevandsler, siltet (lokalitet 1)	1,22
Smeltevandsler, siltet (lokalitet 2)	1,40
Marint interglacialt ler	1,05
Moræneler, sandet (lokalitet A	1,70
Moræneler, sandet (lokalitet B)	2,33
Moræneler (Boring C)	2,03
Moræneler, sandet (lokalitet D)	2,37
Morænesand (lokalitet E)	2,03
Smeltevandssand, m-g, gruset (lok. 4)	2,22
Smeltevandssand, finkornet (lok. 5)	2,19
Smeltevandssand, m gruset, (lok. 6)	2,33
Kvartssand, mellem-groft (Boring 7)	2,31
Kvartssand, mellemkornet (Lok. 8)	2,62
Kvartssand, groft (Lok 9)	2,95
Glimmersand (Lok 11)	1,73
Glimmerler (Lok 12)	1,11
Søvind Mergel (Lok 13)	1,40
Lillebæltsler (Lok 14)	0,90

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Måling af termiske ledningsevne

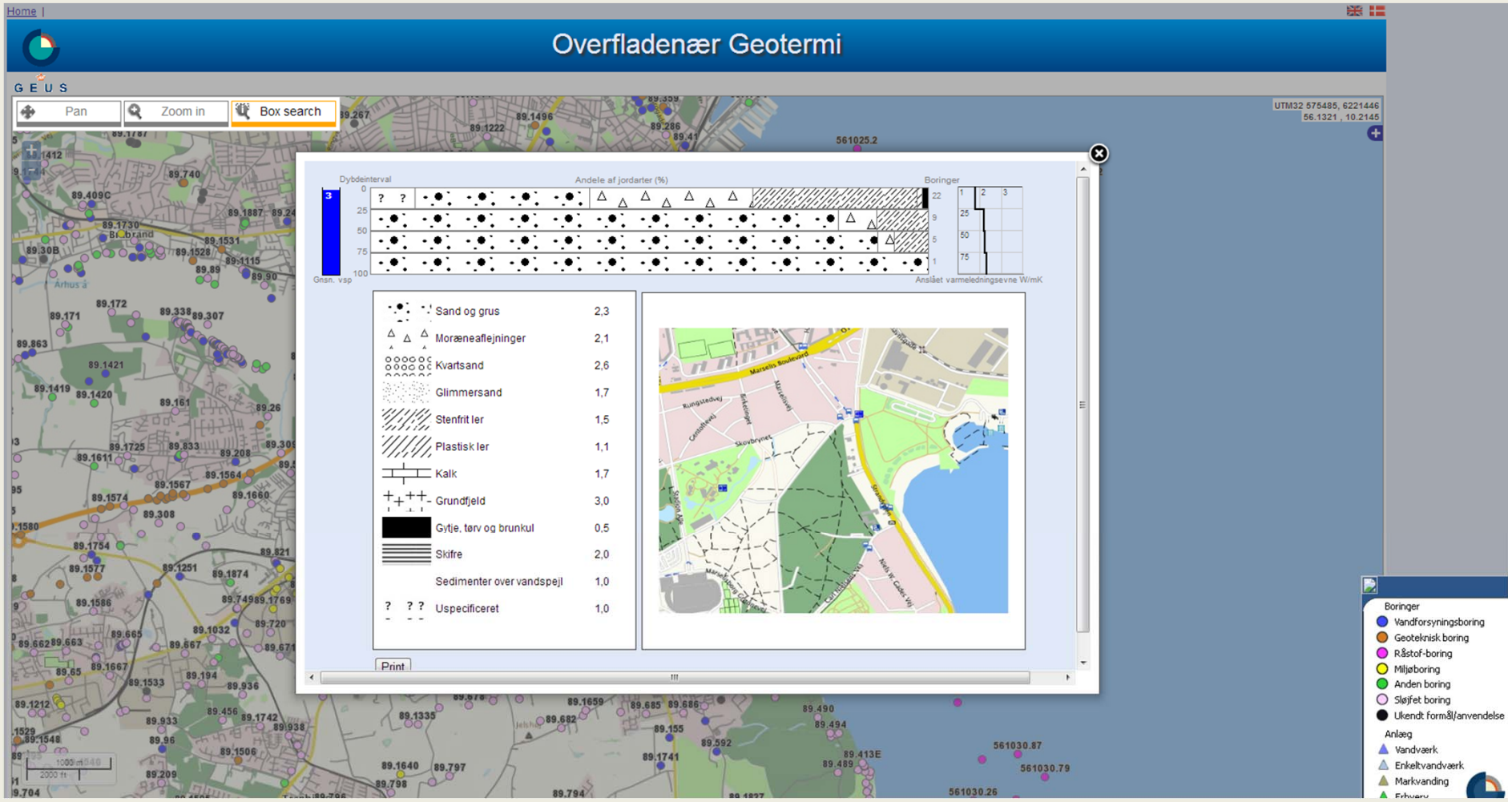
Vandmættede sedimenter

Kommende aktiviteter

Måling på et mindre antal supplerende jordprøver

Sammenligning med målinger foretaget på andre laboratorier

Samlet afrapportering og international publicering

Jordvarme-applikation

–http://geuskort.geus.dk/termiskejordarter/