MULTICONSULT

Totalleverandør av rådgivningstjenester

NGF – In situ seminar

Stjørdal 24.-25.05.2011

Resultater fra feltforsøk – CPTU og vingebor

Rolf Sandven

MULTICONSULT TRONDHEIM

In situ seminar

Resultater fra feltundersøkelser – CPTU og vingeboring

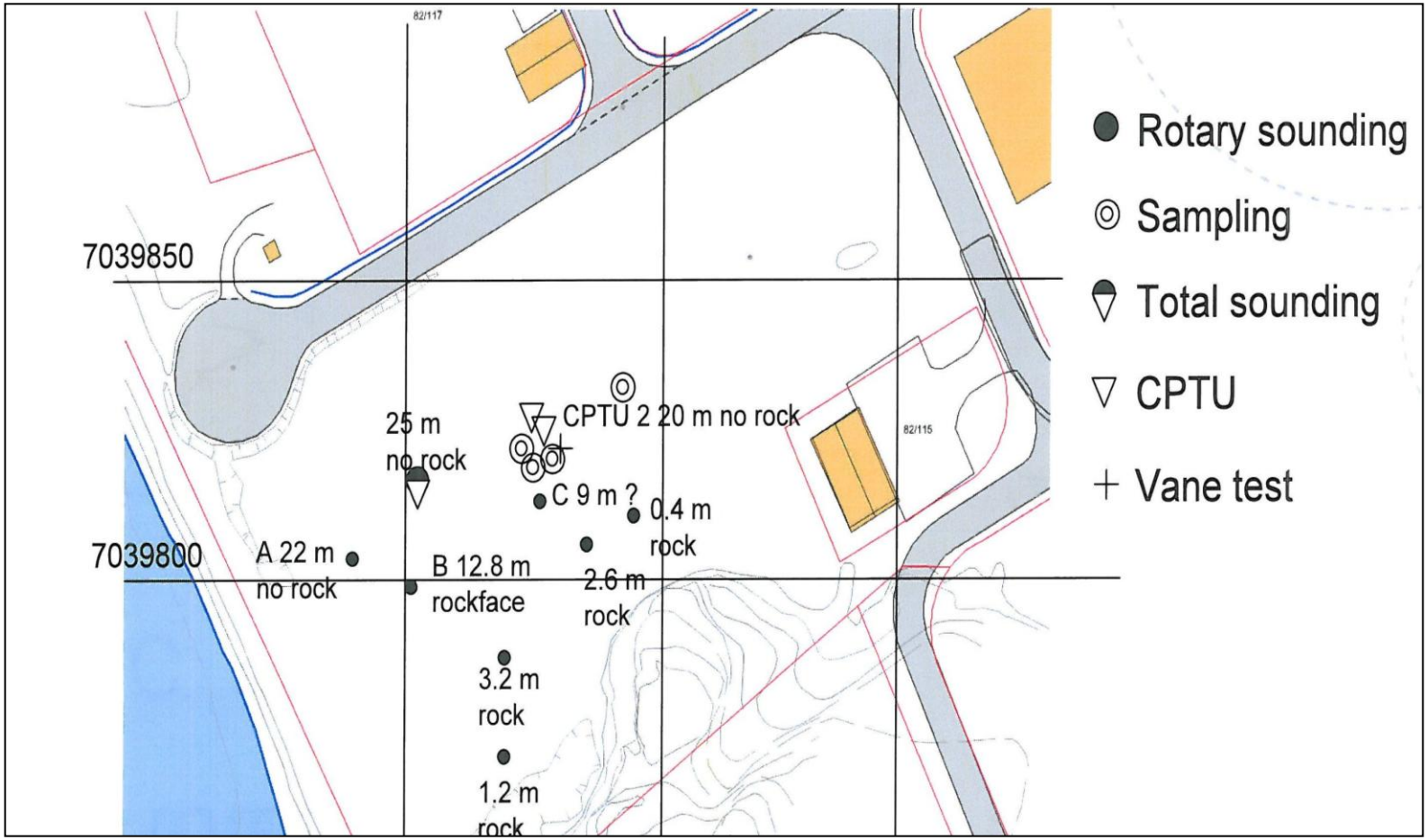
Oversikt over forsøksområde

CPTU – resultater fra feltforsøk

Bakgrunnsinformasjon

- Grunnforhold: 3-4 m topplag av innspylte sandmasser over middels OC-leire
- Grunnvannstand: 1-2 m under terreng
- Godt dokumenterte grunnforhold etter NTNU aktivitet:
  - Feltdata
    - Dreietrykksondering
    - Totalsondering
    - CPTU
    - Vingeboring
  - Laboratoriedata
    - Rutine
    - Ødometer
    - Treaksialforsøk

CPTU – resultater fra feltforsøk



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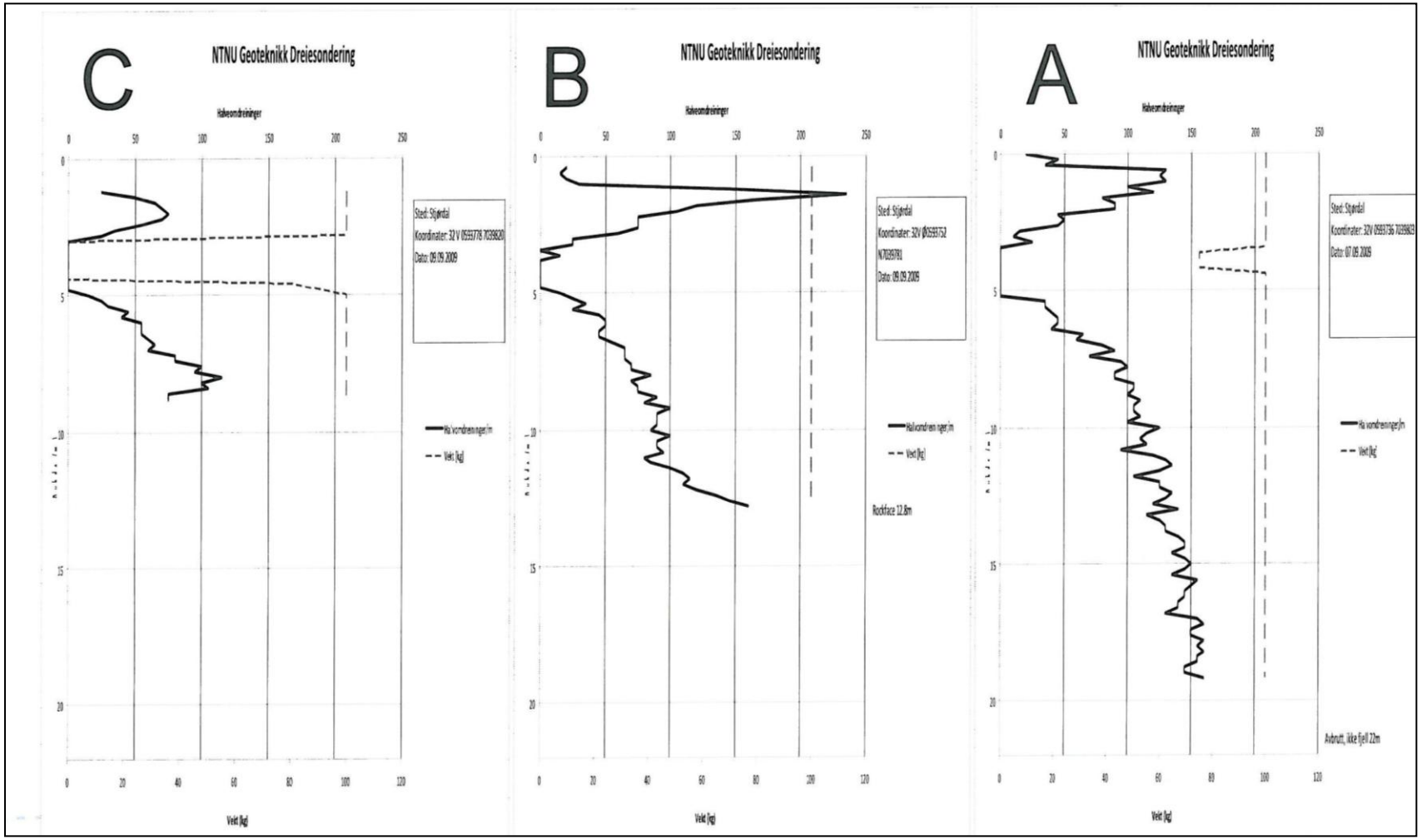

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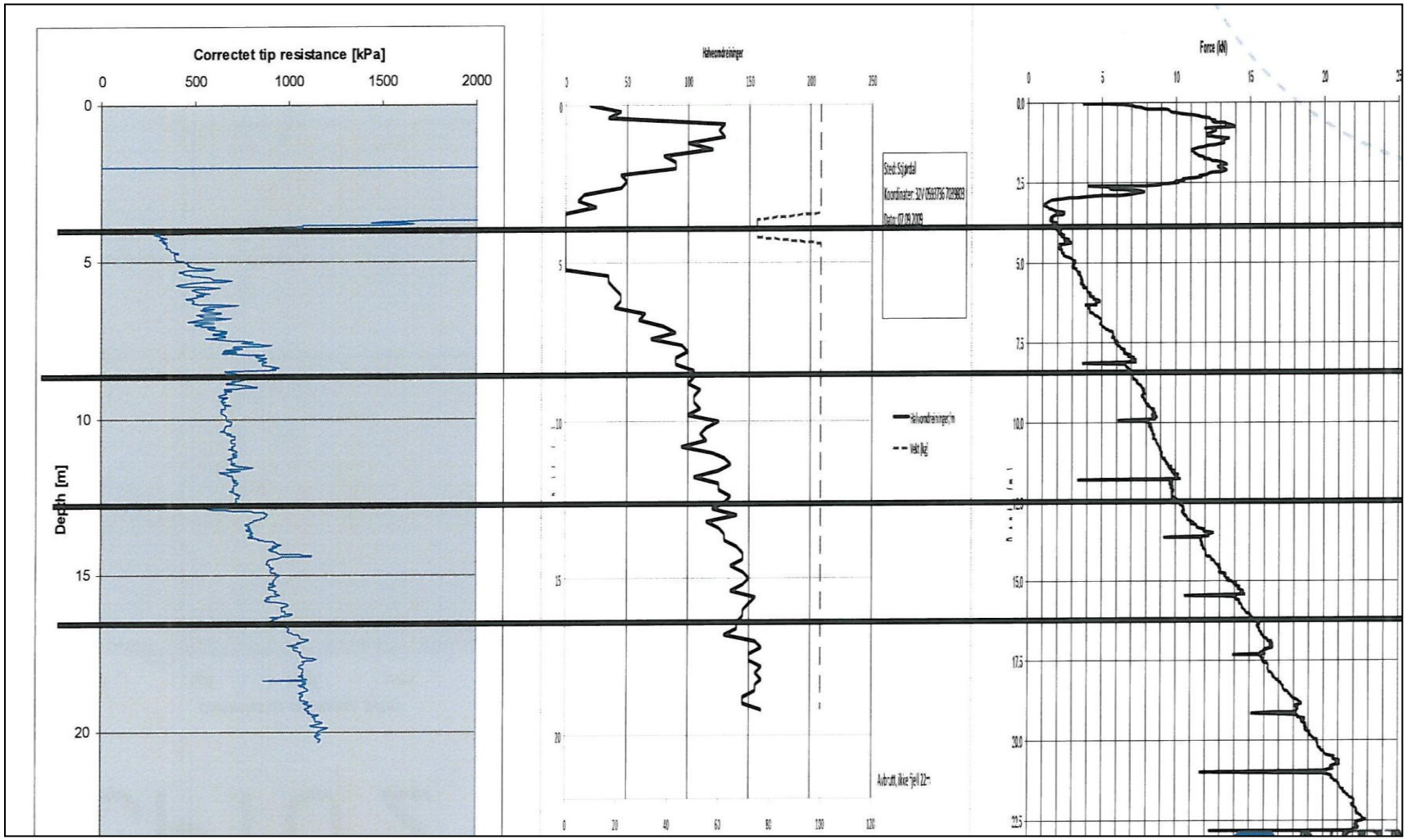
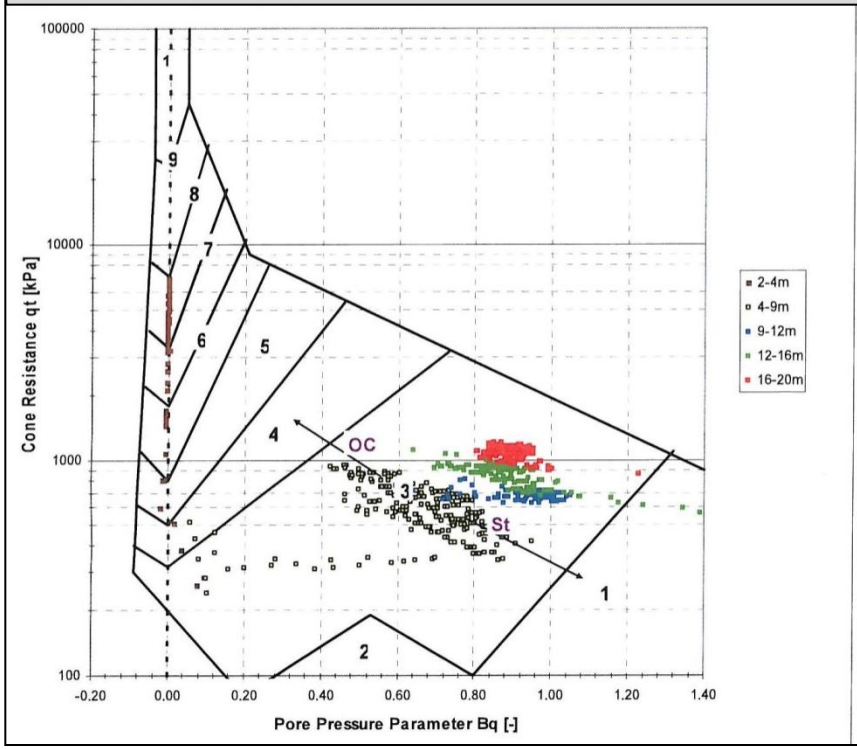
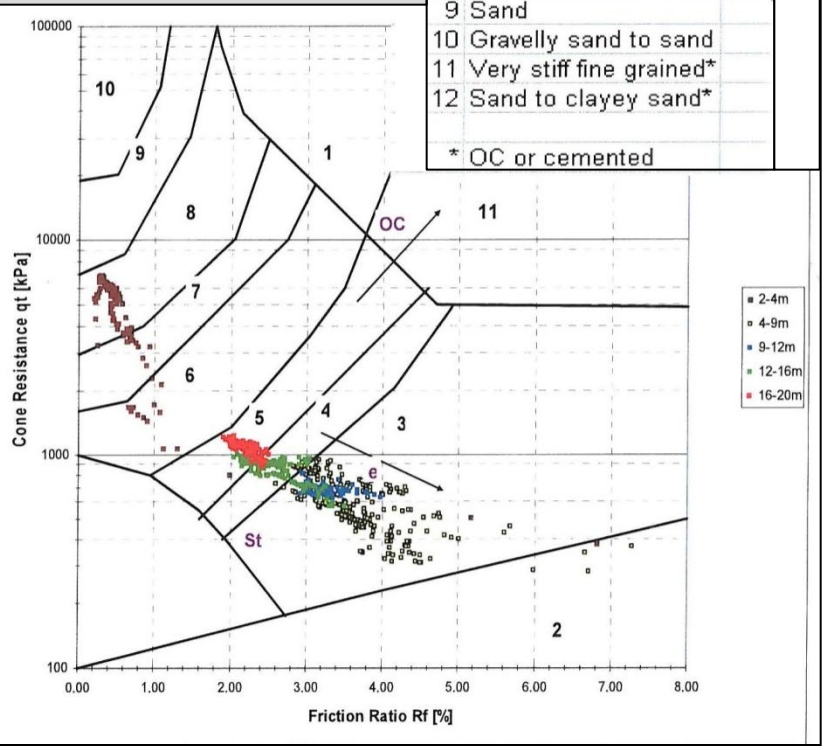


CPTU – resultater fra feltforsøk

CPTU Klassifisering

1	Sensitive fine grained
2	Organic material
3	Clay
4	Silty clay to clay
5	Clayey silt to silty clay
6	Sandy silt to clayey silt
7	Silty sand to sandy silt
8	Sand to silty sand
9	Sand
10	Gravelly sand to sand
11	Very stiff fine grained*
12	Sand to clayey sand*
*	OC or cemented

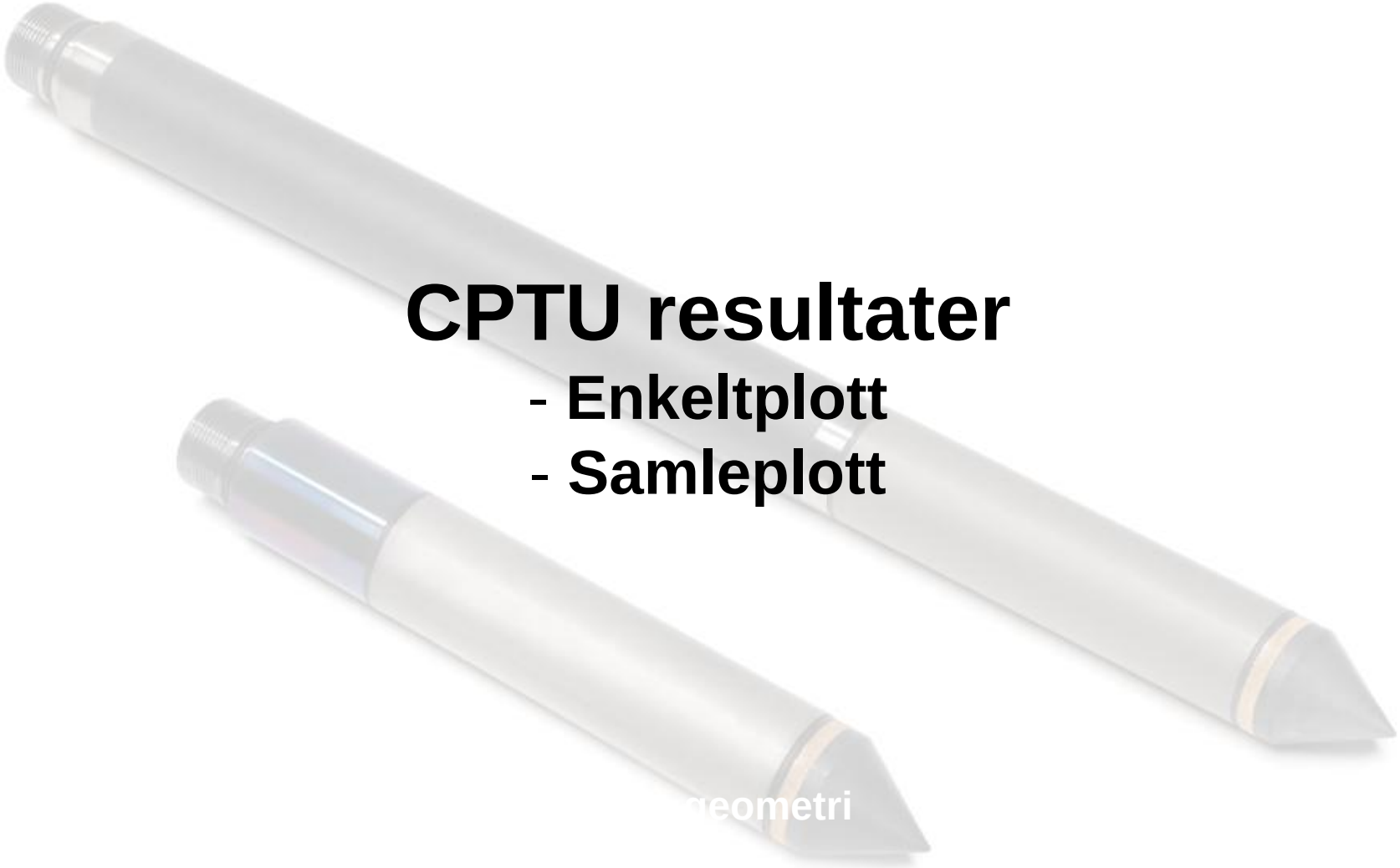




Resultater fra feltforsøk

Omfang av undersøkelsene:

- CPTU med porøst filter
  - Profil med god metning: Ferdigmettet filter med glyserin/gel
  - Profil med god metning: Mettet filter med parafin
  - Profil med dårlig metning: Sonde mettet med Farris
- CPTU med spaltefilter
  - Profil med god metning: Bruk av fettpresse og vakuumert væske
  - Profil med dårlig metning: Ufullstendig fettmetting etter montering
  - Manglende væske i kammer
- **Vingeboring**
  - Manuell boring

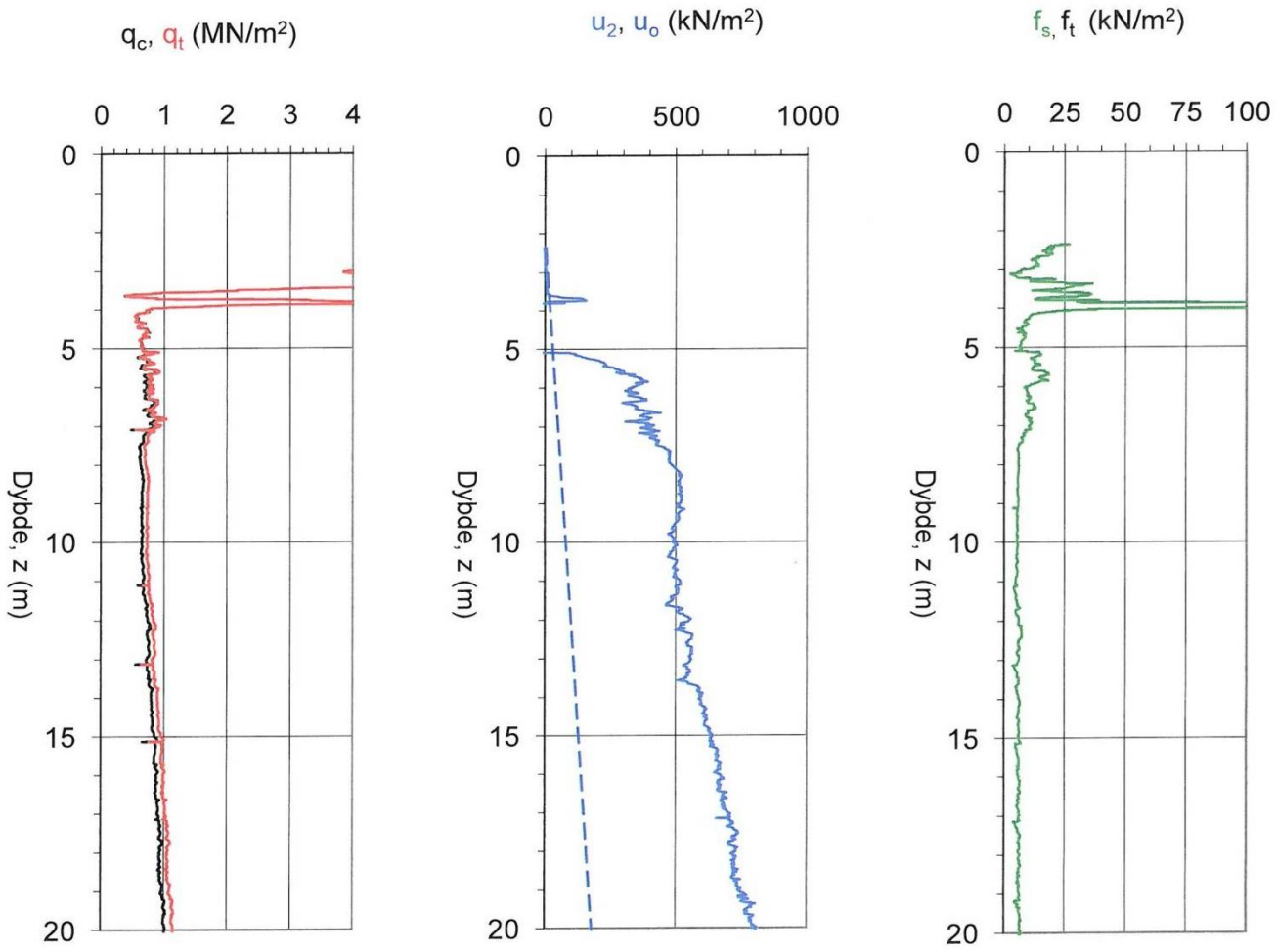


CPTU resultater

- Enkeltplott
- Samleplott

geometri

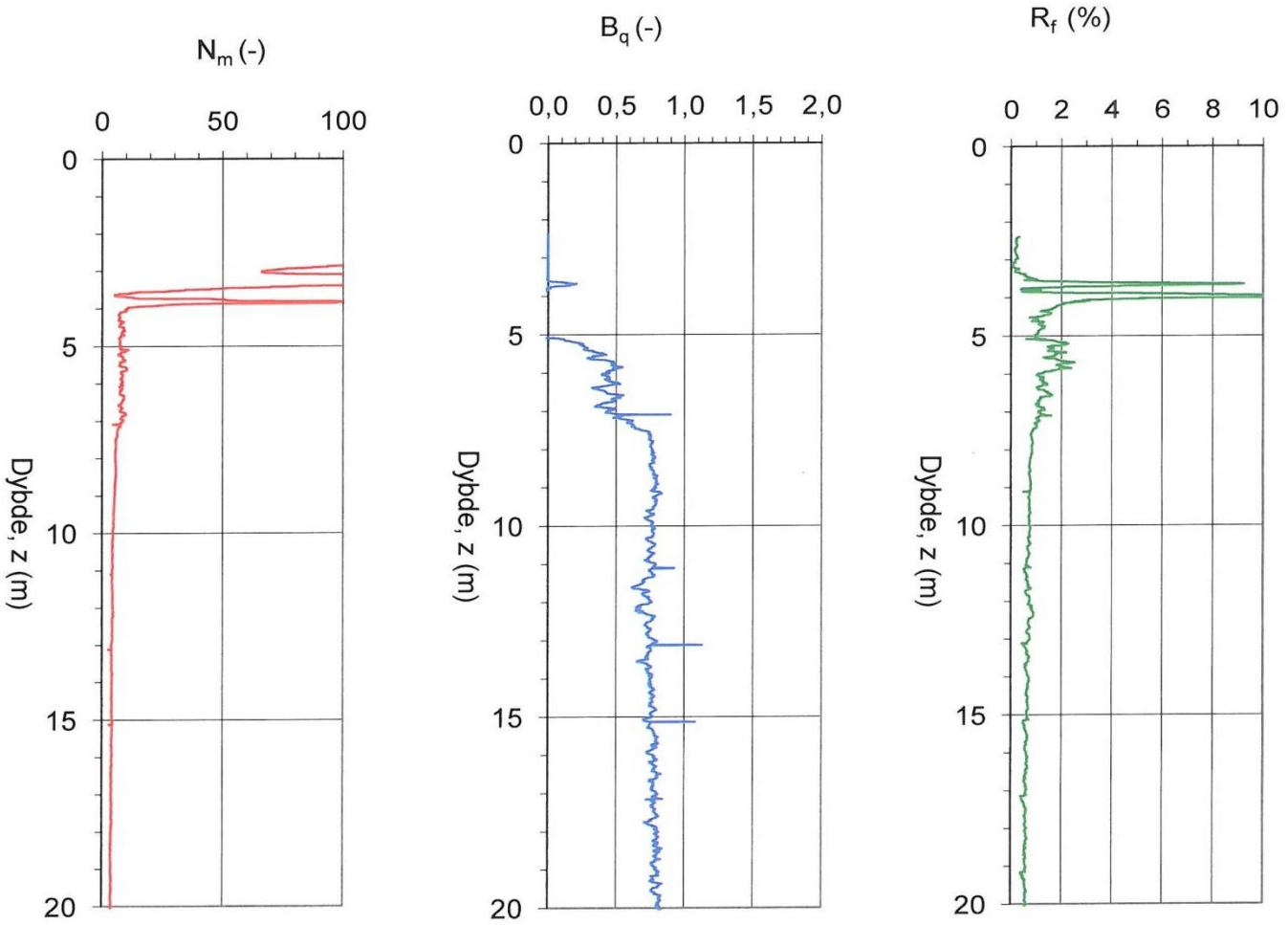
CPTU – resultater fra feltforsøk



Nullpunktavvik:
q : -28 kPa
u: -0,6 kPa
f: 0,1 kPa

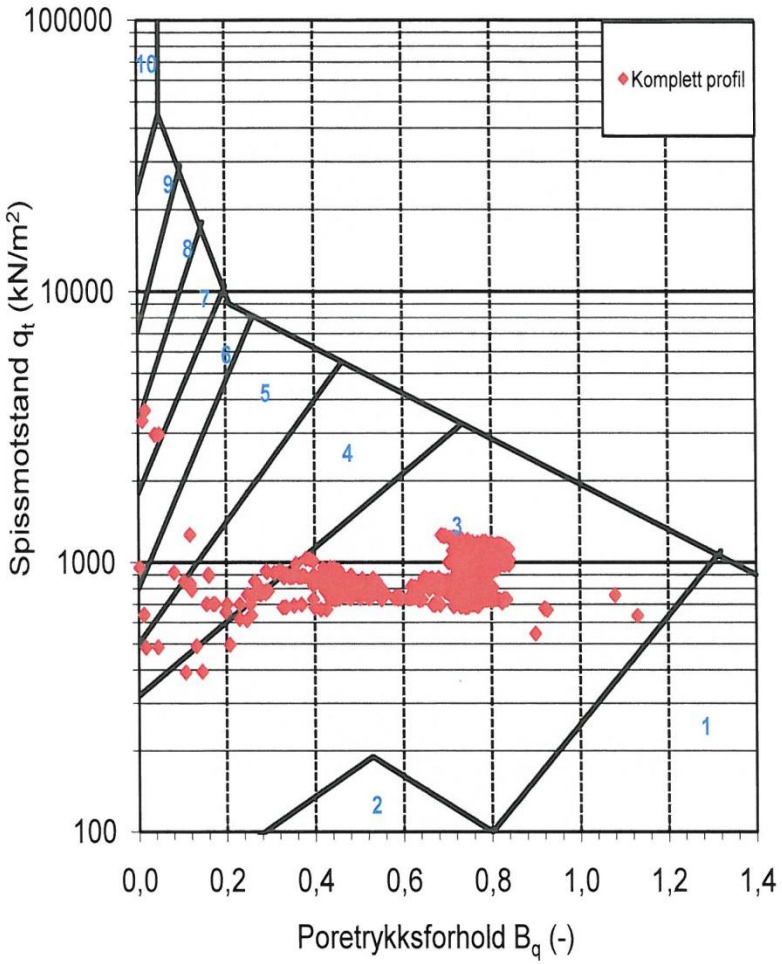
Ferdigmettet filter med glyserin

CPTU – resultater fra feltforsøk

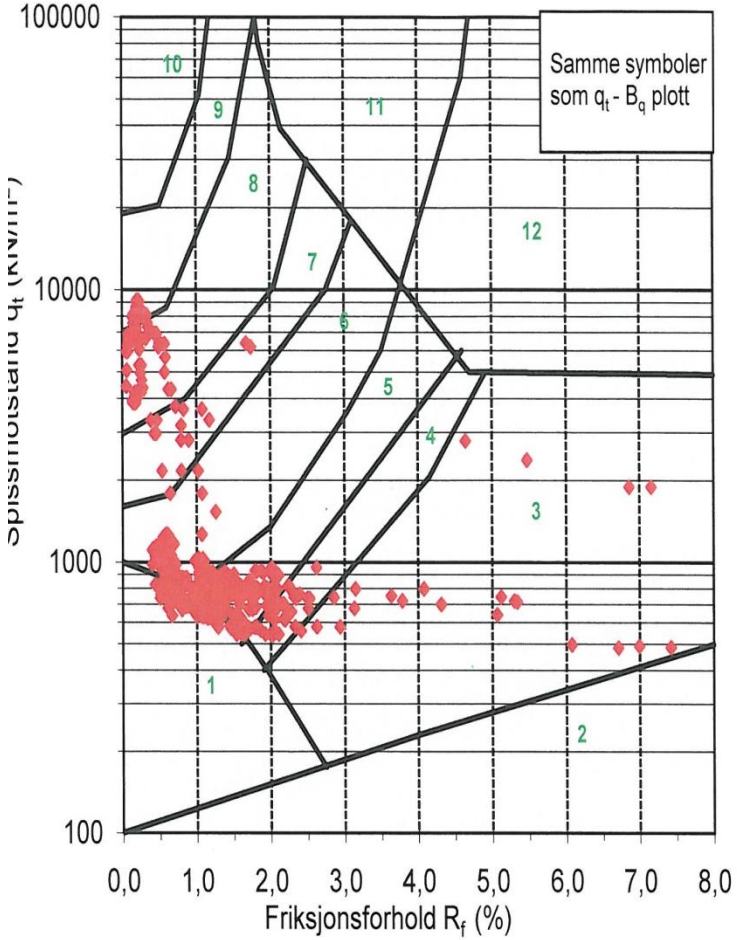


Ferdigmettet filter med glyserin

CPTU – resultater fra feltforsøk

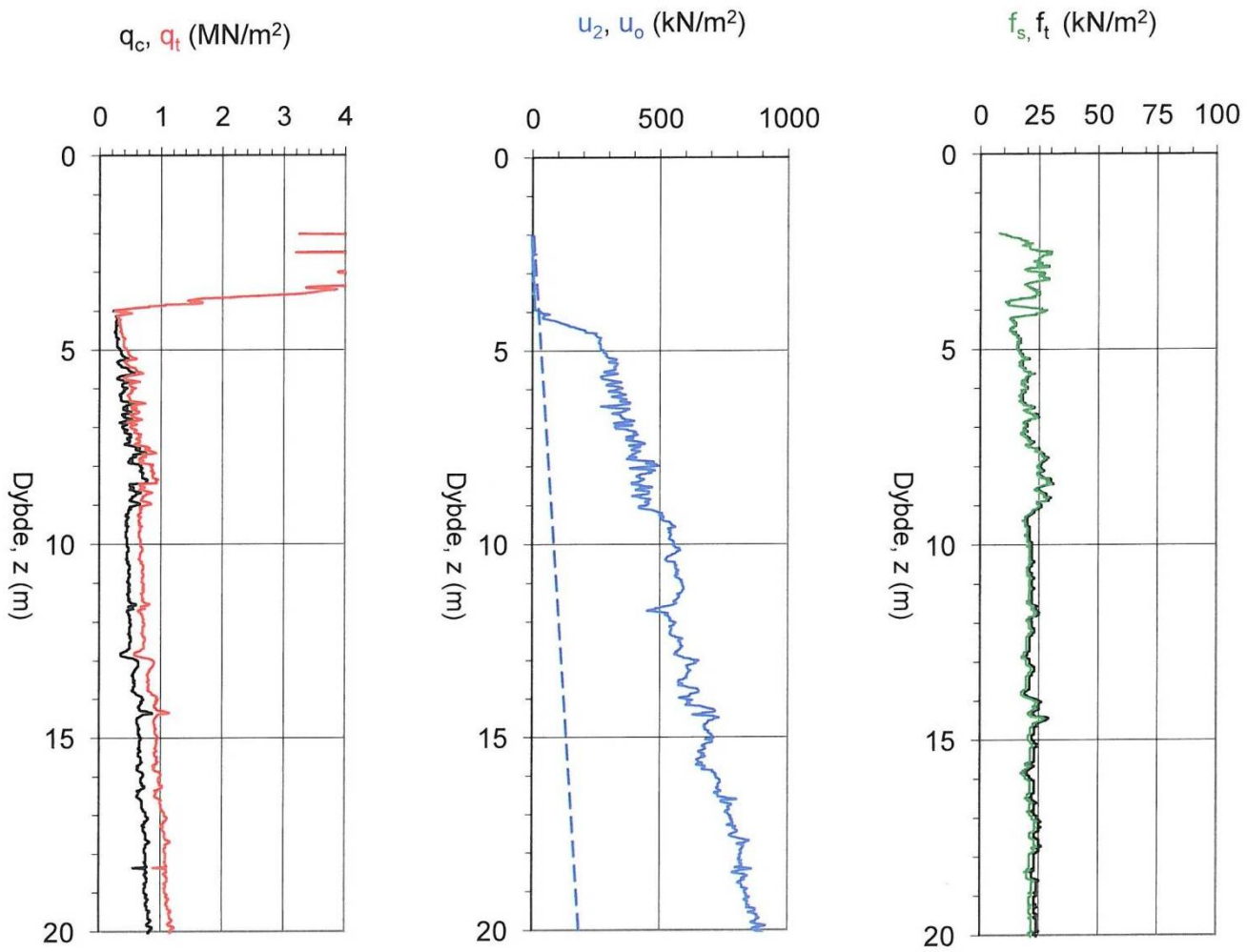


q_t - B_q



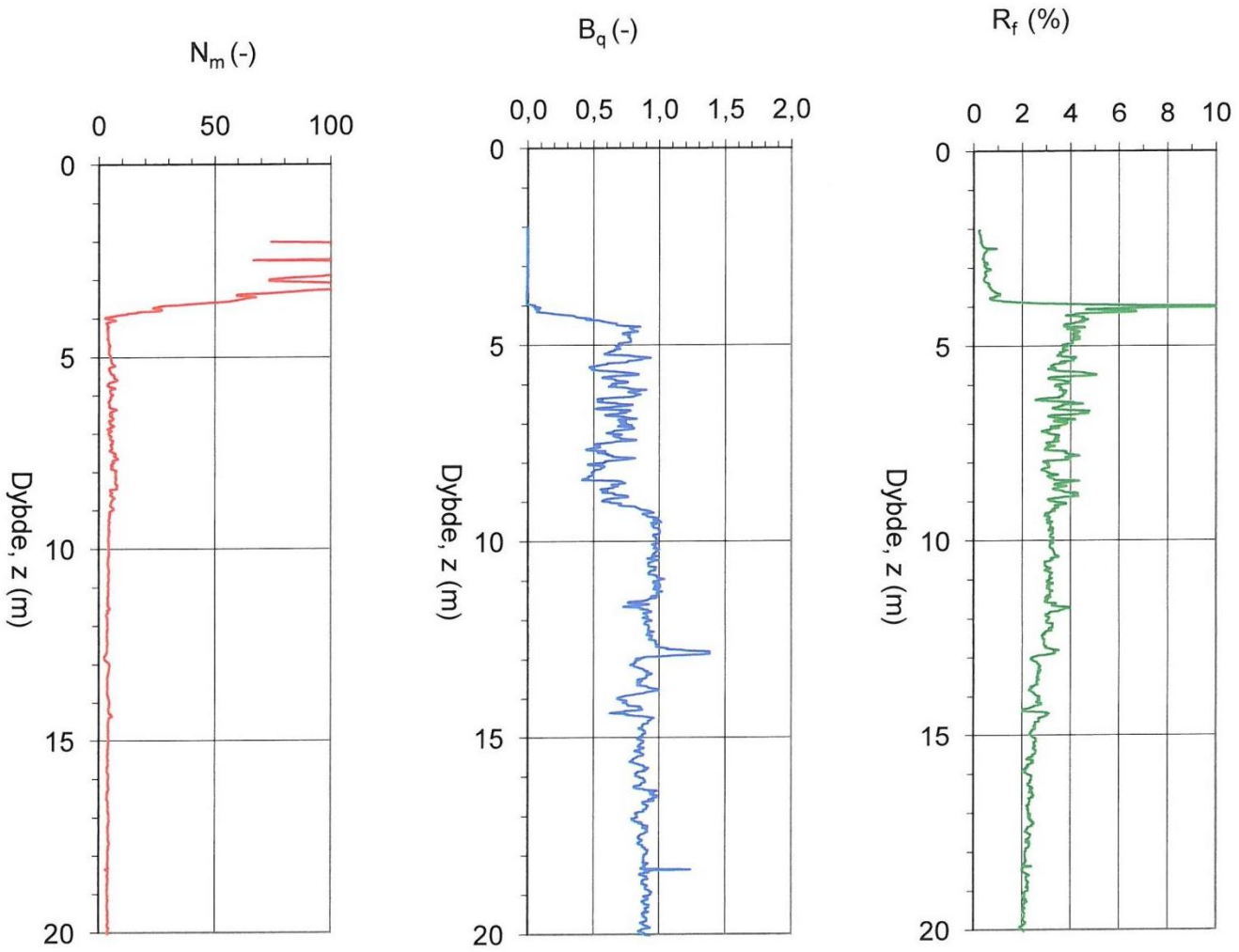
q_t - R_f

CPTU – resultater fra feltforsøk



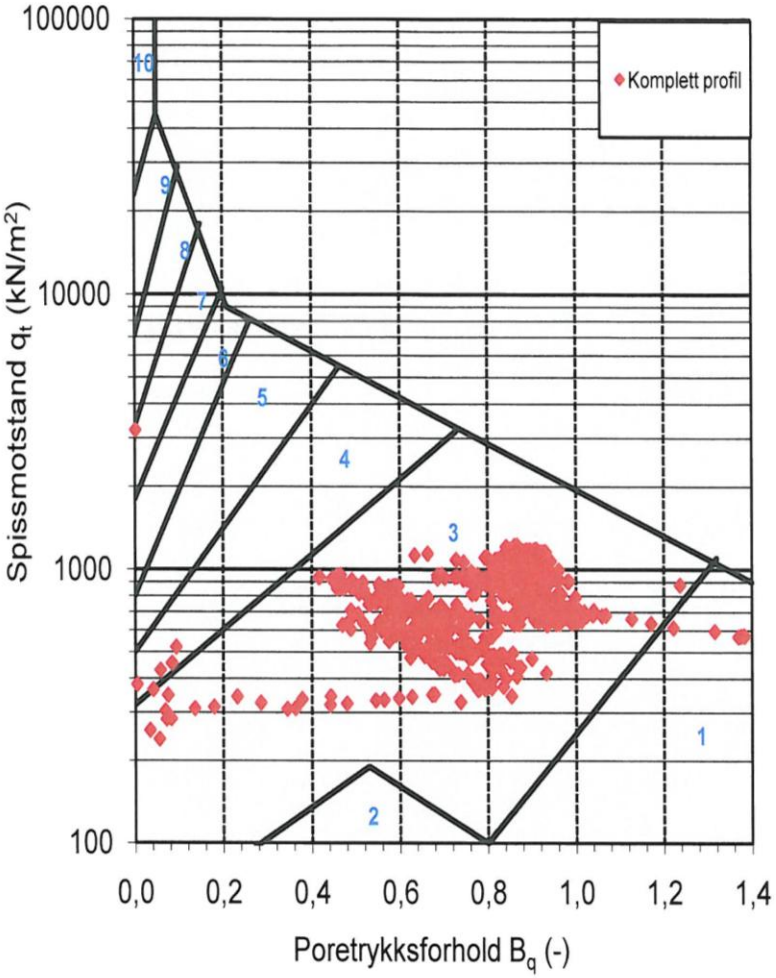
Filter mettet med parafin (NTNU)

CPTU – resultater fra feltforsøk

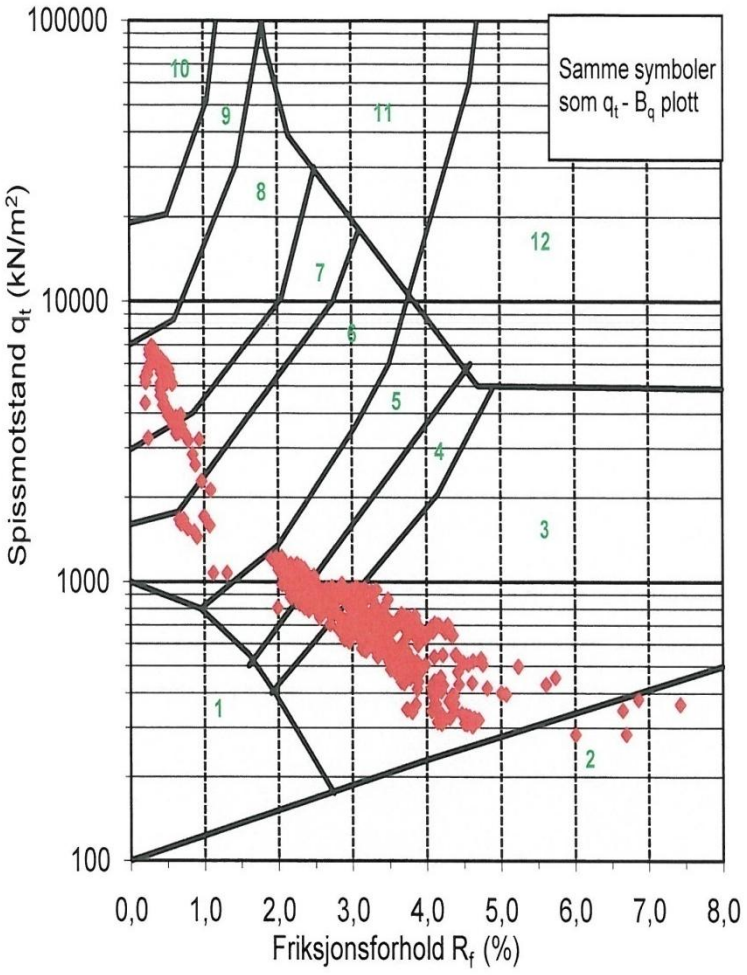


Filter mettet med parafin

CPTU – resultater fra feltforsøk



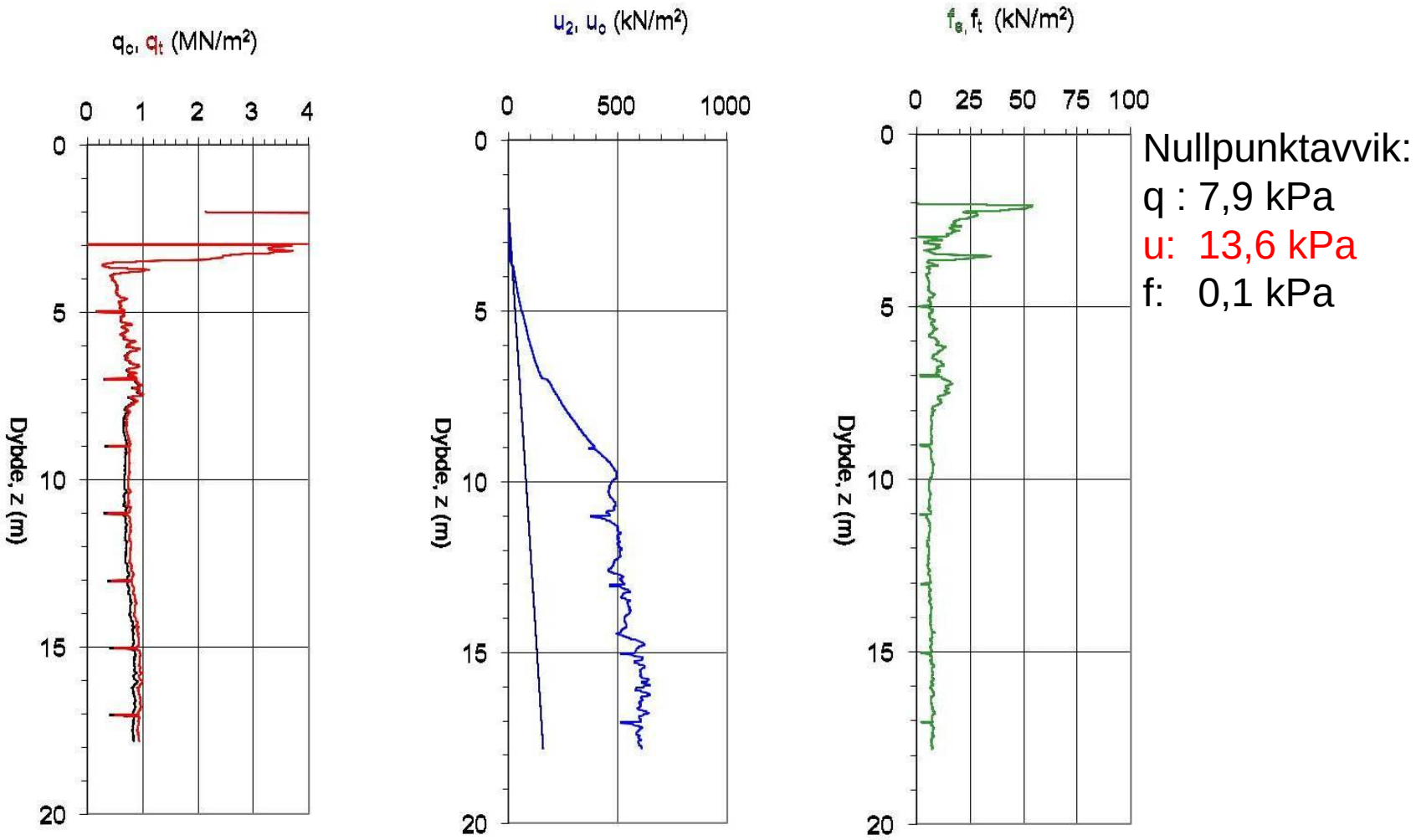
q_t - B_q



q_t - R_f

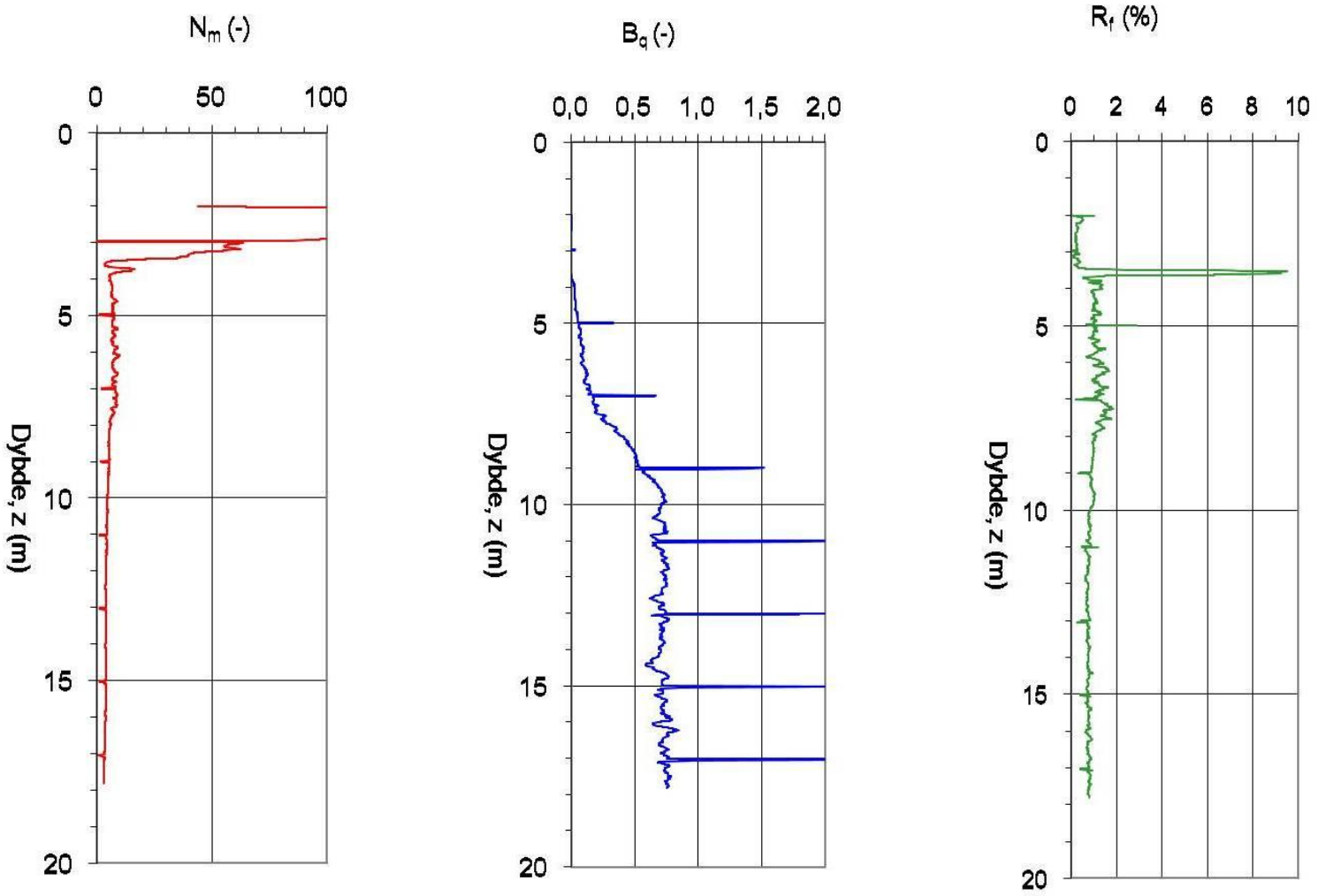
Filter mettet med parafin

CPTU – resultater fra feltforsøk



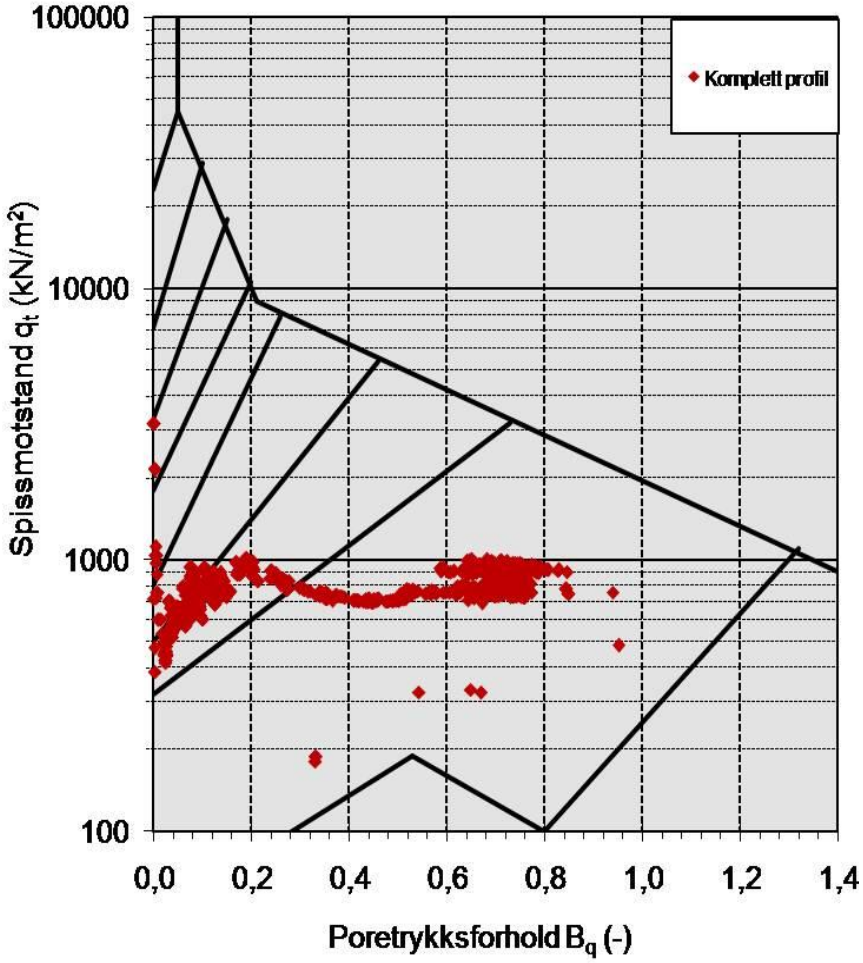
Nullpunktavvik:
q : 7,9 kPa
u: 13,6 kPa
f: 0,1 kPa

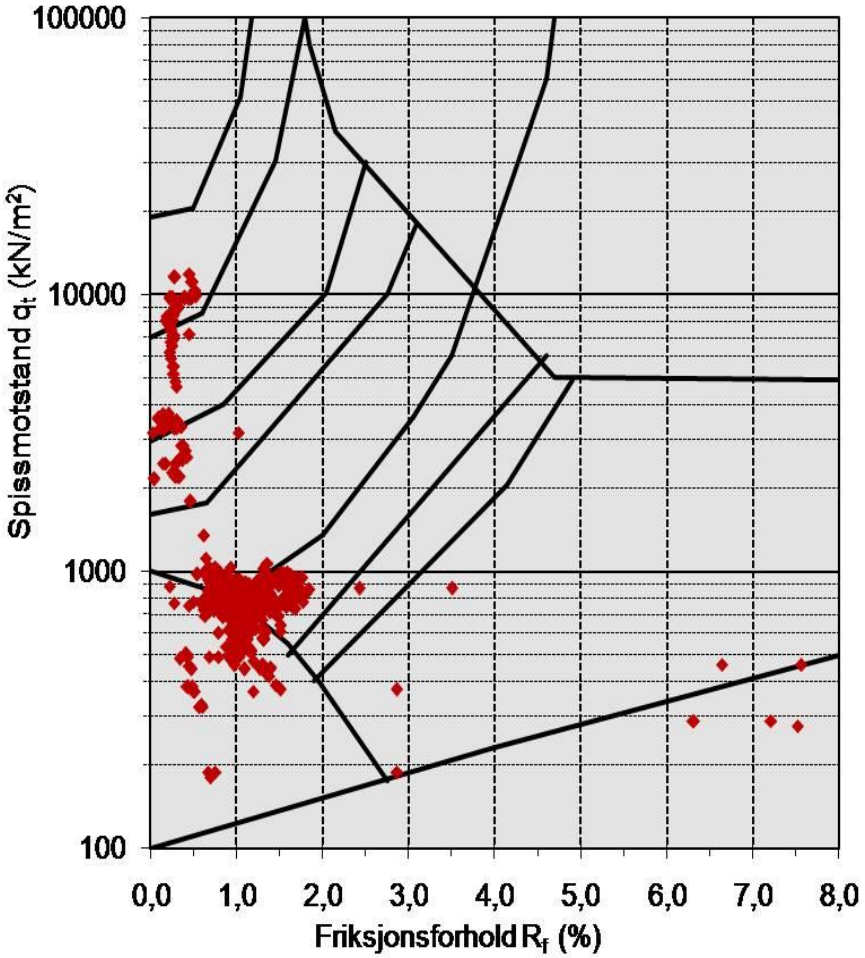
CPTU – resultater fra feltforsøk



Filter mettet med Farris

CPTU – resultater fra feltforsøk





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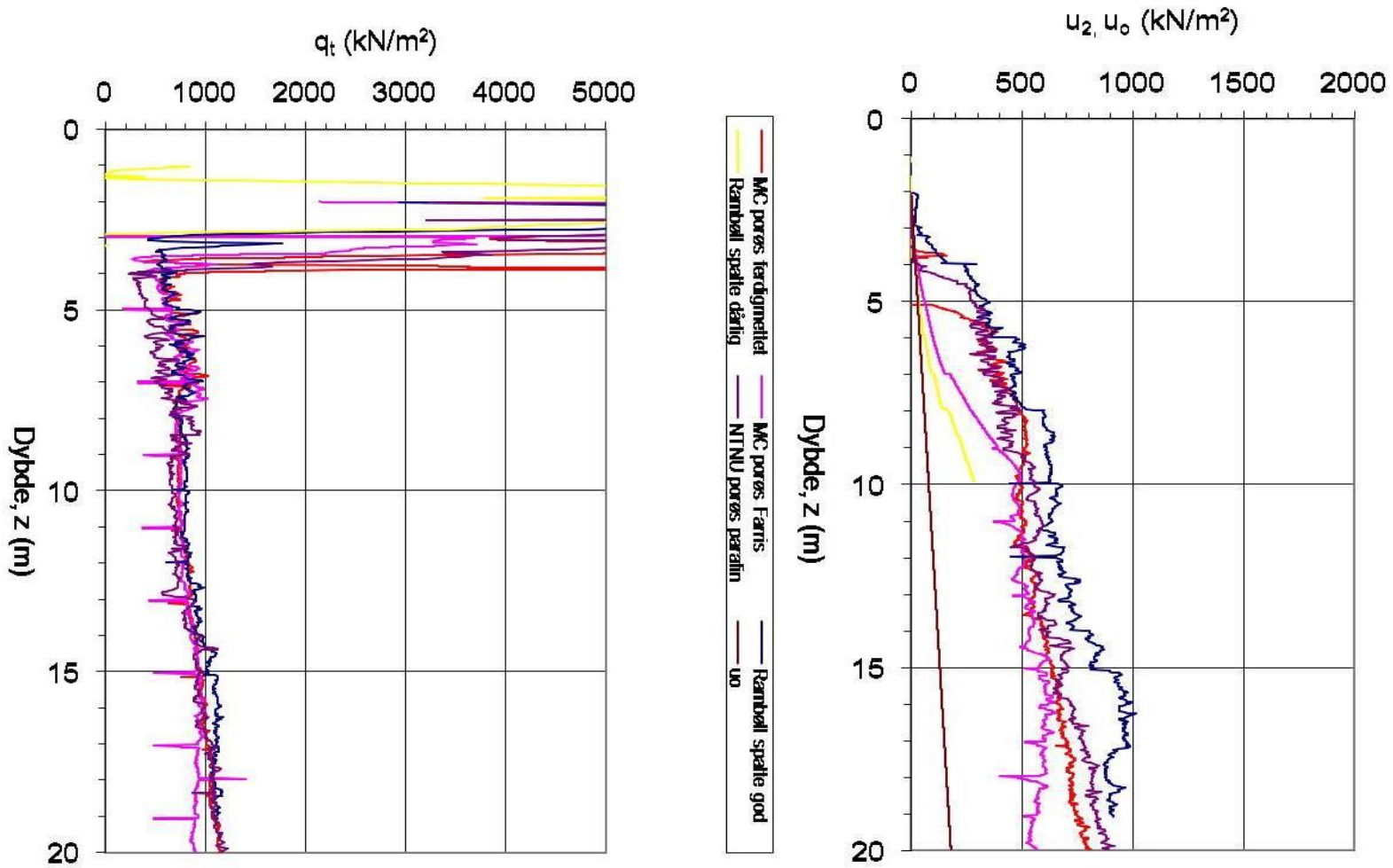
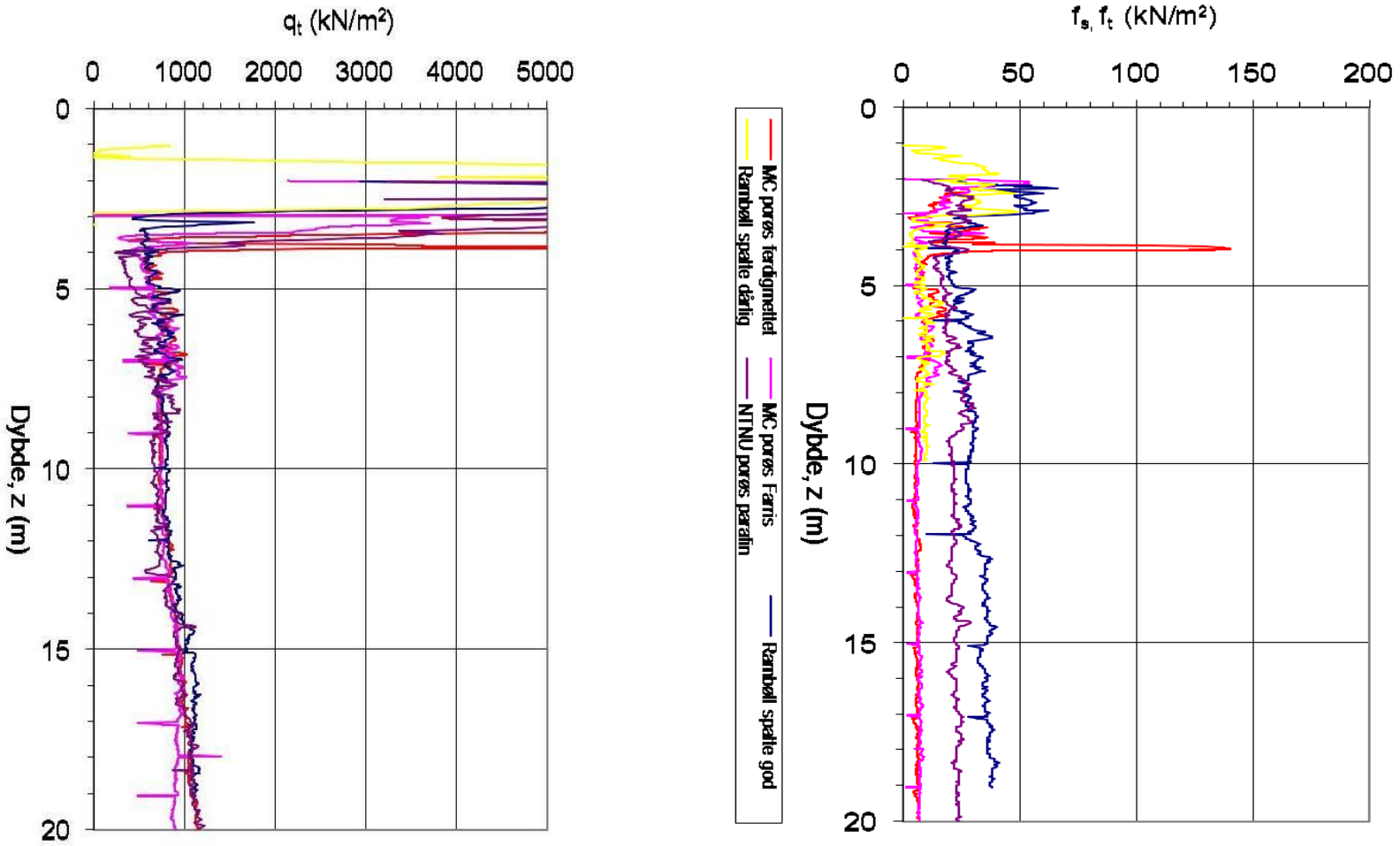


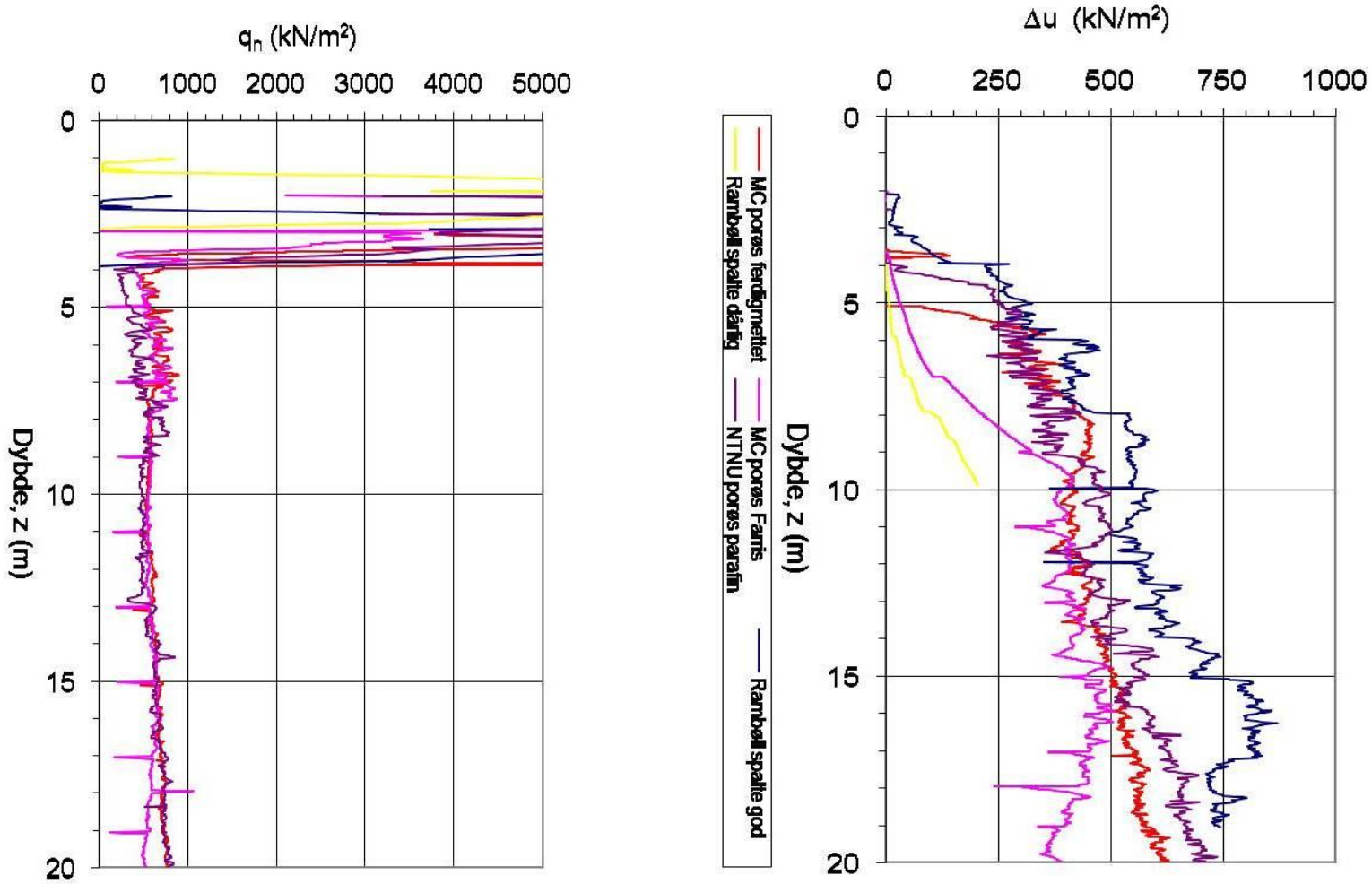
Samleplott alle CPTU, q – u

CPTU – resultater fra feltforsøk



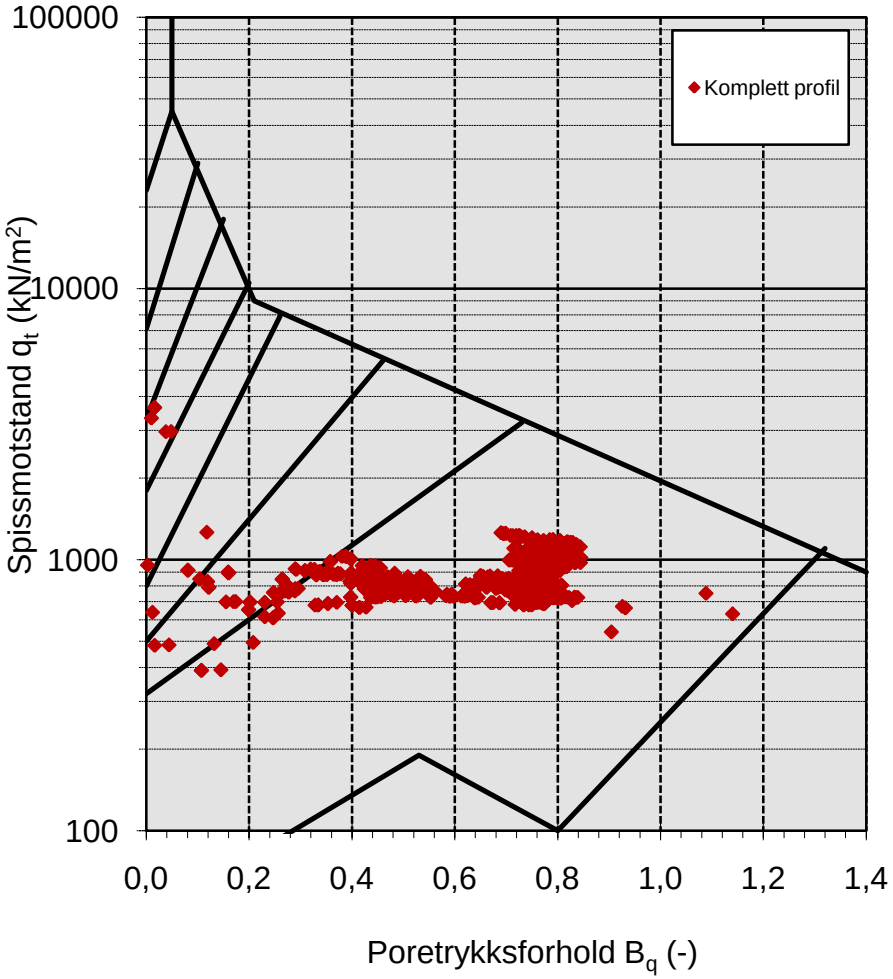
Samleplott alle CPTU, q – f

CPTU – resultater fra feltforsøk

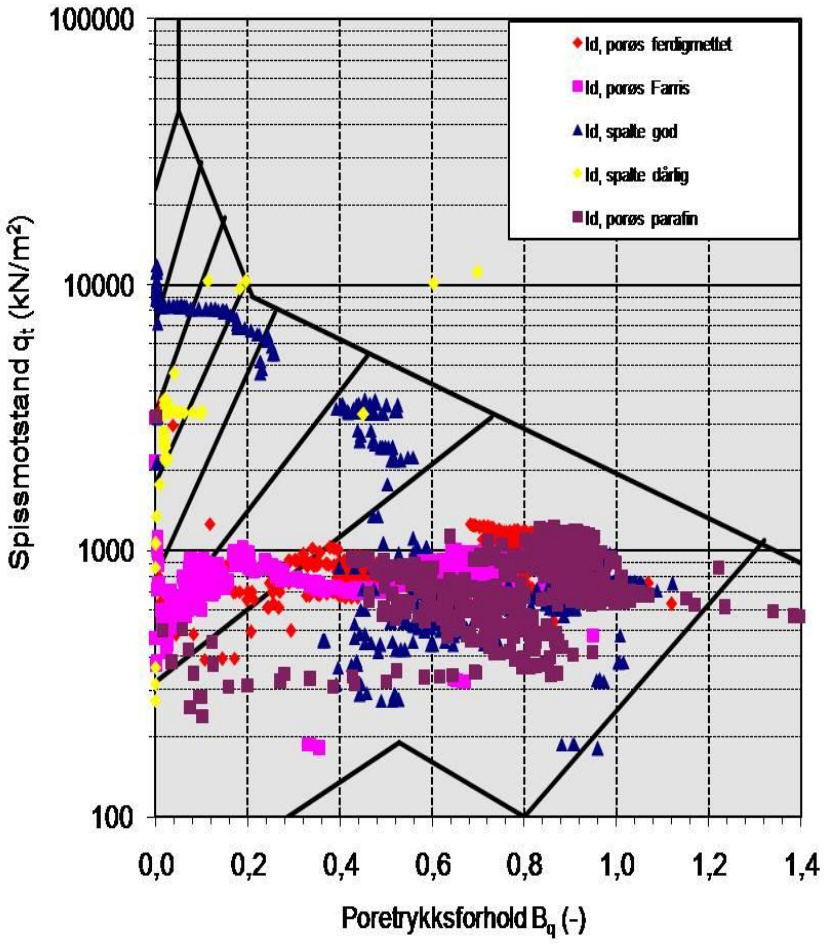


Samleplott alle CPTU, q_n – Δu

CPTU – resultater fra feltforsøk



Klassifisering ferdigmettet, q_n – Δu



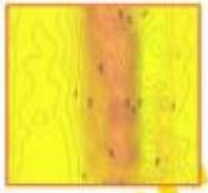
Samleplott alle CPTU, q_n – Δu

Sammenliknende tolkning

- CPTU
- Vingeboring
- Rutinedata
- Ødometerforsøk
- Treaksialforsøk

Integrated Ground Investigation

Drilling & Sampling



Geology & Geophysics

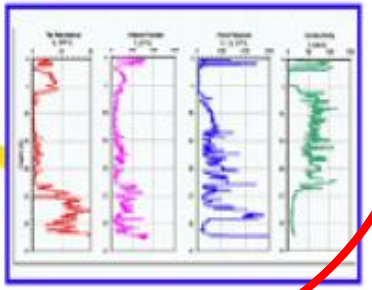
Constitutive Modeling

Soil Parameters Evaluation

$OCR, e_o, \gamma_T, \sigma_{vo}', D_R, \sigma_p',$
$G_o, D, K_o, \nu, \phi', \Psi, \Lambda, \Gamma,$
$c', k, c_v, K', M', G', E',$
$C_c, C_r, C_s, C_\alpha, s_u, E_u$

Laboratory Testing

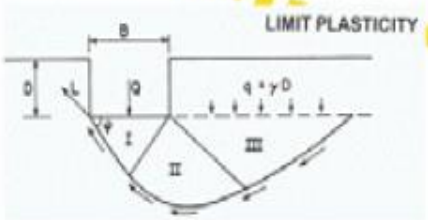
In-Situ Testing



Micromechanics

Constitutive Modeling

Analytical Methods



Numerical Simulation

CPTU – tolkning av data

- **Tolkningsmetoder basert på teoretiske eller empiriske metoder:**
  - Teoretiske løsninger søker å beskrive oppførselen for jorden i kontinuerlig bruddtilstand, basert på velkjente prinsipper og modeller (analogi: bæreevne for enkeltpel)
  - Empiriske metoder benytter korrelasjoner mellom CPTU målinger og referansedata fra andre felt- eller laboratorieundersøkelser

    Eks.: Bestemmelse av udrenert skjærstyrke fra CPTU-data:

$$N_{lokal} = q_n / s_{ulab/felt}$$

$$s_{uCPTU} = q_n / N_{lokal}$$

- **Profilering**
  - Laggrenser
  - Jordartsoppførsel
- **De mest aktuelle parametrene:**
  - Udrenert skjærstyrke, s_u
  - Friksjonsvinkel, ϕ
  - Prekonsolideringsspenning, σ_c', OCR
  - Deformasjonsmoduler, M, G
- **Dissipasjonstester i utvalgte nivåer - poretrykksreduksjon mot tid:**
  - Konsolideringskoeffisient, c
  - Permeabilitetskoeffisient, k
- **Andre parametre:**
  - Sensitivitet S_t (leire)
  - Relativ densitet, D_r (sand)

CPTU – tolkning av data

NGI korrelasjoner (Karlsrud et al (1996))

Basert på CAUc treaksialforsøk på blokkprøver av høy kvalitet

$s_u = (q_t - \sigma_{v0}) / N_{kt}$ $\quad$ $s_u = \Delta u / N_{\Delta u}$

$N_{kt} = f (B_q = \Delta u/q_n)$ $\quad$ $N_{\Delta u} = f (B_q = \Delta u/q_n)$

Kurvetilpasning (Kirkebø, (2005))

$N_{kt} = 19 - 12.5 \cdot B_q$ $\quad$ $N_{\Delta u} = 1.0 + 9.0 \cdot B_q$

$N_{ke} = 16 - 14.5 \cdot B_q$

CPTU – tolkning av data

NGI korrelasjoner (Karlsrud et al (2005))

Basert på CAUc treaksialforsøk på blokkprøver av høy kvalitet (større spredning i egenskaper)

$s_u = (q_t - \sigma_{v0}) / N_{kt}$ $\quad$ $s_u = \Delta u / N_{\Delta u}$

$N_{kt} = f(S_t, OCR, I_p)$ $\quad$ $N_{\Delta u} = f(S_t, OCR, I_p)$

$S_t < 15$:

$N_{kt} = 7.8 + 2.5 \cdot \log OCR + 0.082 \cdot I_p$ $\quad$ $N_{\Delta u} = 6.9 - 4.0 \cdot \log OCR + 0.07 \cdot I_p$

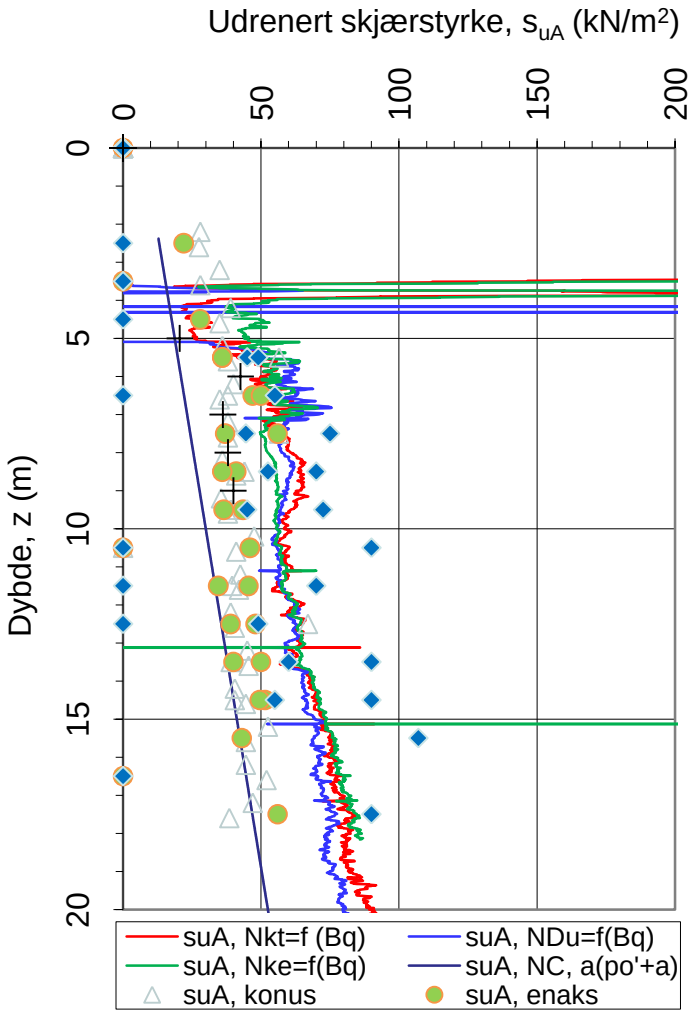
$N_{ke} = 11.5 - 9.05 \cdot B_q$

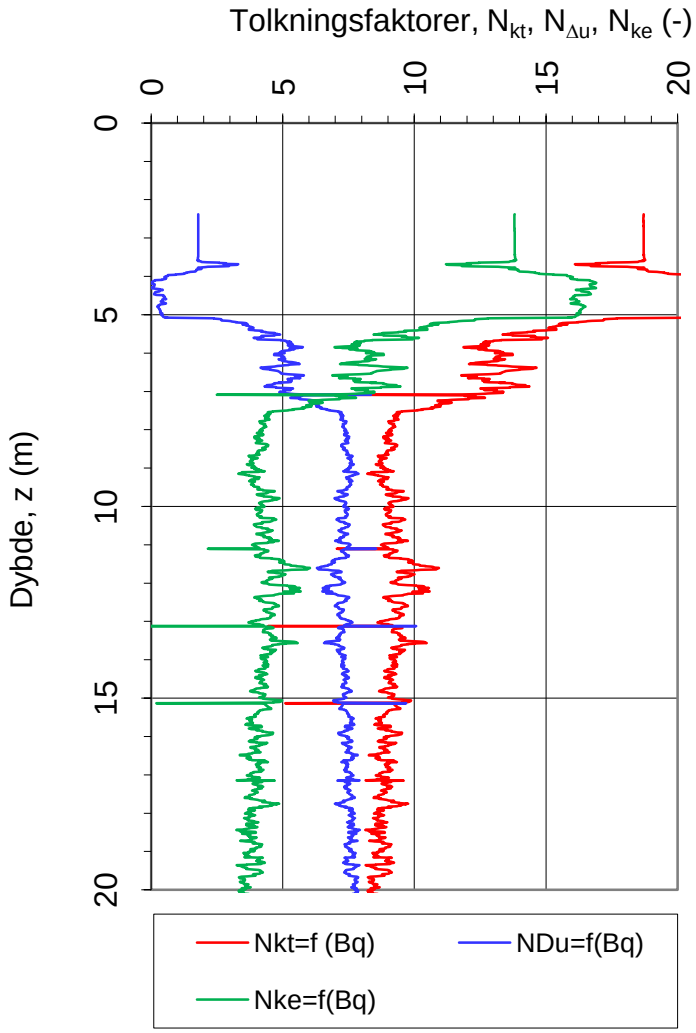
$S_t > 15$:

$N_{kt} = 8.5 + 2.5 \cdot \log OCR$ $\quad$ $N_{\Delta u} = 9.8 - 4.5 \cdot \log OCR$

$N_{ke} = 12.5 - 11.0 \cdot B_q$

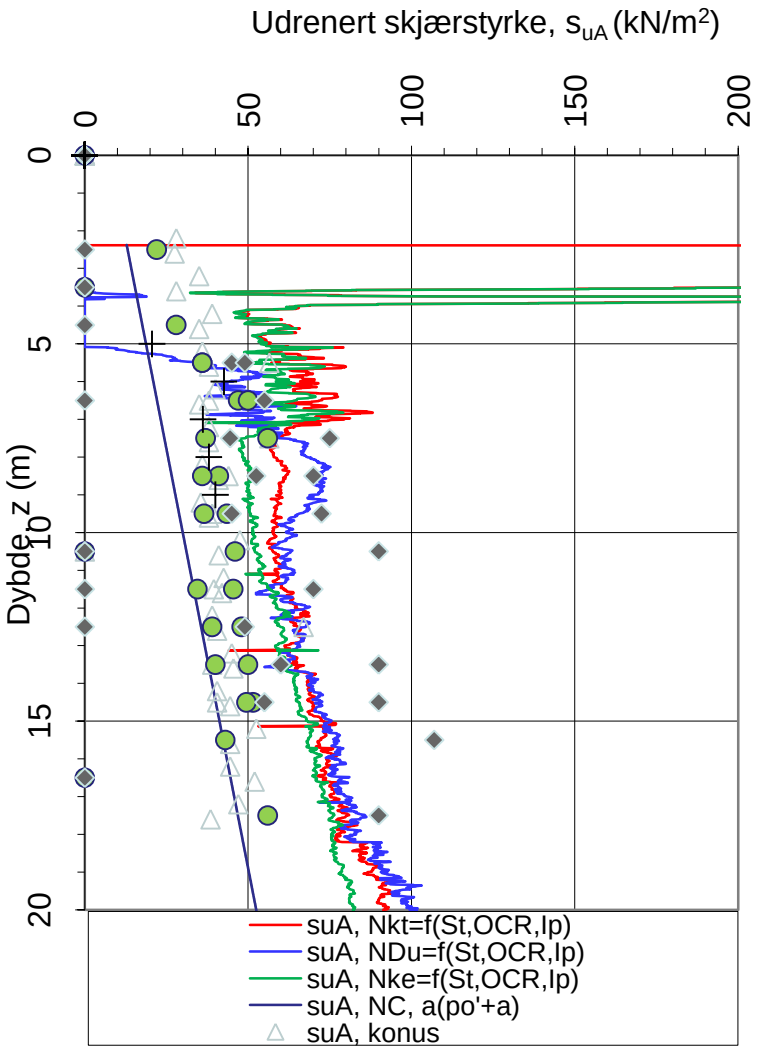
Sammenlignende resultater in situ – lab

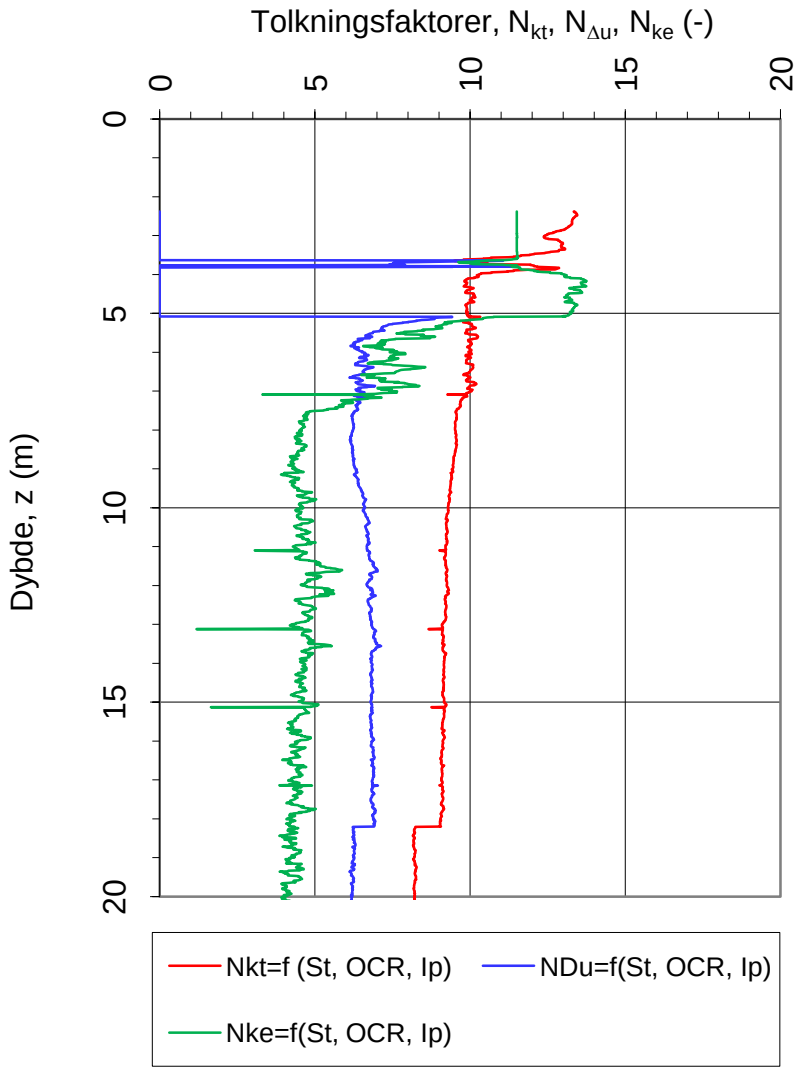




s_{uA}, alle faktorer, f(B_q), ferdigmettet

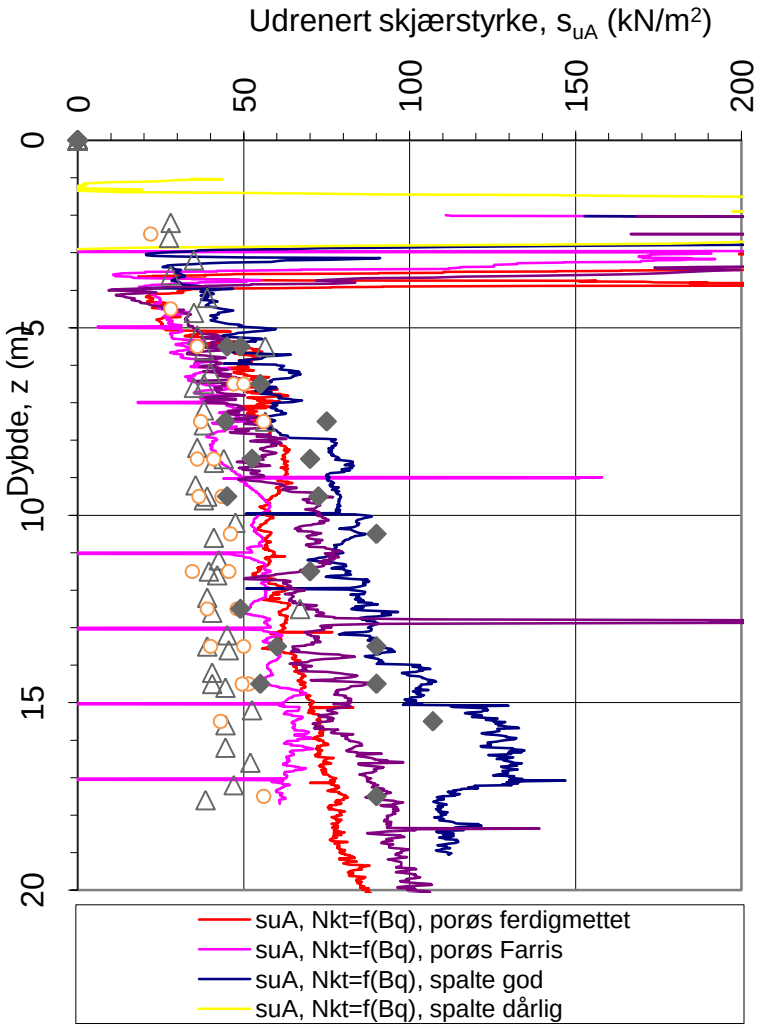
Sammenlignende resultater in situ – lab

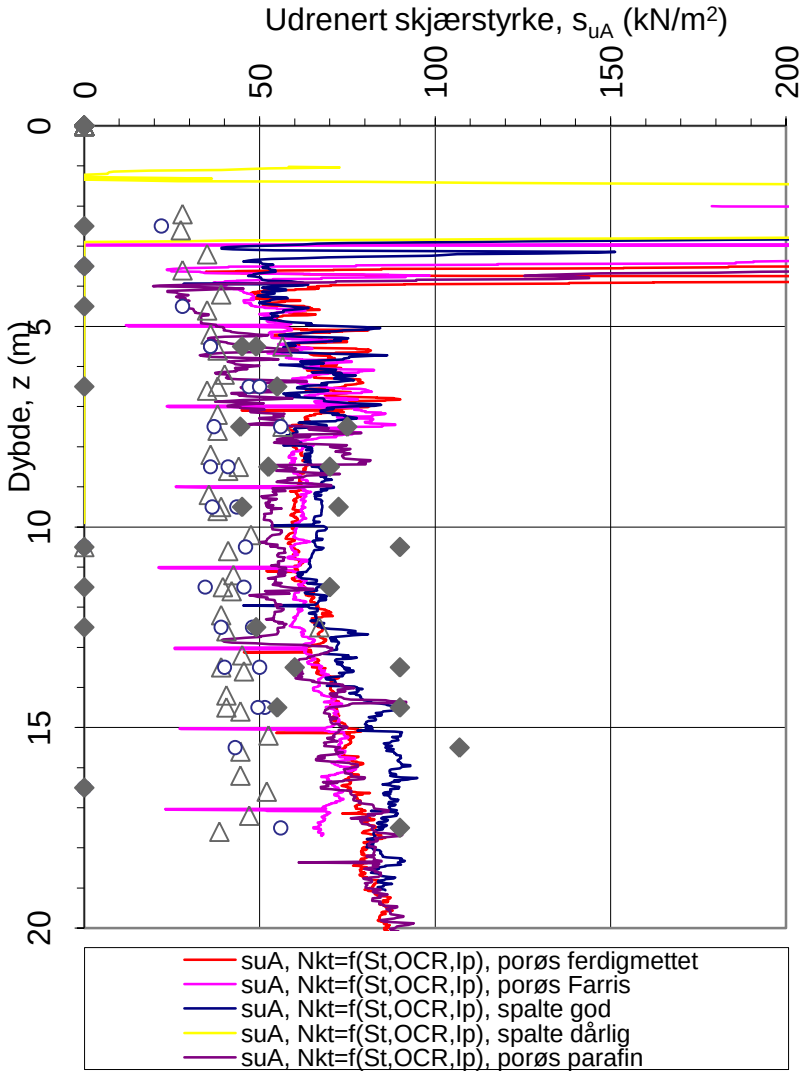




s_{uA}, alle faktorer, f(S_t, OCR, I_p), ferdigmettet

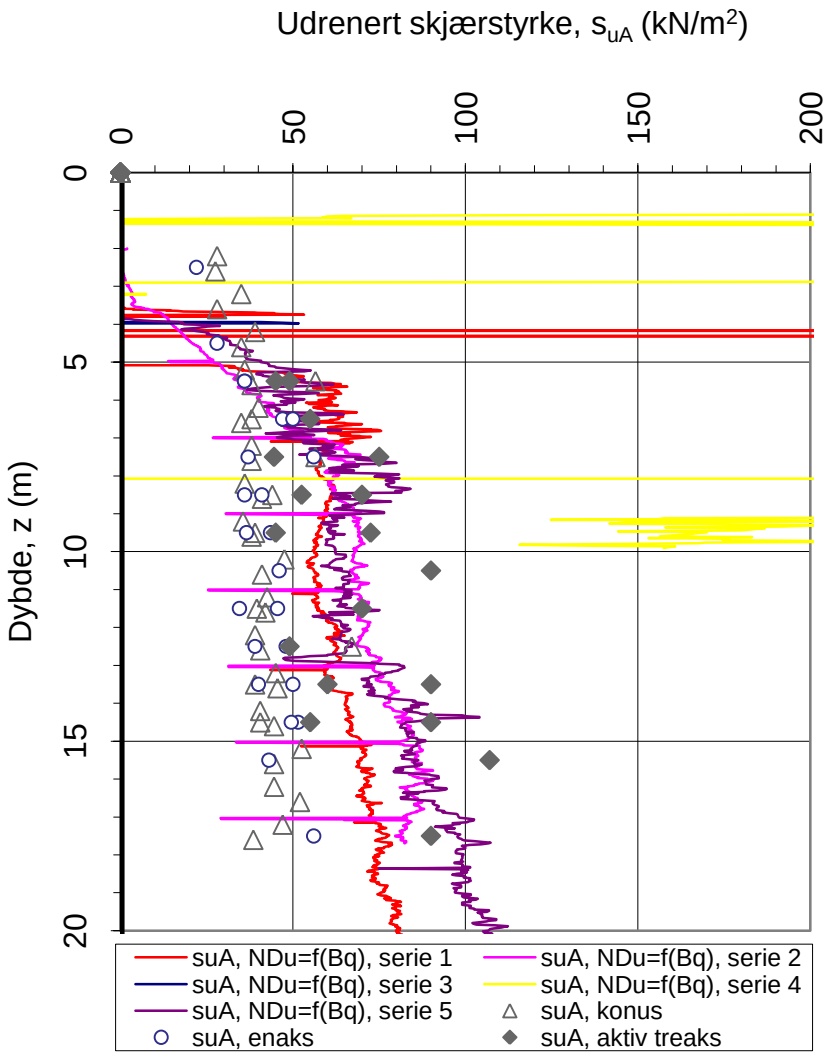
Sammenlignende resultater in situ – lab

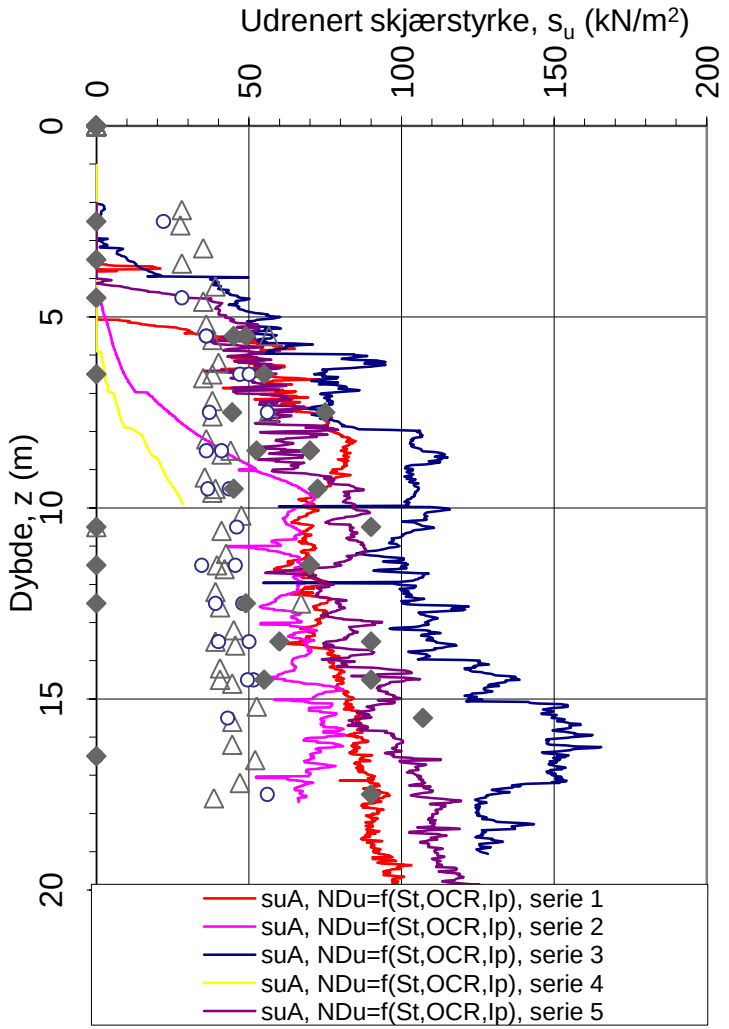




s_{uA}, N_{kt}, alle profiler

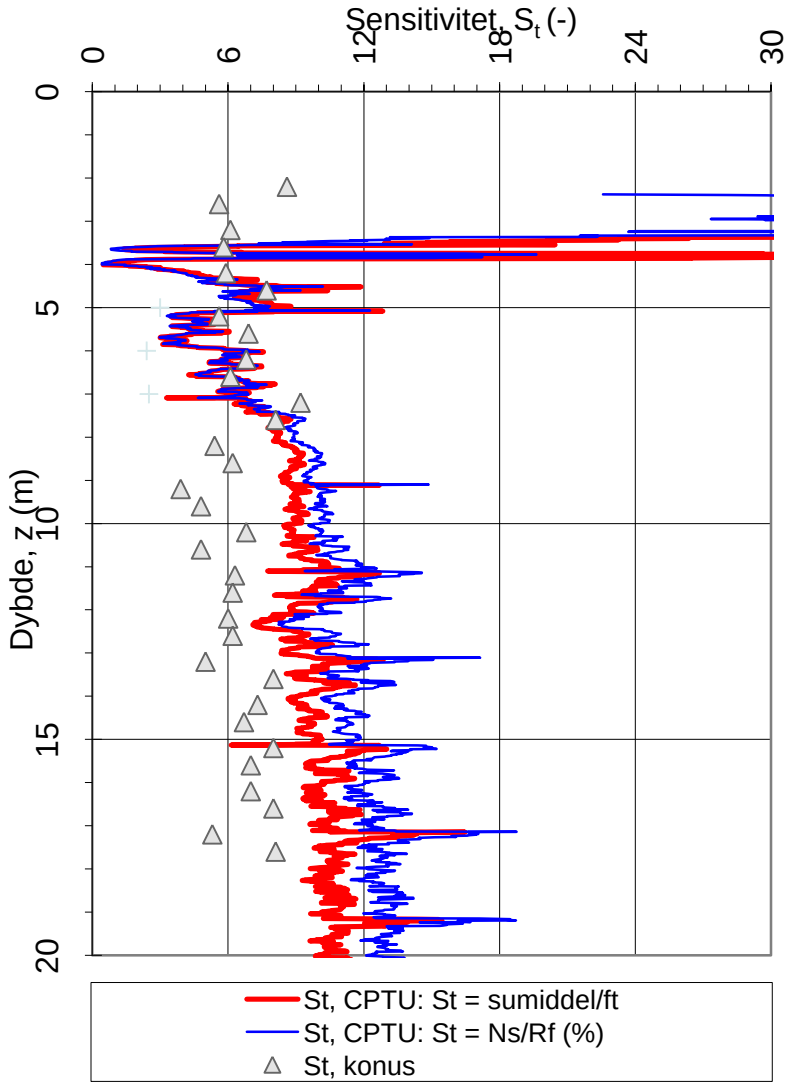
Sammenlignende resultater in situ – lab

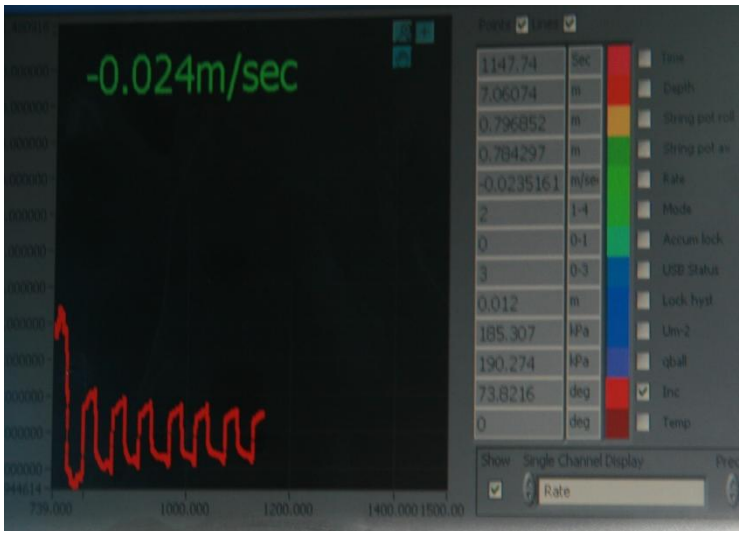




s_{uA}, $N_{\Delta u}$, alle profiler

Sammenlignende resultater in situ – lab





Repeterte penetrasjonssykler for Bestemmelse av reell omrørt skjærstyrke og sensitivitet

CPTU – tolkning av data

Spissmotstand i NC - leirer

- Teoretisk spissmotstand i leire:

$$q_t = N_c s_u + \gamma z$$

- Udrenert skjærstyrke i NC -leire:

$$s_u = \alpha(\gamma' z + a)$$

α = 0.22 - 0.25

a = attraksjon (kan negl.)

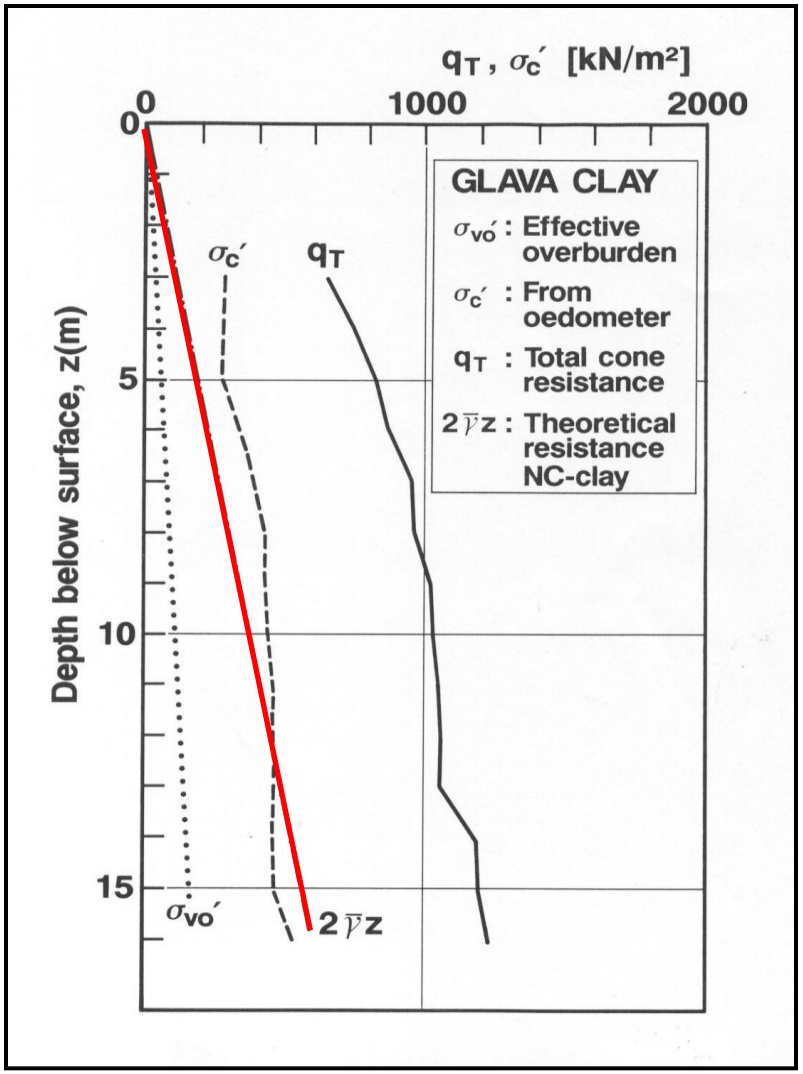
- Kombinasjon gir:

$$q_t = K_c \gamma z$$

$K_c = [(N_c \alpha \gamma'/\gamma) + 1] \sim 2$

$$q_t \sim 2\gamma z: \text{ NC - leire}$$

$$q_t > 2\gamma z: \text{ OC - leire}$$



CPTU – tolkning av data

Totalspenningsbasert tolkning

- Spissmotstand i leire:

$$q_t = N_c s_u + \gamma z$$

$$\Delta u = N_{\Delta u} + \gamma z$$

- Udrenert skjærstyrke i NC -leire:

$$s_u = \alpha(\sigma_c' + a)$$

α = 0.22 - 0.30

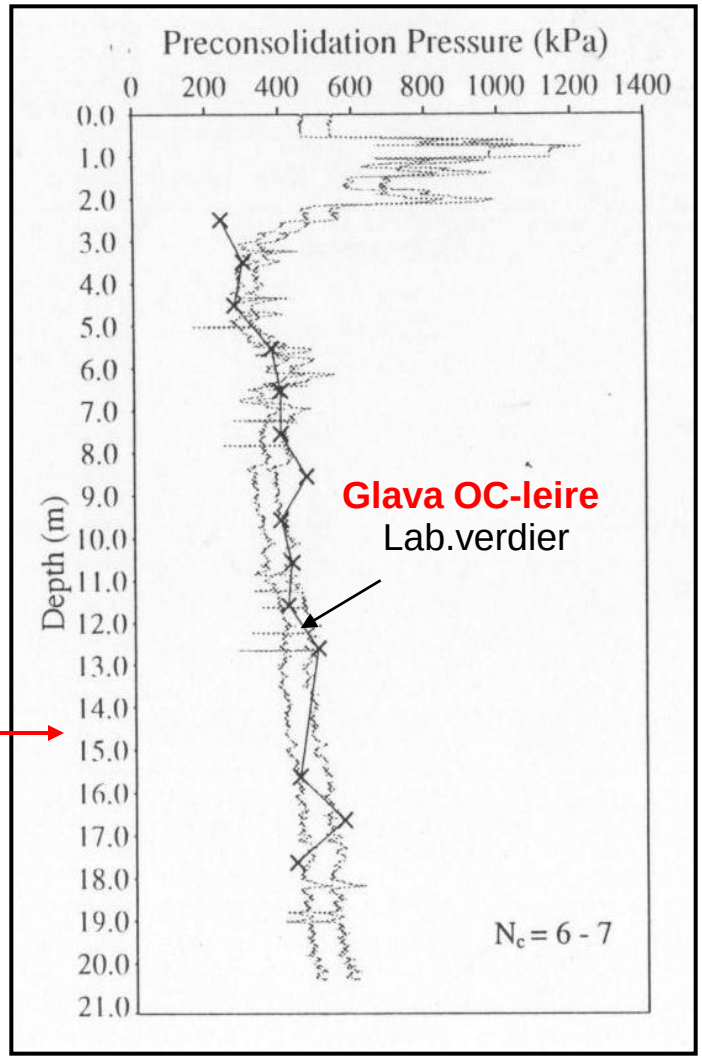
- Kombinasjon gir:

$$\sigma_c' = (q_n / N_c \alpha) - a$$

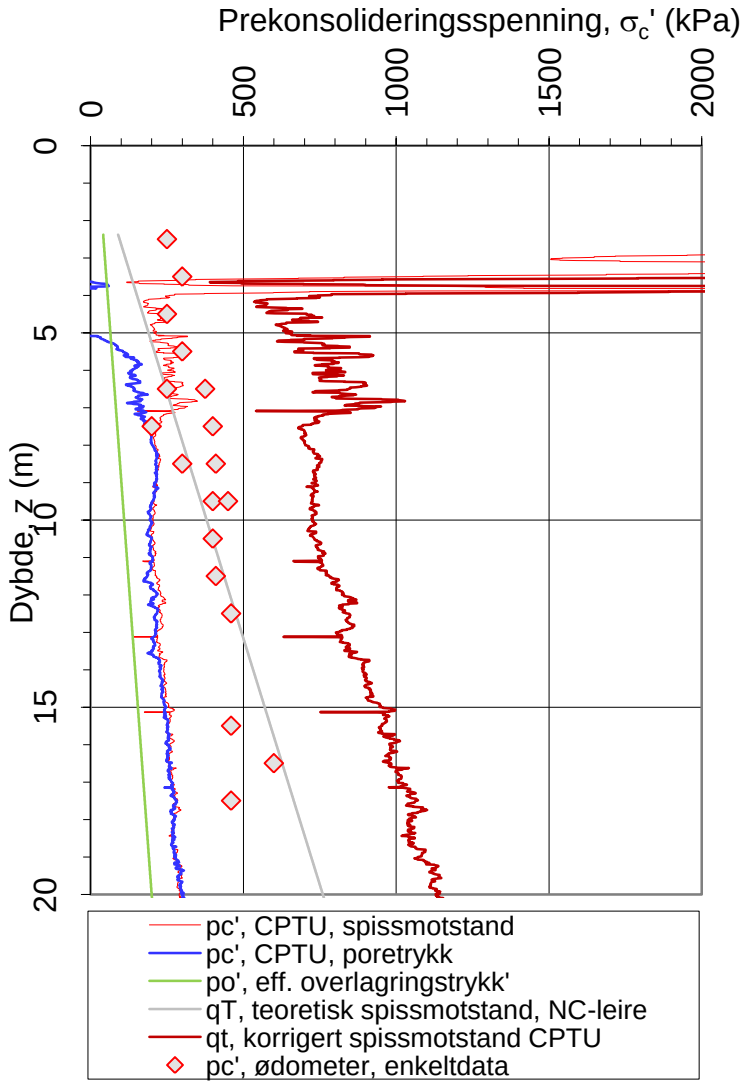
$N_c\alpha$ ~ 1.5 - 2.25

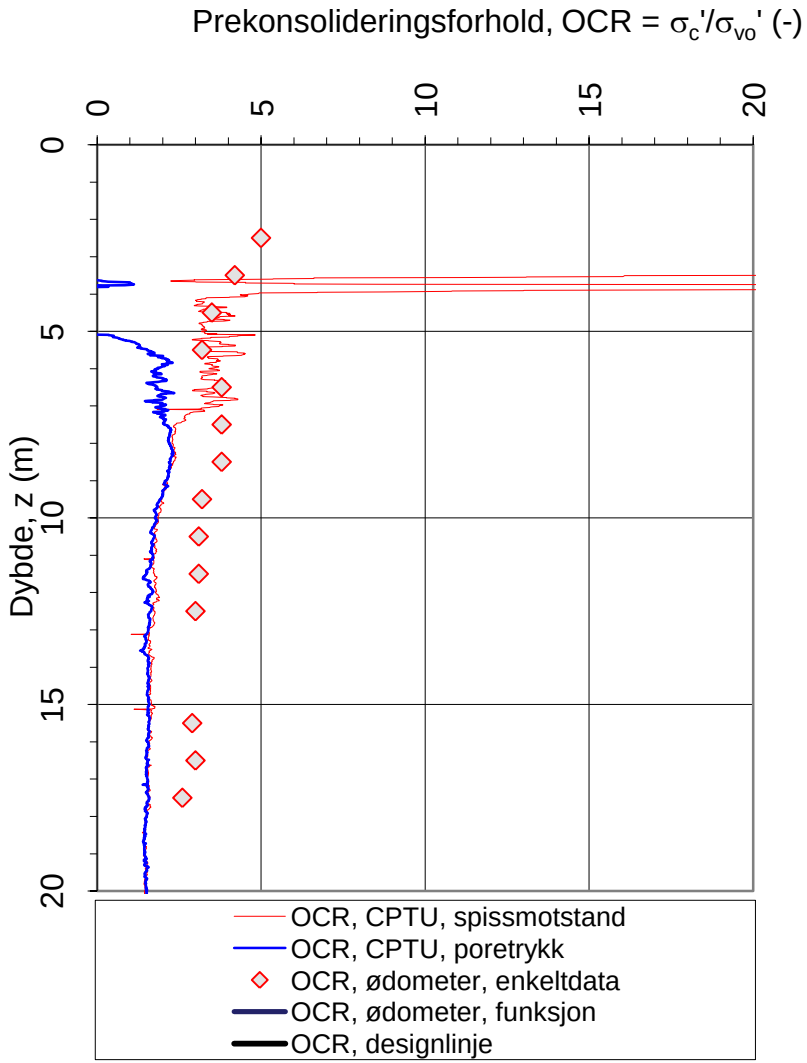
$$\sigma_c' = (\Delta u / N_{\Delta u} \alpha) - a$$

$N_{\Delta u}\alpha$ ~ 1.25 - 2.00



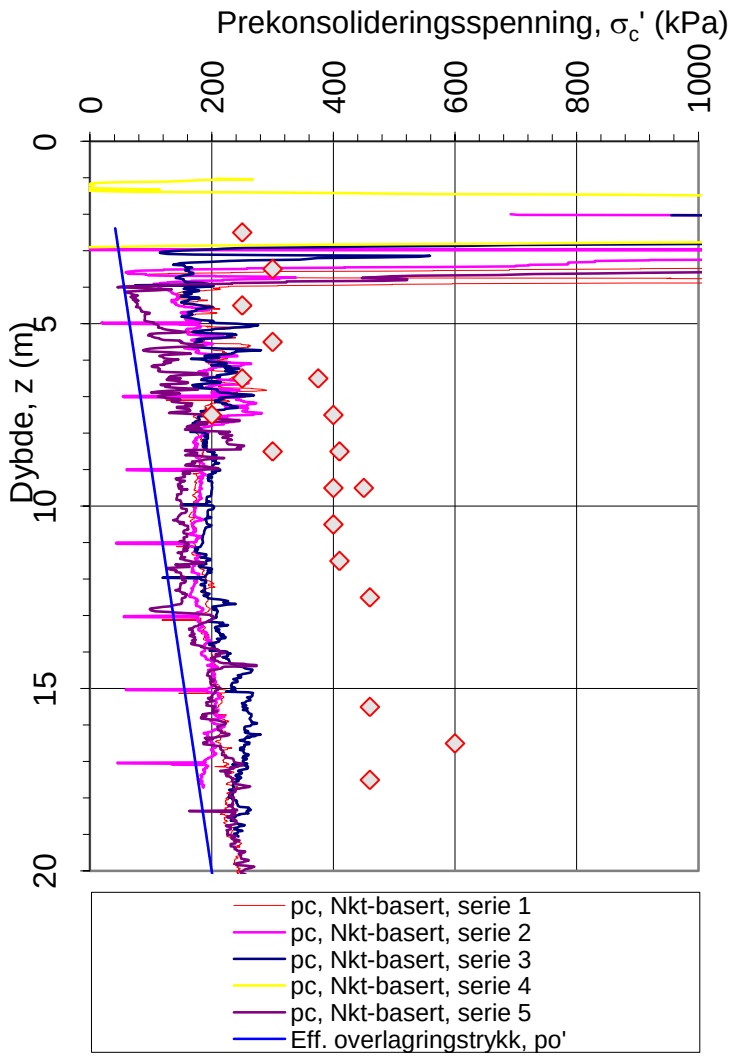
Sammenlignende resultater in situ – lab

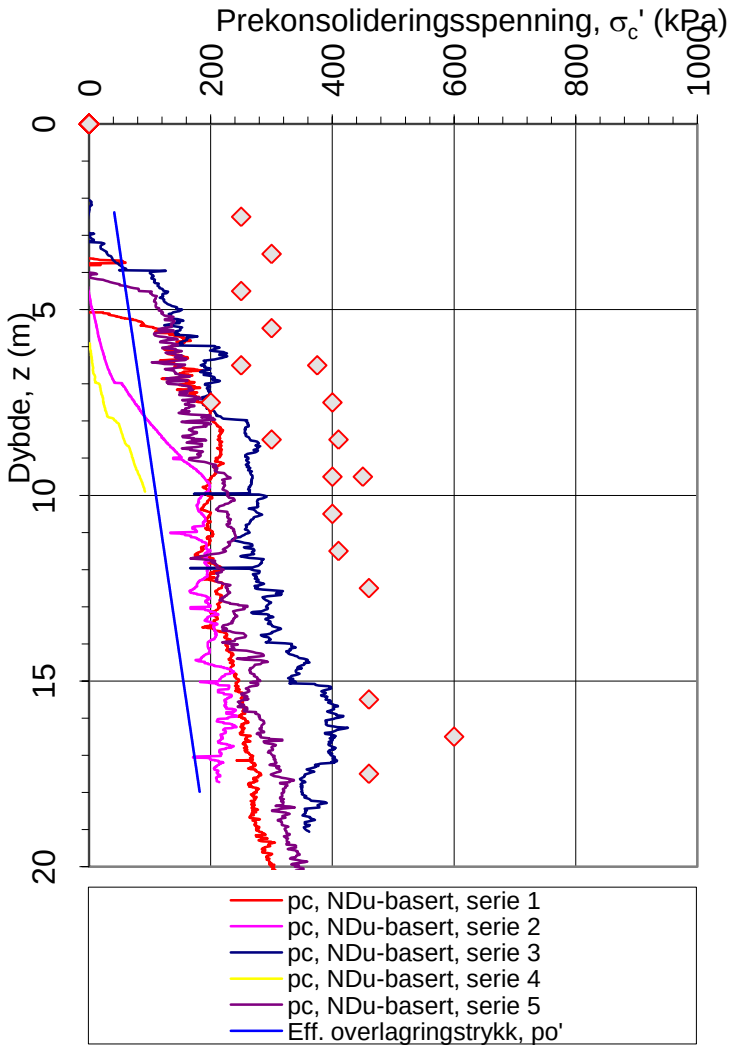




Prekonsolideringsspenning, ferdigmettet

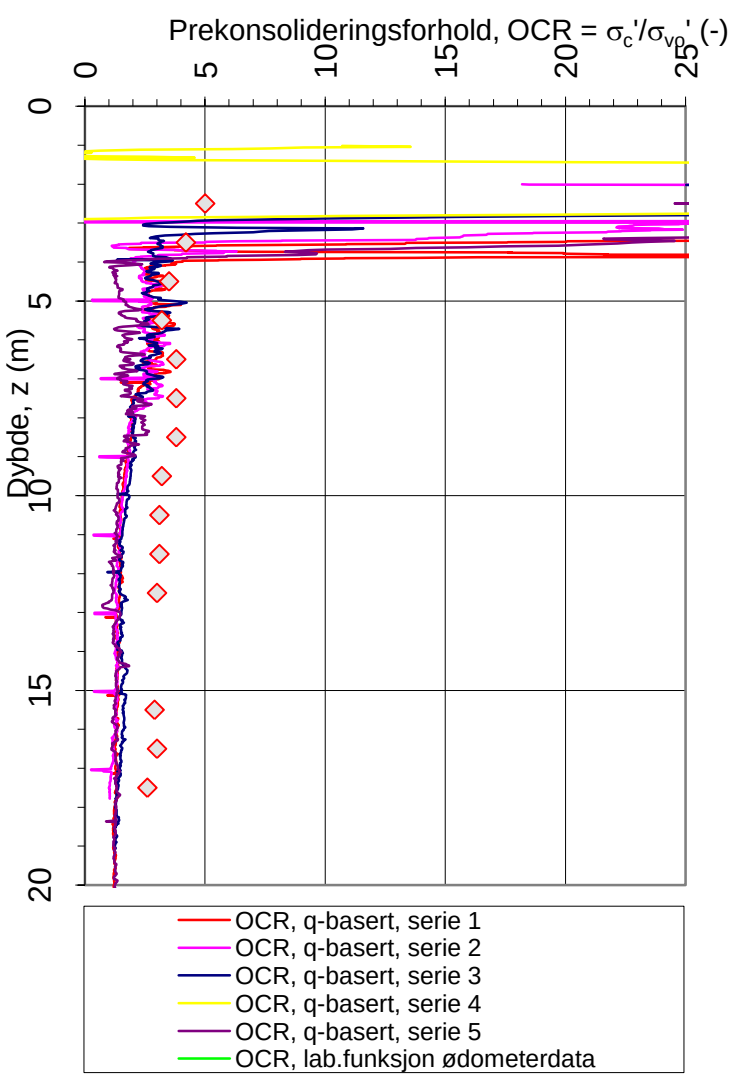
Sammenlignende resultater in situ – lab

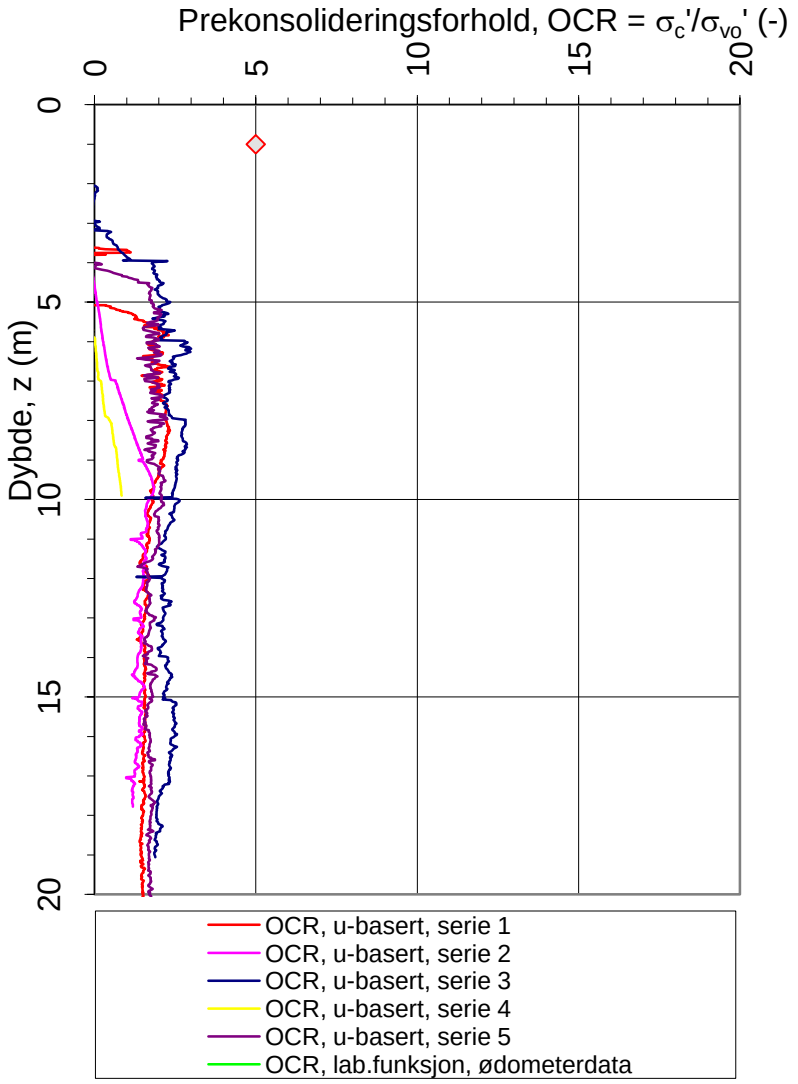




Prekonsolideringsspenning, alle profiler

Sammenlignende resultater in situ – lab





Prekonsolideringsforhold, alle profiler

CPTU – tolkning av data

Bæreevneteori,
udrenert effektivspenningsanalyse

- **Fra CPTU data:**

  Spissmotstandstall:

  $$N_m = q_n / (\sigma_{vo}' + a)$$

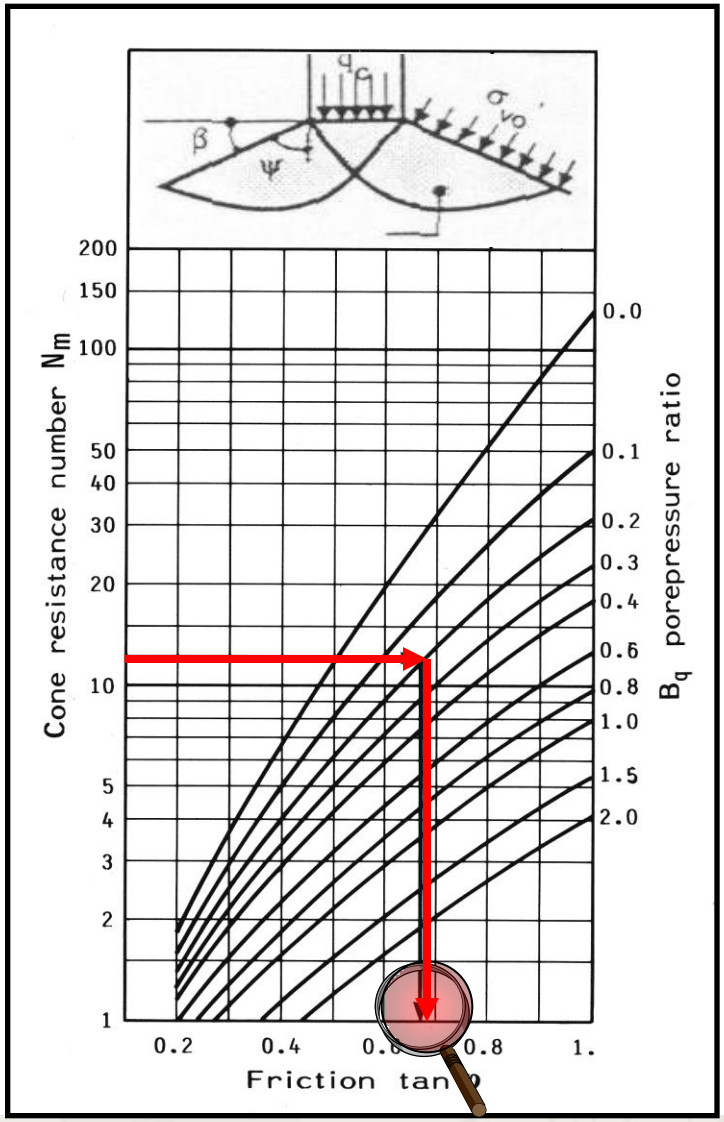
  $$N_m = (N_q - 1)/(1 + N_u B_q)$$

  funksjon av:

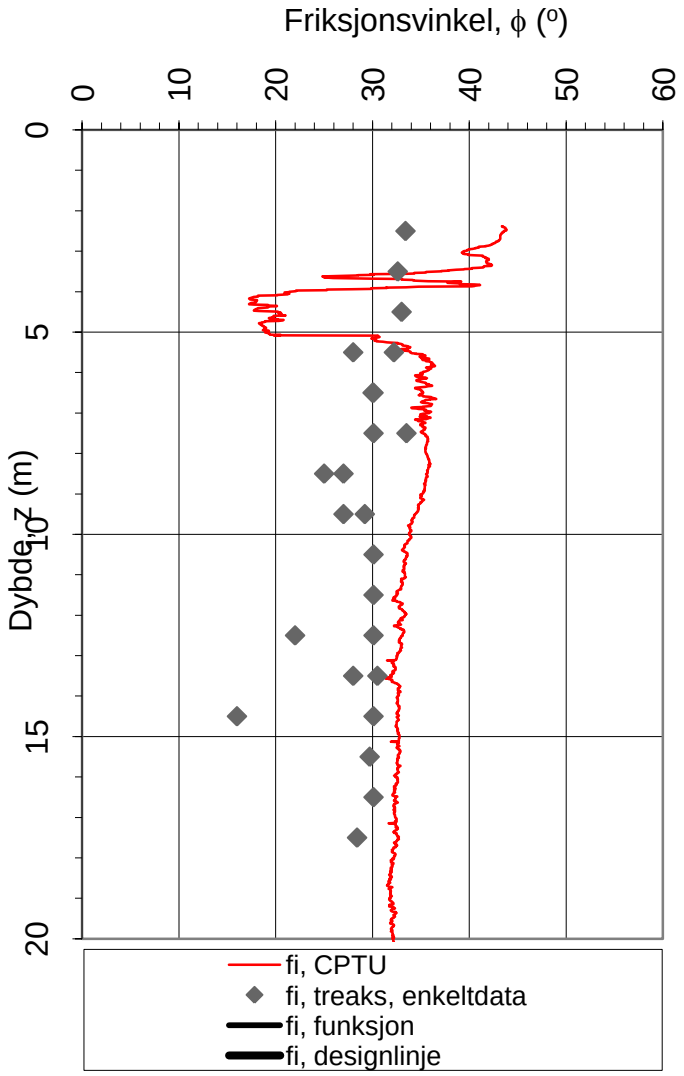
  - friksjon tanϕ, plastifiseringsvinkel β og poretrykksforhold: $B_q = \Delta u_2 / q_n$
  - $N_q = \tan^2(45+\phi/2)e^{(\pi-2\beta)\tan\phi}$
  - $N_u = 6\tan\phi(1+\tan\phi)$

  Poretrykksforhold:

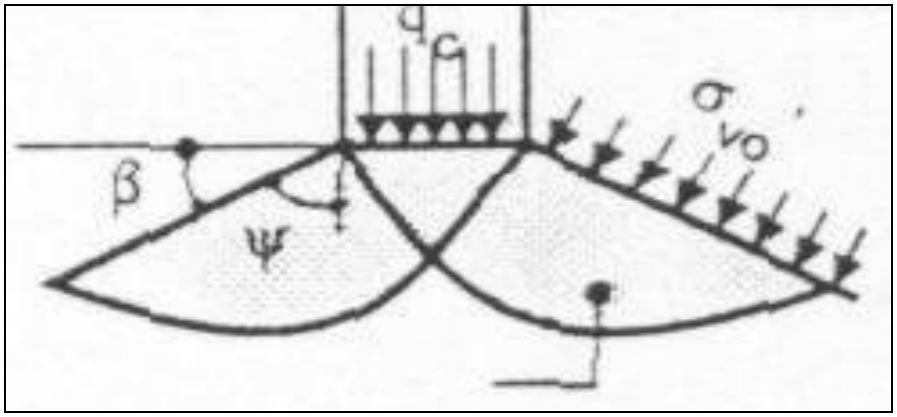
  $$B_q = \Delta u_2 / q_n$$



Sammenlignende resultater in situ – lab



Empirisk tilpasning for plastifiseringsvinkel $\beta = 2/3 - \tan\phi$ er lagt inn. Gir noe høy tolket ϕ i leire.



CPTU – tolkning av data

Tolkningsprinsipp

Erfaringsbasert tilpasning til tangentmoduler fra ødometerforsøk

Prekonsolideringsområdet, leire:

$$M_i = m_i \cdot q_n$$

$m_i = 10 \pm 5$

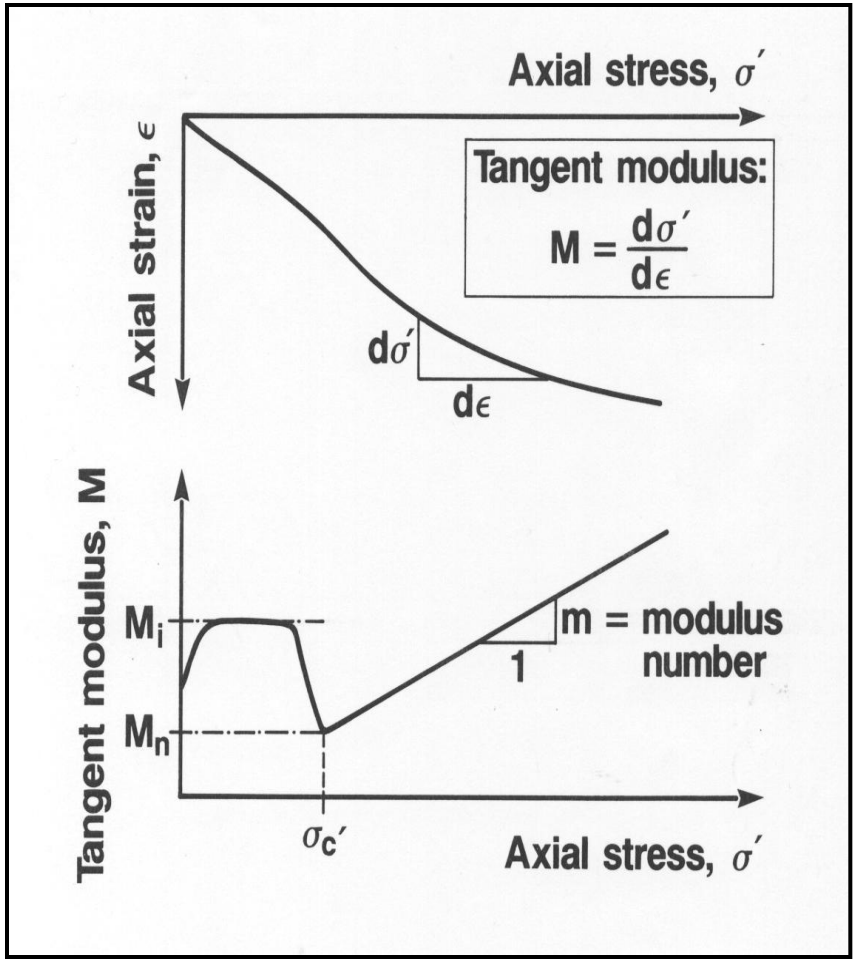
$\sigma < \sigma_c'$

Jomfruspenningsområdet, leire:

$$M_n = m_n \cdot q_n$$

$m_n = 6 \pm 2$

$\sigma \sim \sigma_c'$



CPTU – tolkning av data

Tolkningsprinsipp

- Erfaringsbasert tilpasning til tangentmodulkonseptet:

$$M = m\sigma_a(\sigma'/\sigma_a)^{1-\alpha}$$

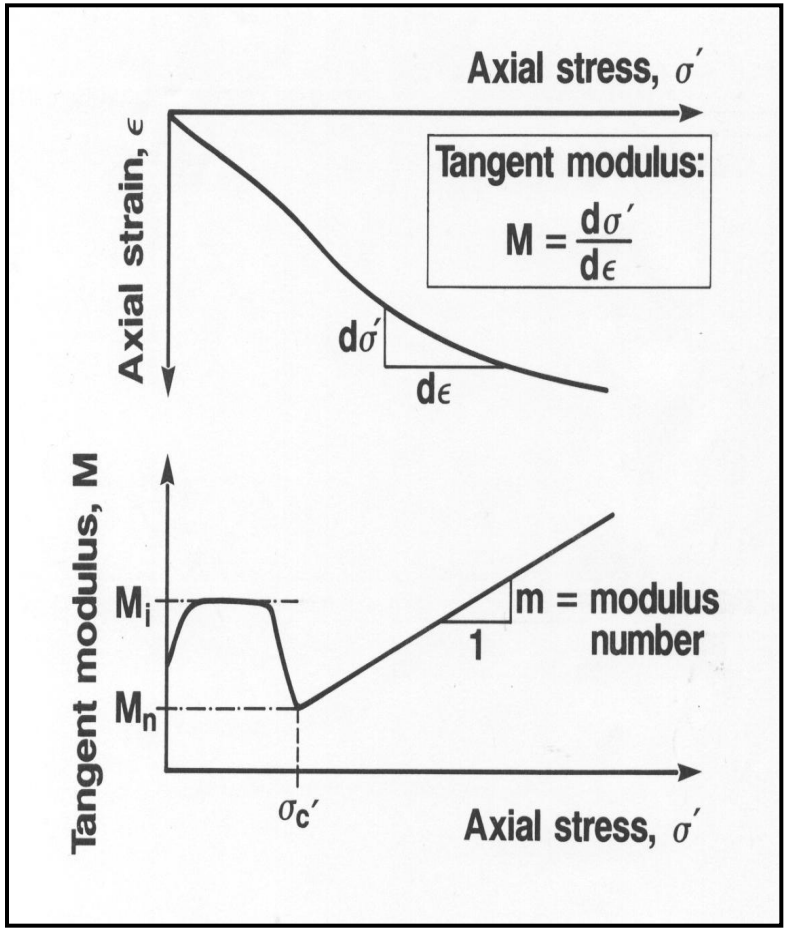
α = 0.5 for sand

- Designområdet sand, silt:

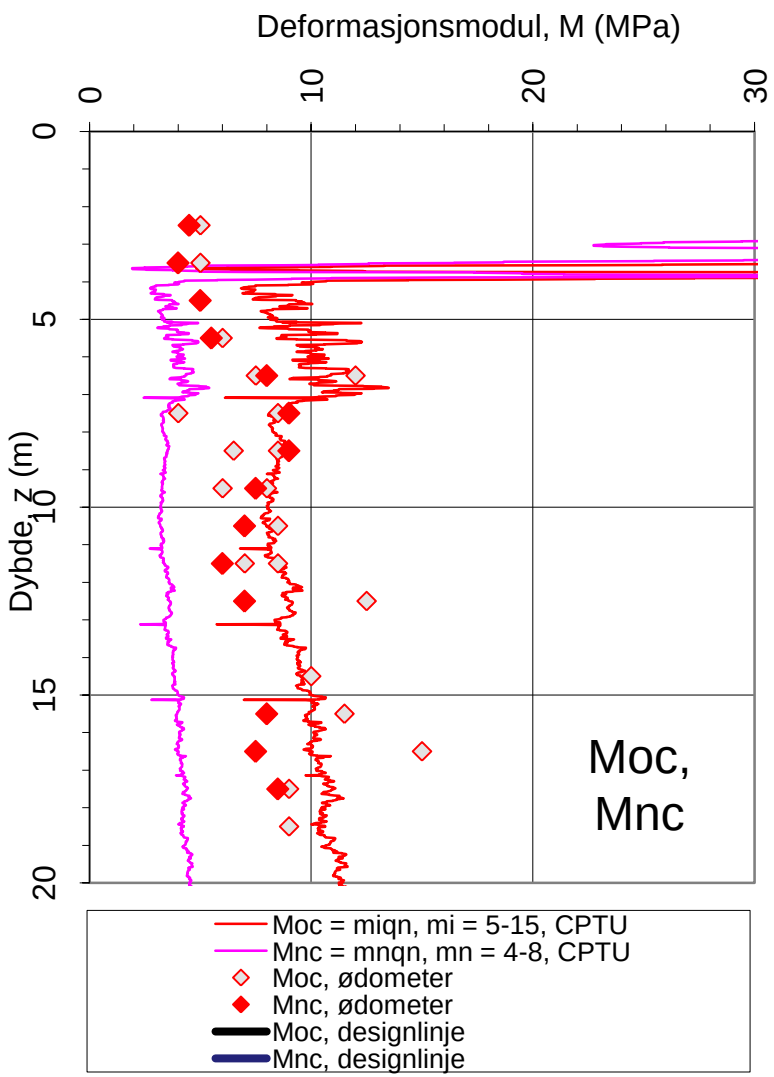
$$\sigma' = \sigma_{vo}' + \Delta\sigma'$$

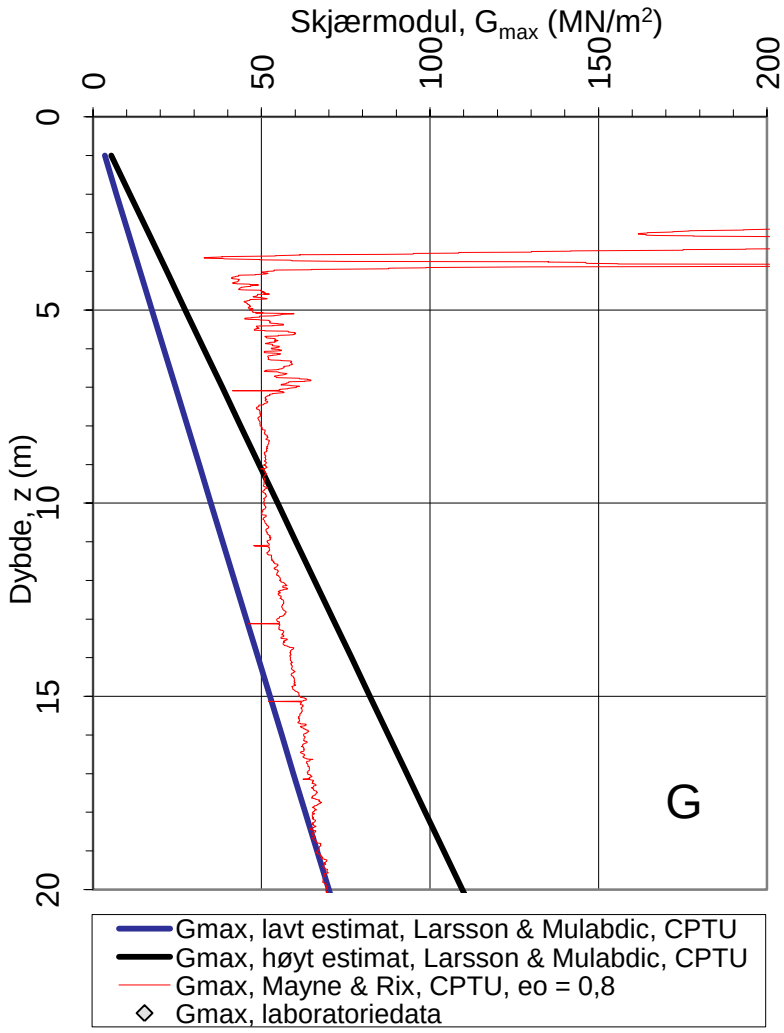
$$M_s = m_s\sqrt{q_n\, q_a}$$

$m_s = 30 \pm 10$

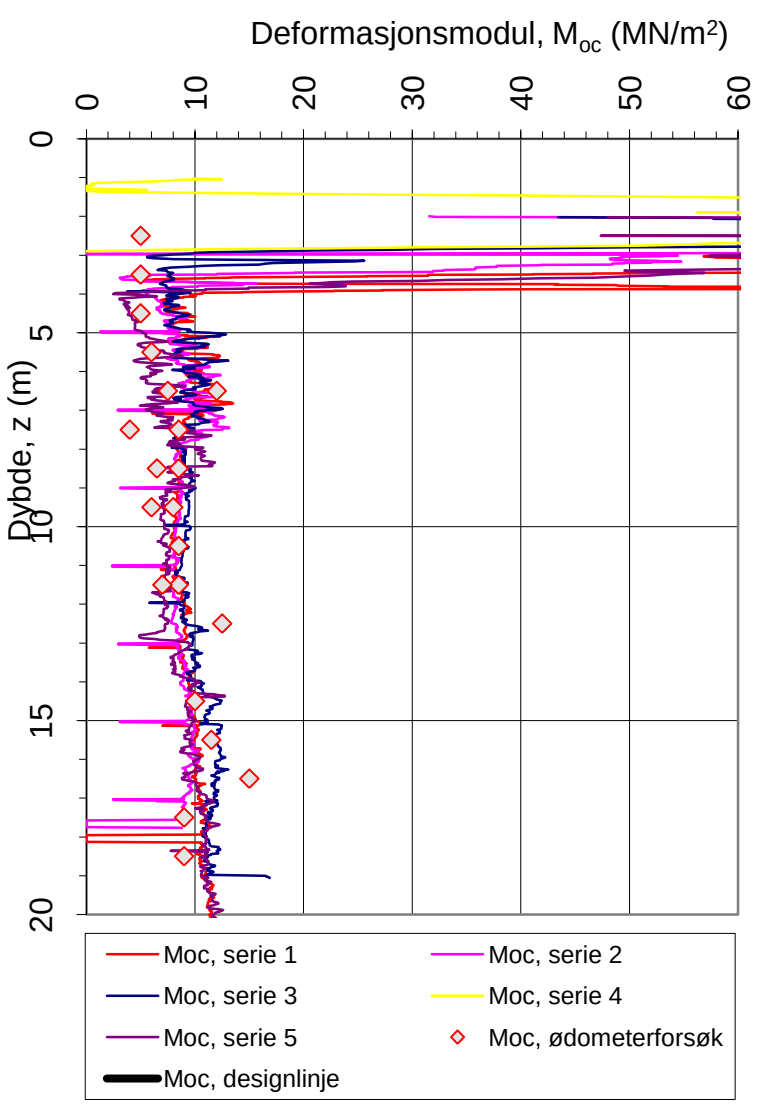


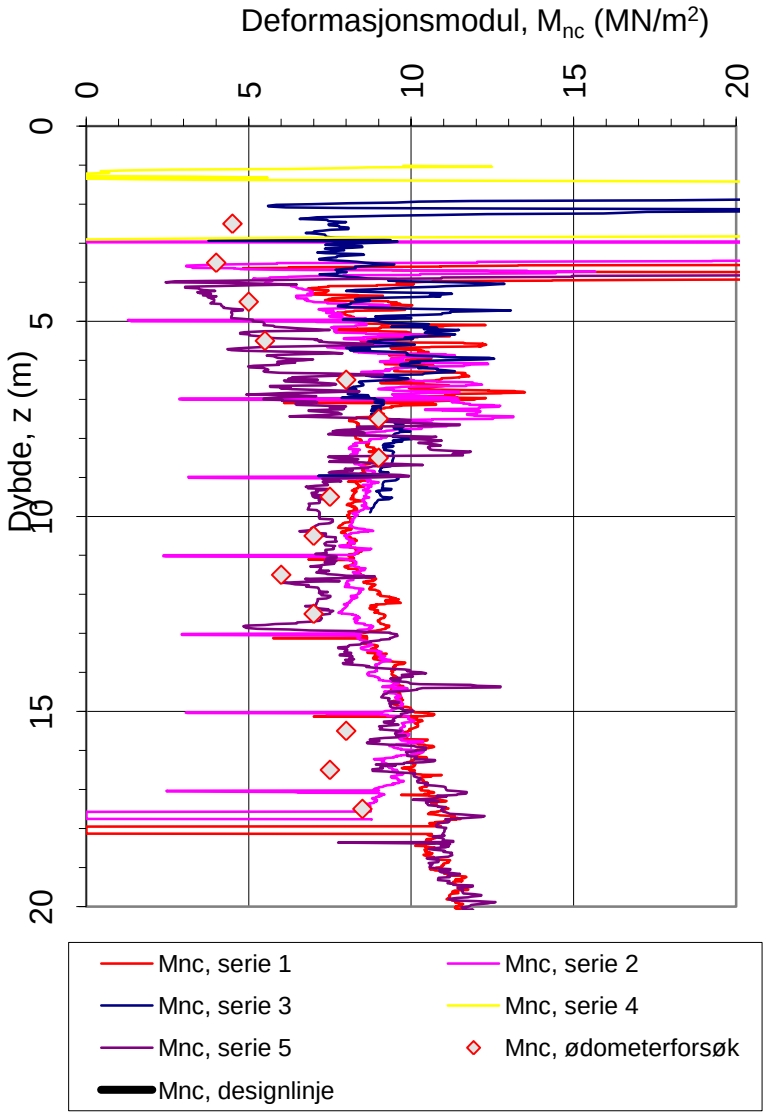
Sammenlignende resultater in situ – lab





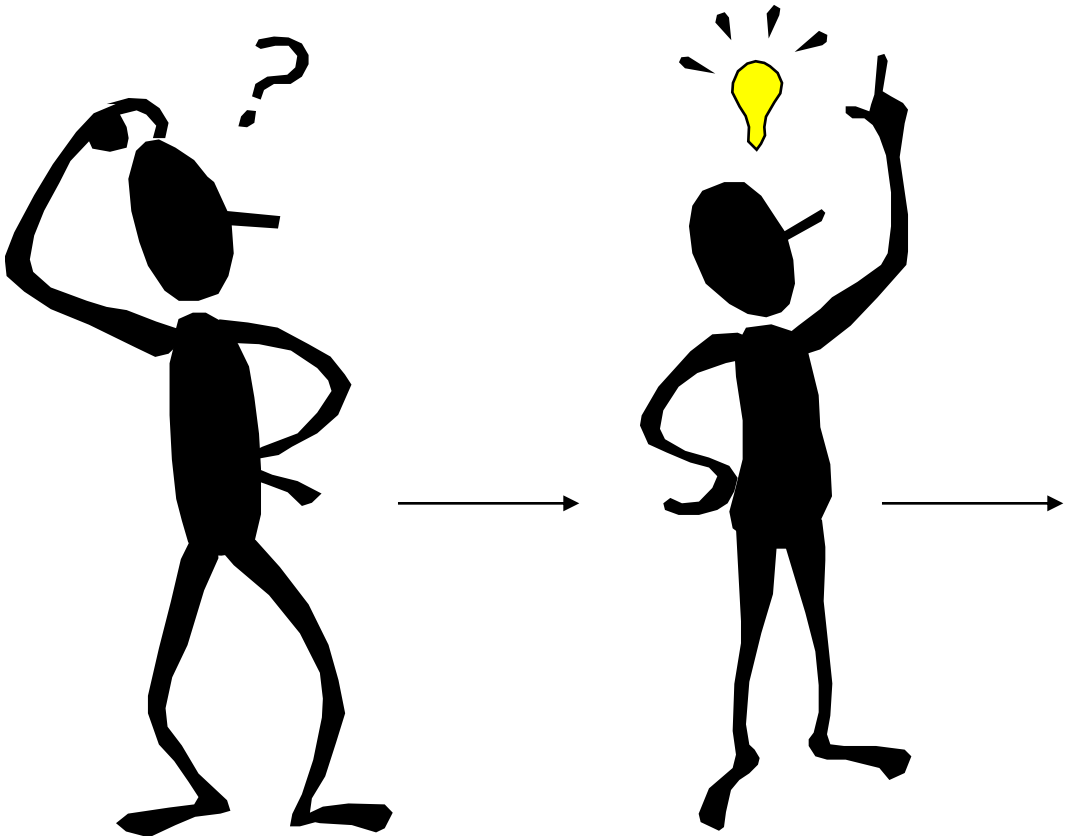
Sammenlignende resultater in situ – lab





Deformasjonsmoduler, alle profiler

Fremtidens Coneheads?



24.05.2011,09.29 25.05.2011,16.01→ Fremtiden i våre hender!