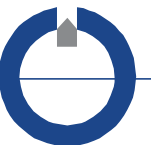


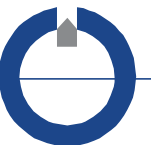
Udvikling af DCIP til Cross borehole

Thue Bording



Motivation

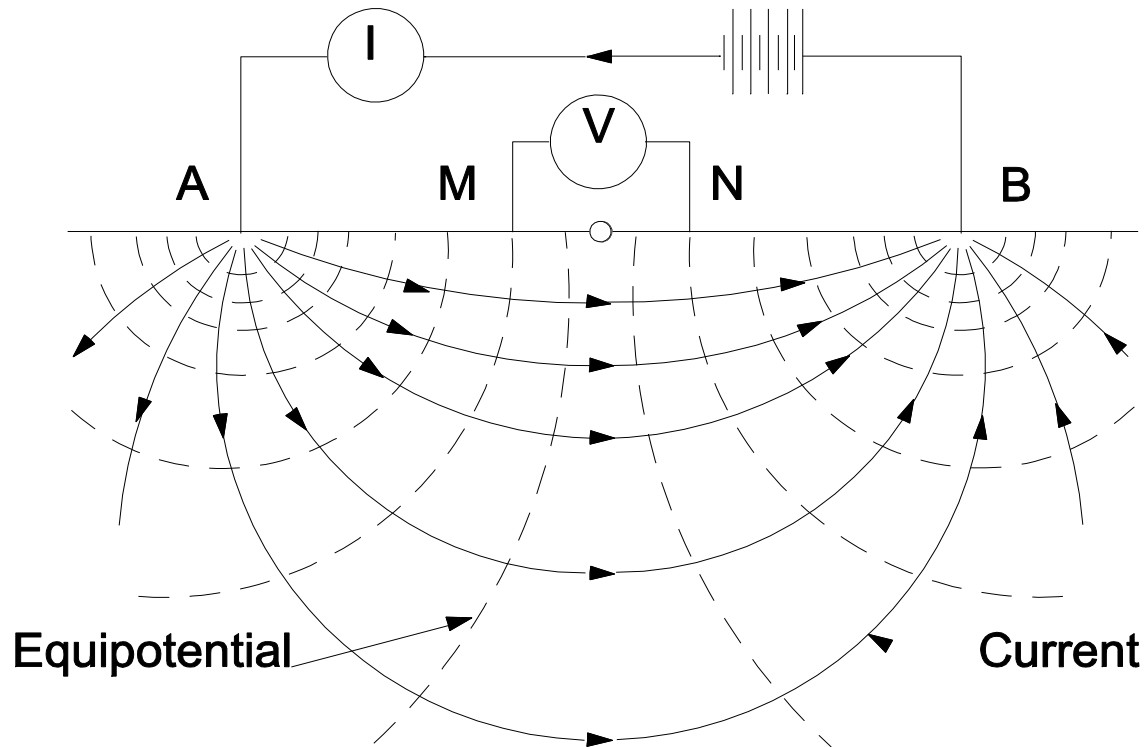
- **Overflade DCIP**
 - Taber opløsning med dybden.
- **Moniteringsboringer**
 - Punktinformation
- **Cross borehole tomografi**
 - 2D billede mellem boringer.
 - Opløsning kun afhængig af geometri
- **Resistivitets data (DC)**
 - Kontraster i ledningsevne (geologi, ledningsevne, porevæske kemi mm.)
- **IP data**
 - Overfladeledningsevne, bestemmelse af hydraulisk ledningsevne.
 - Indsamles sammen med DC data
 - Mere tidskrævende



DC målinger

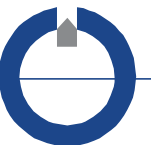
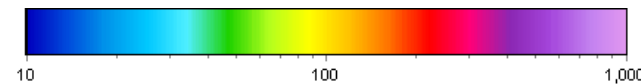
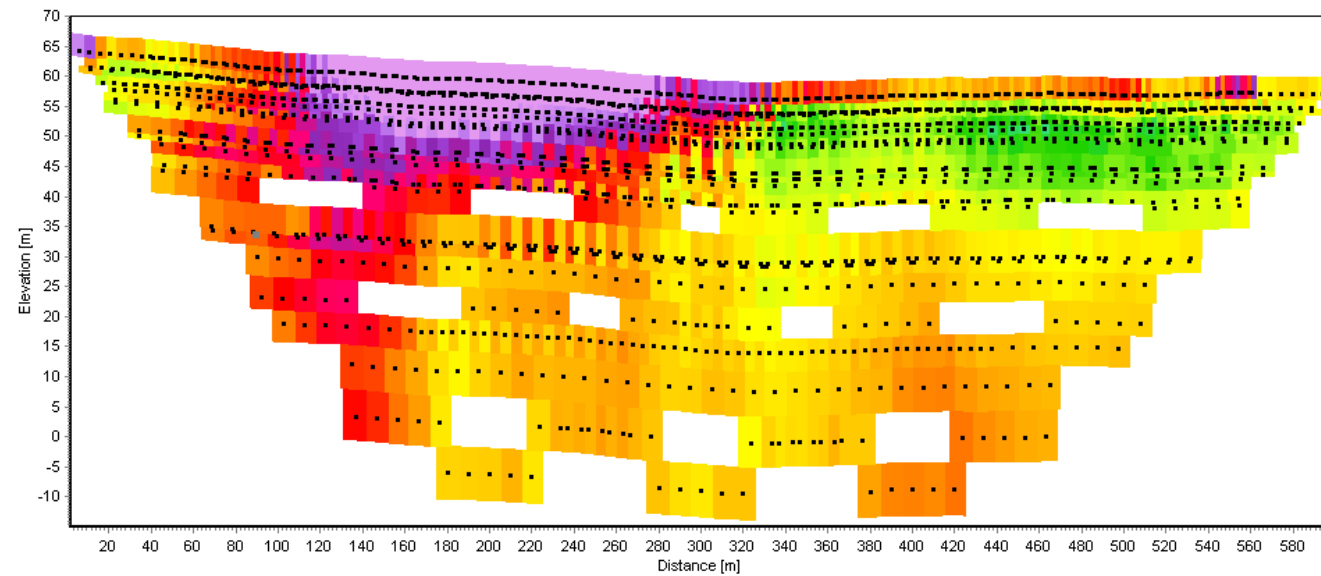
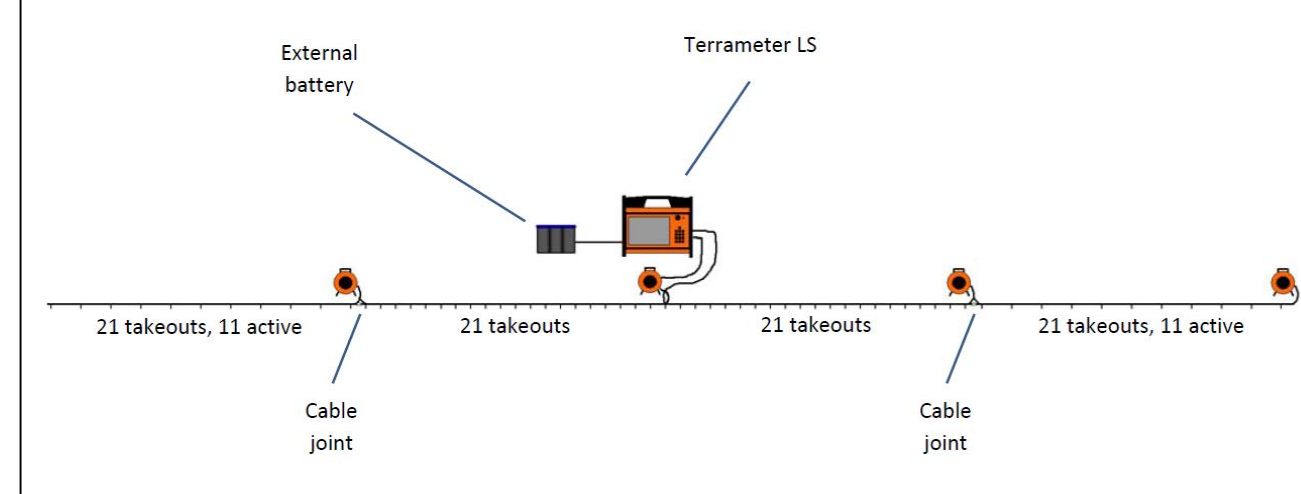
- Tilsyneladende resistivitet

- $\rho_a = \frac{\Delta V}{I} 2\pi \left(\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN} \right)^{-1} = \frac{\Delta V}{I} K$



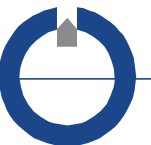
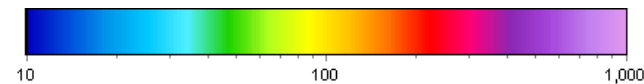
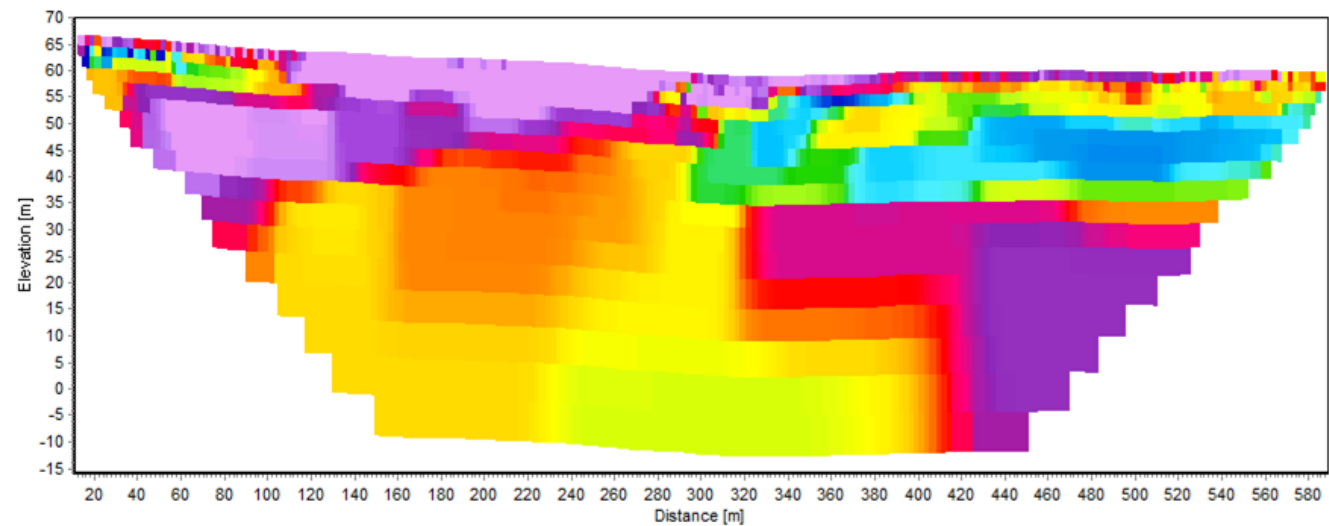
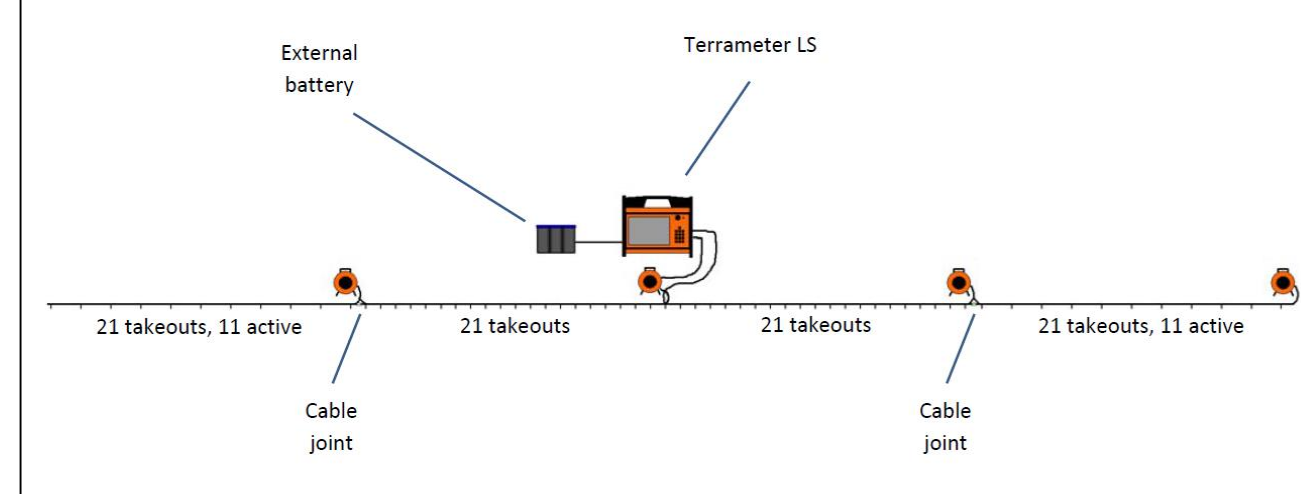
Overflademålinger

- **CVES, MEP, ERT**
 - Continuous Vertical Electrical sounding
 - Multi Elektrode Profiling
 - Electrical Resistivity Tomography

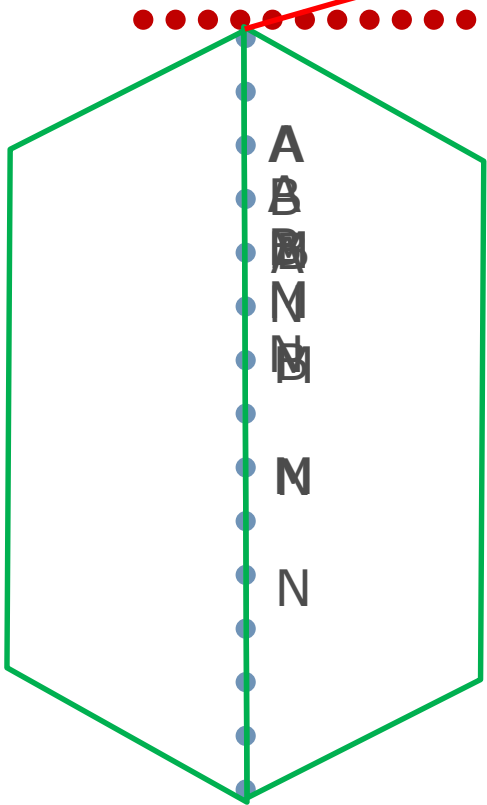


Overflademålinger

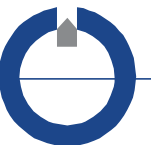
- **CVES, MEP, ERT**
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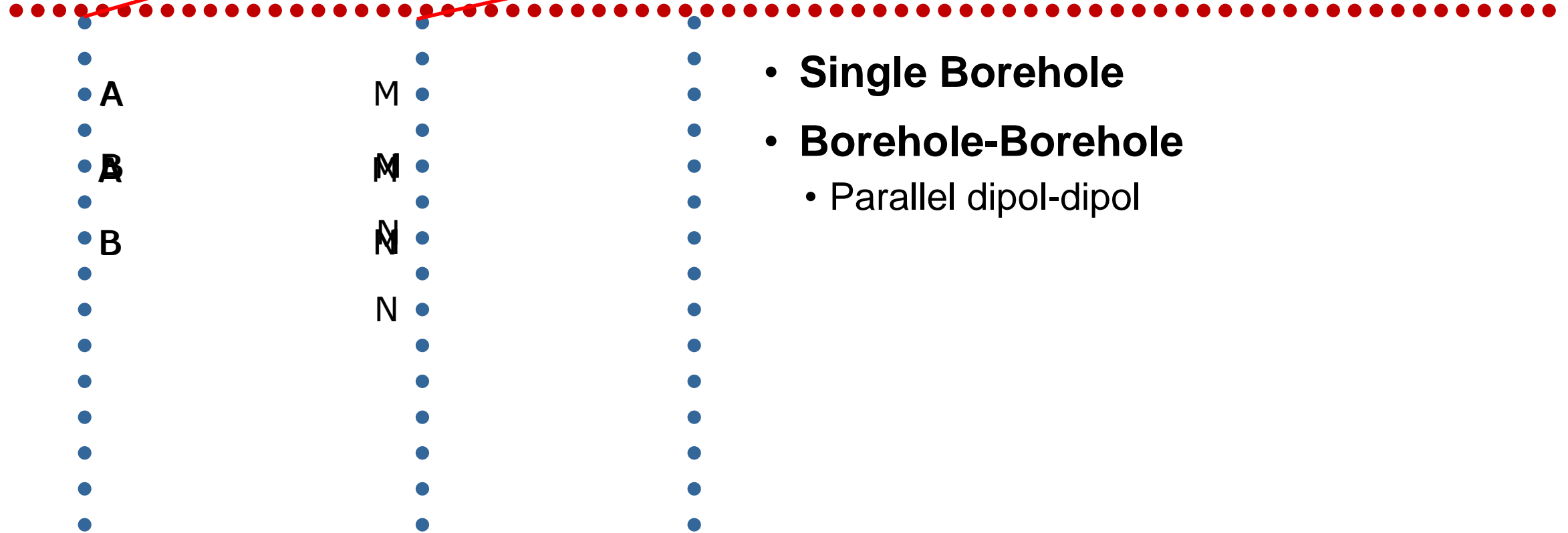
Cross-borehole målinger



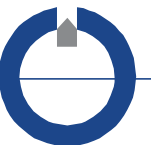
- **Single Borehole**



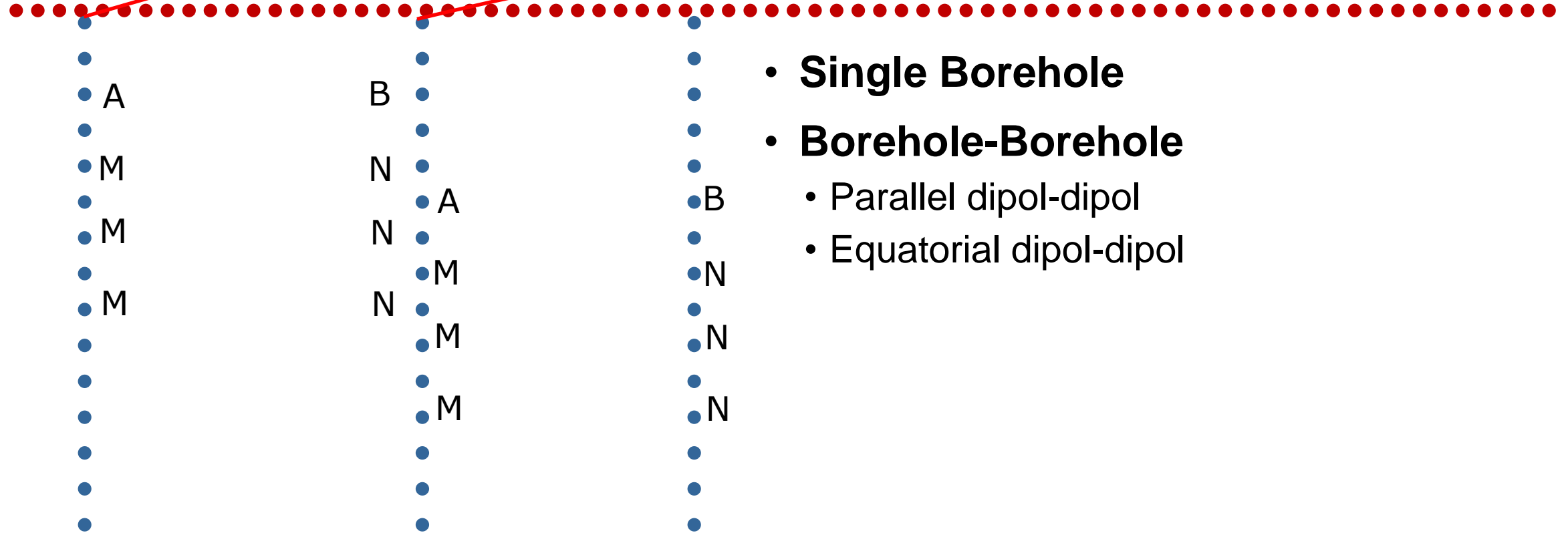
Cross-borehole målinger



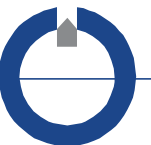
- **Single Borehole**
- **Borehole-Borehole**
 - Parallel dipol-dipol



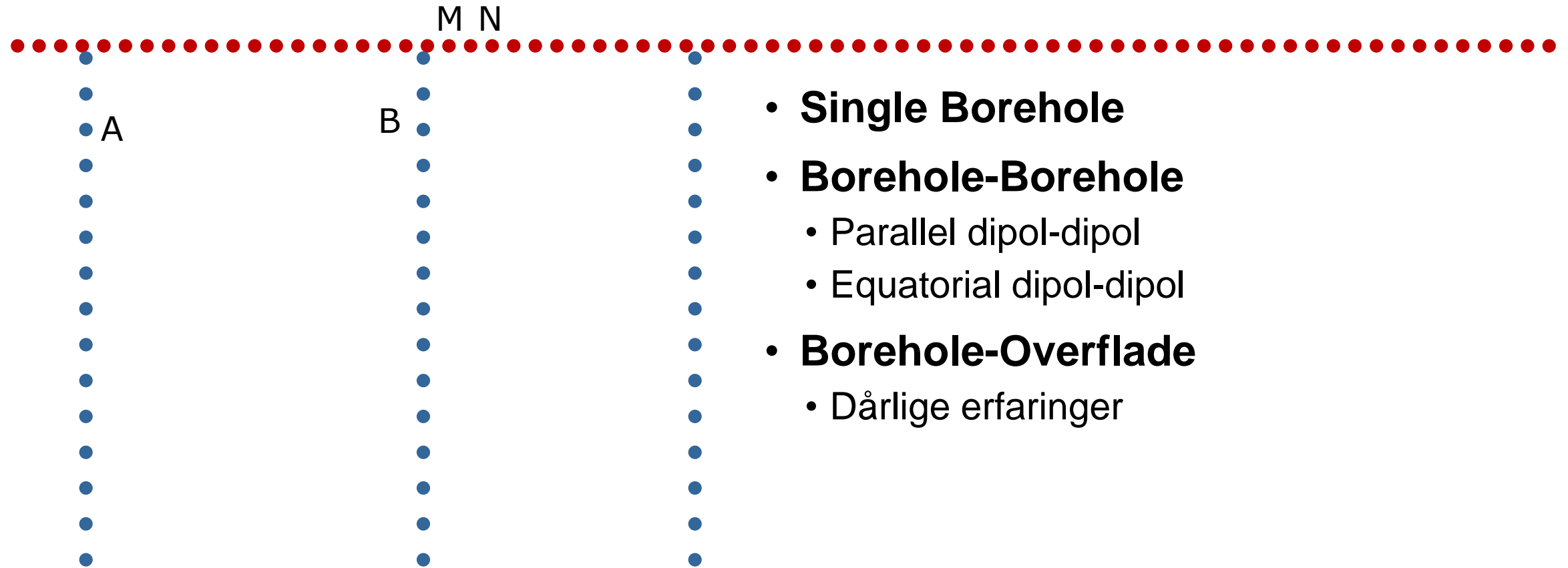
Cross-borehole målinger



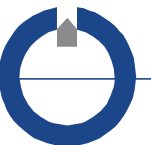
- **Single Borehole**
- **Borehole-Borehole**
 - Parallel dipol-dipol
 - Equatorial dipol-dipol



Cross-borehole målinger



- **Single Borehole**
- **Borehole-Borehole**
 - Parallel dipol-dipol
 - Equatorial dipol-dipol
- **Borehole-Overflade**
 - Dårlige erfaringer



Projekter

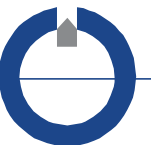
- **Sandlinse projekt, Kallerup Grusgrav, RH, 2015-2016**
 - Kortlægning af sandlinser i moræne
 - Tre borehuller af 10 m, elektrodeafstand 20 cm

- **Kærgaard Klitplantage, grube 3, RS, 2018-2019**
 - Kortlægning af injektionsmiddel, ifb. ISCO, lille skala
 - Ti borehuller af 8 m, elektrodeafstand 25 cm

- **Hvedemarken, Farum, RH, 2019-2020**
 - Permeabel reaktiv barriere
 - Ni borehuller af 20 m, elektroder i nederste 10 m, elektrodeafstand 30 cm.

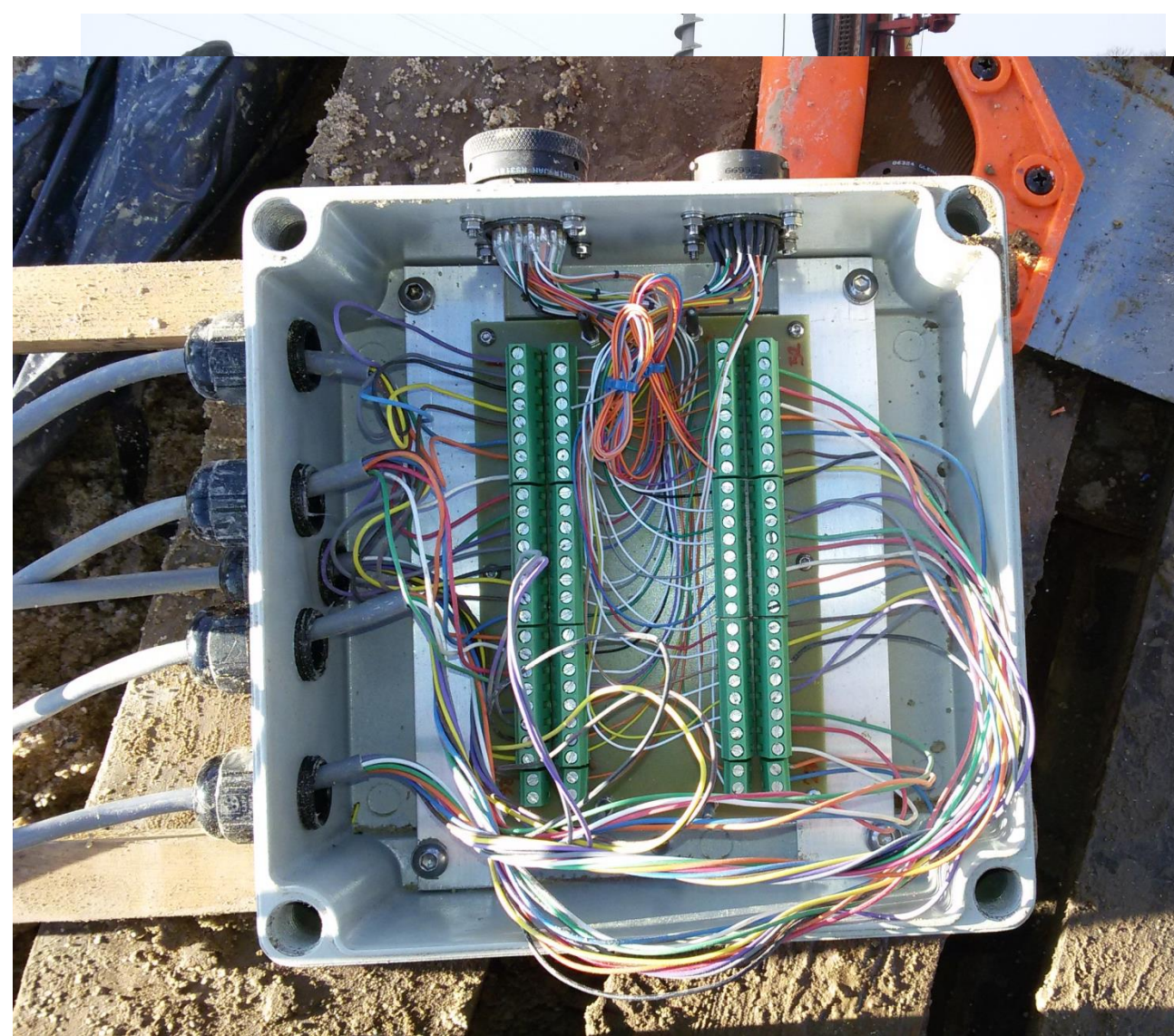
- **Kærgaard Klitplantage, grube 1, RS, 2019-2020**
 - Kortlægning af injektionsmiddel, ifb. ISCO, stor skala
 - 30 borehuller af 8 m, elektrodeafstand 25 cm

- **GIREM, Innovationsfonden, 2018-2020**
 - Mange nyudviklinger og forbedringer

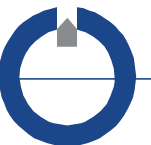


Sandlinse projekt

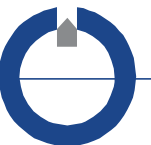
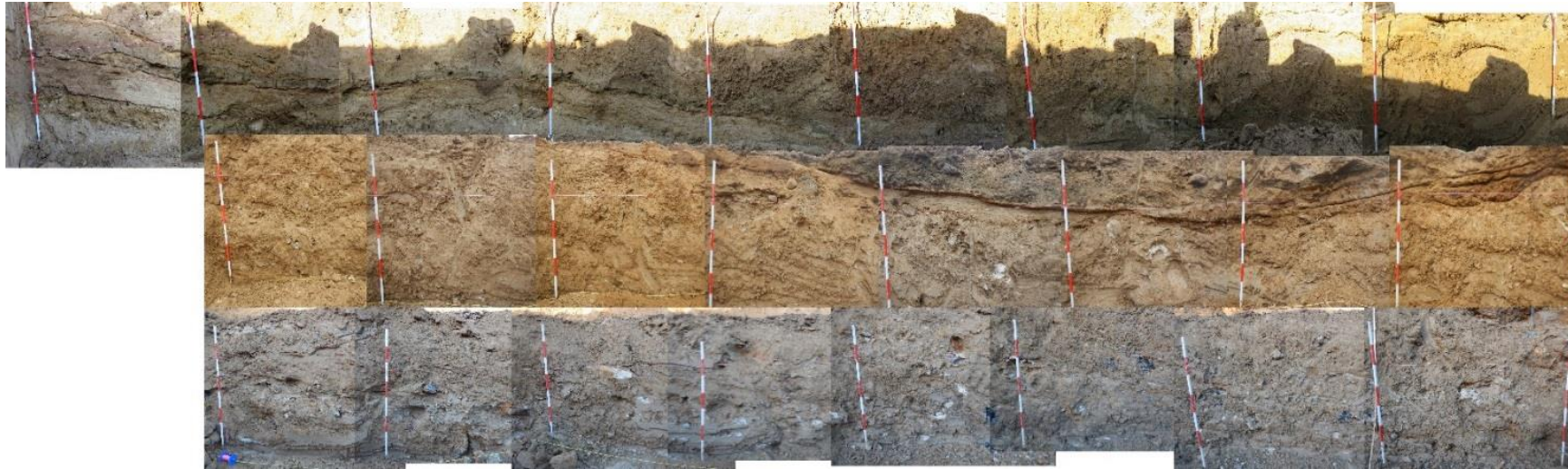
- Tre styk 10 m elektroderør på linje
- 20 cm elektrodeafstand
- Installeret ved sneglebor og efterfyldning af filtersand.
- Ledninger trukket på indersiden af røret, loddet på kobbertape.



Groundtruthing

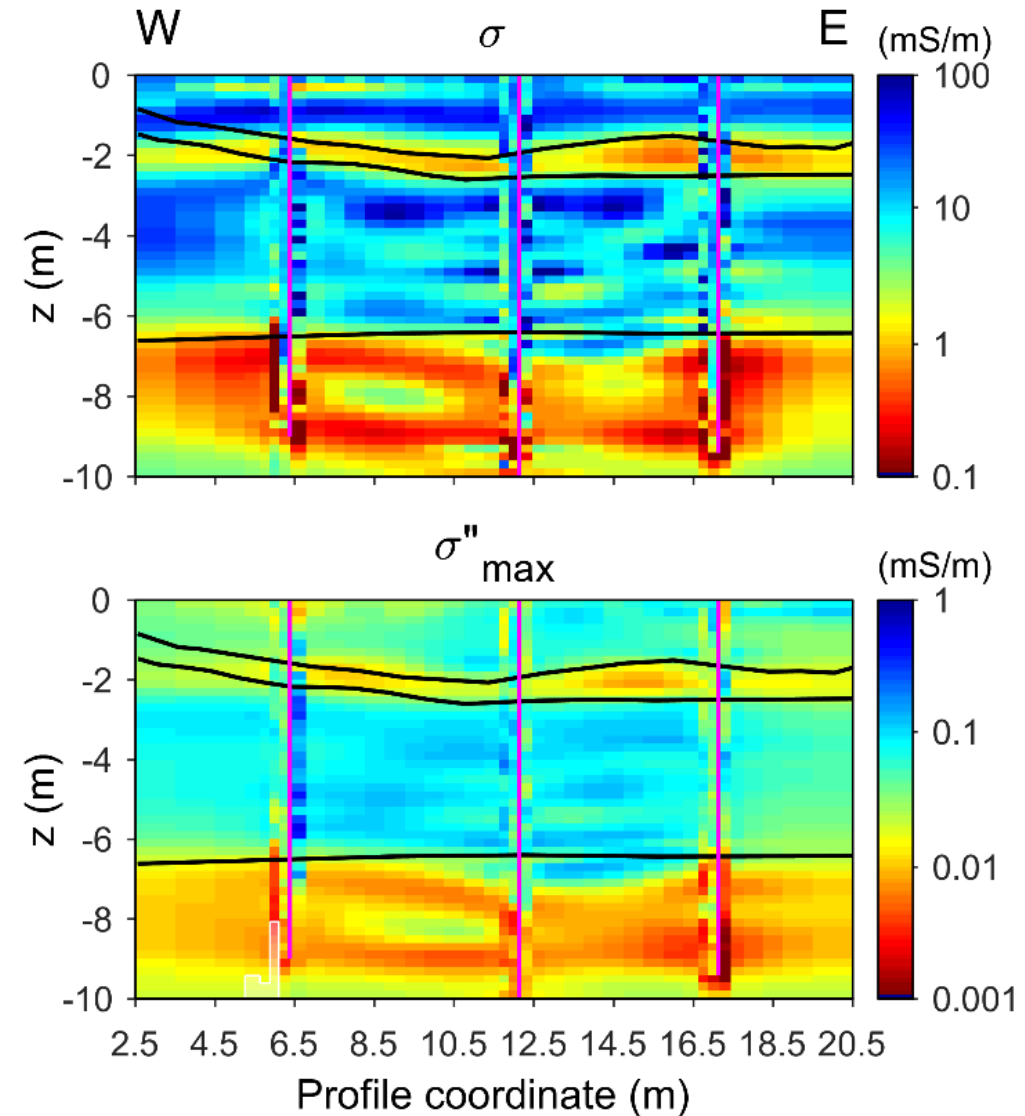
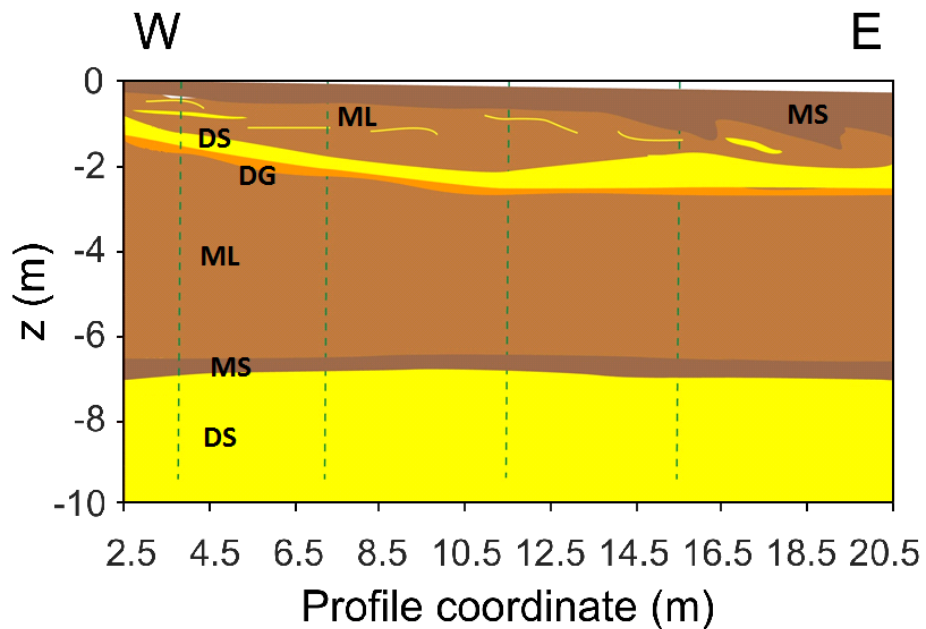


Groundtruthing



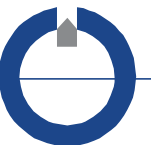
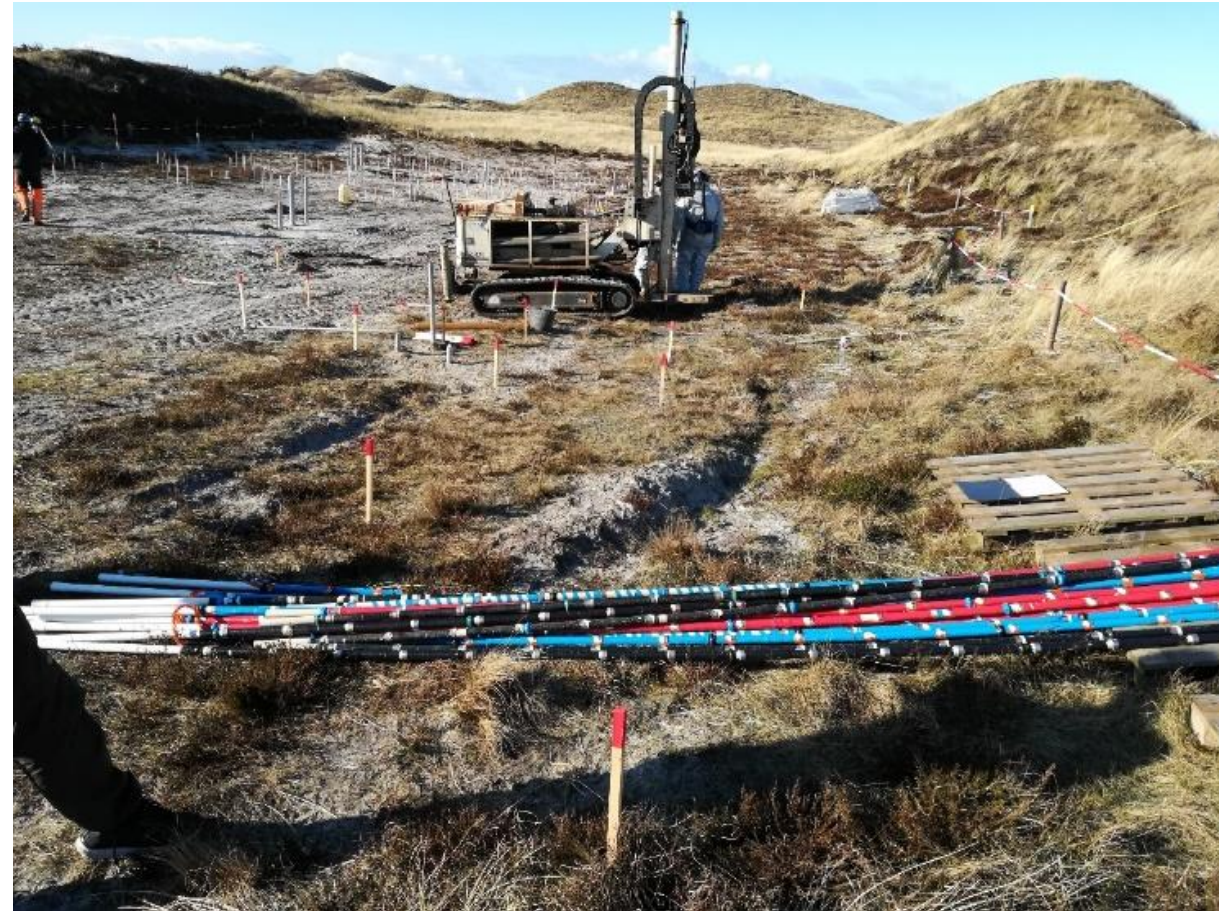
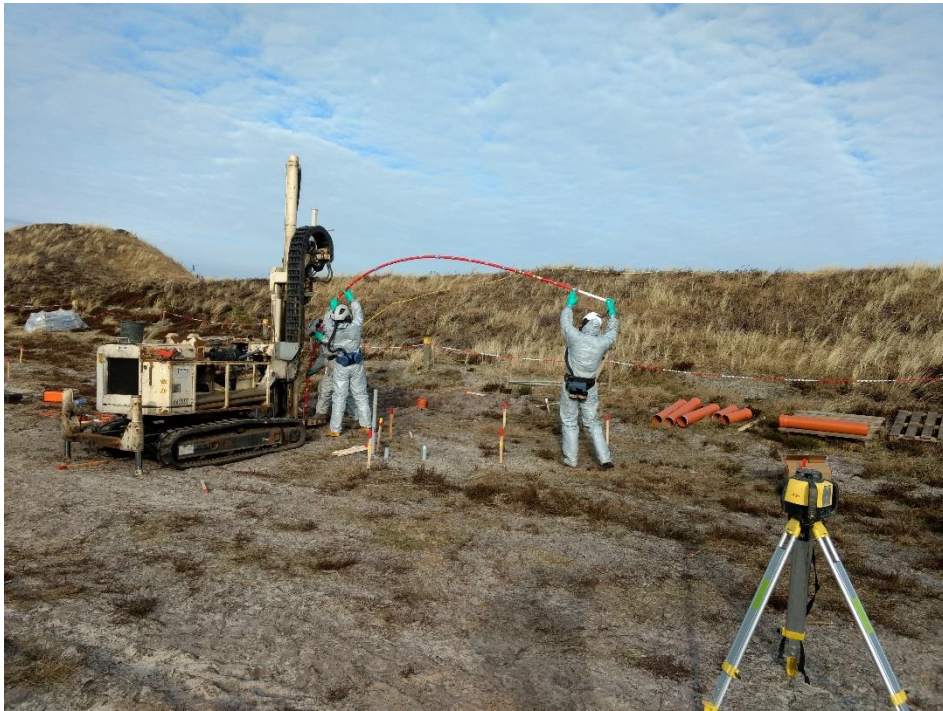
Sandlinse projekt

- **Data inverteret i AarhusInv, MIC model**
 - Maximum imaginary conductivity
- **Stramme laterale bånd, bortset fra modelceller med borehuller**
- **Sandlinsen er ret klart kortlagt**

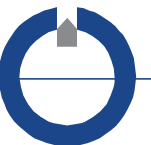


Kærgaard Klitplantage, grube 3

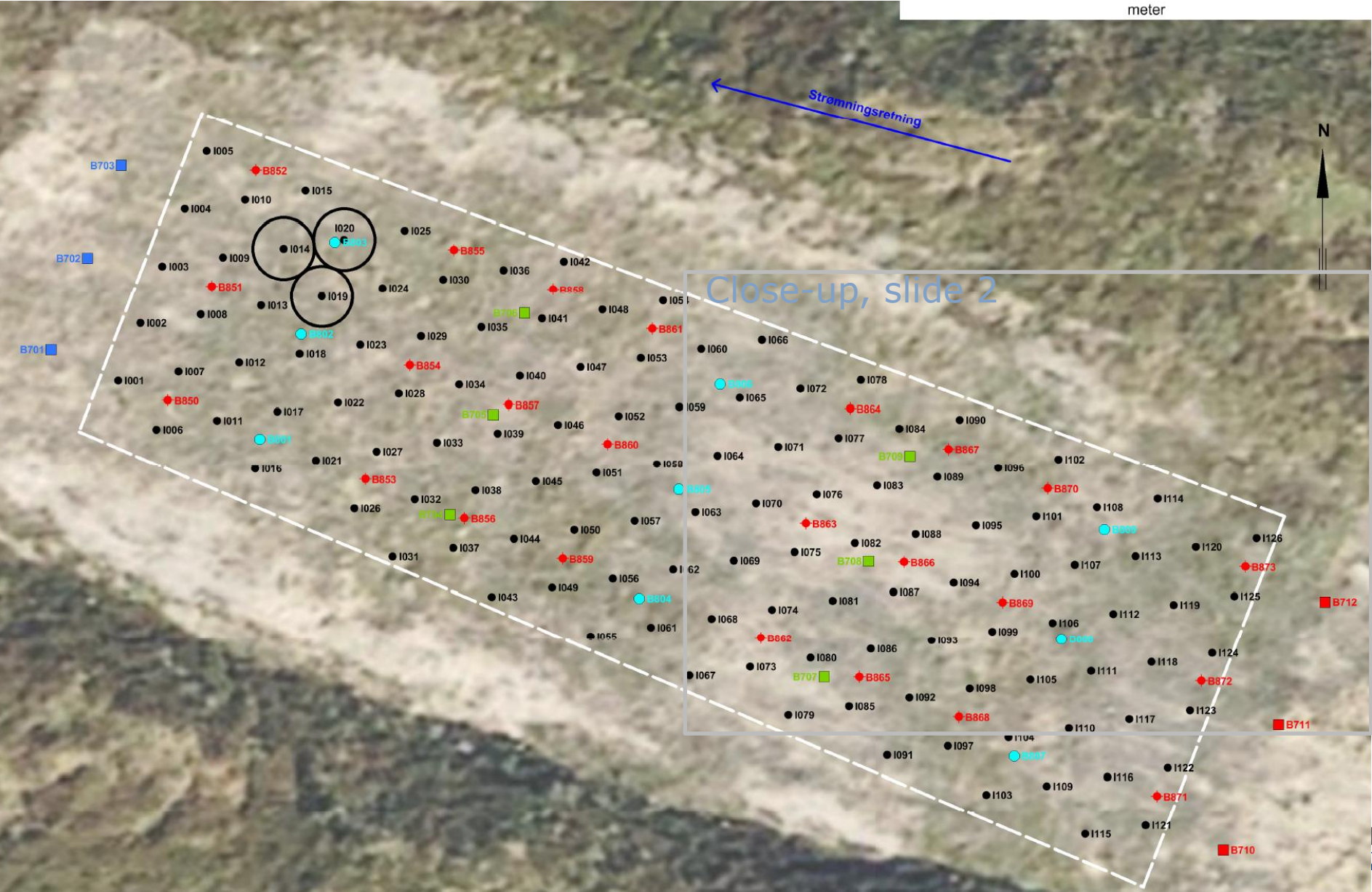
- 10 styk 8 m elektroderør
- 25 cm elektrodeafstand
- Syrefast stål tapet og loddet på rotekrør
- Installeret med Geoprobe, 3,25" hulrør.



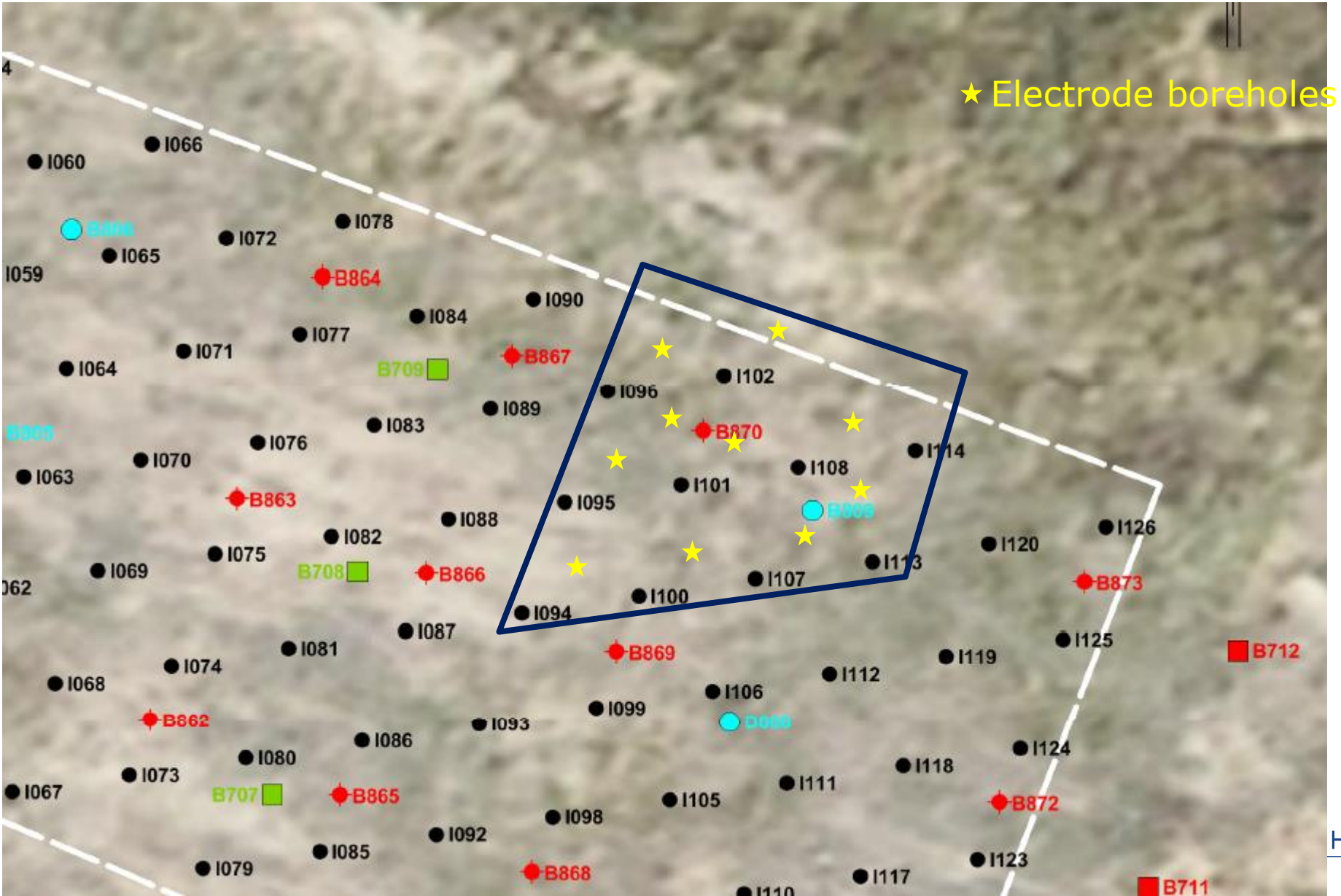
Kærgaard Klitplantage, grube 3



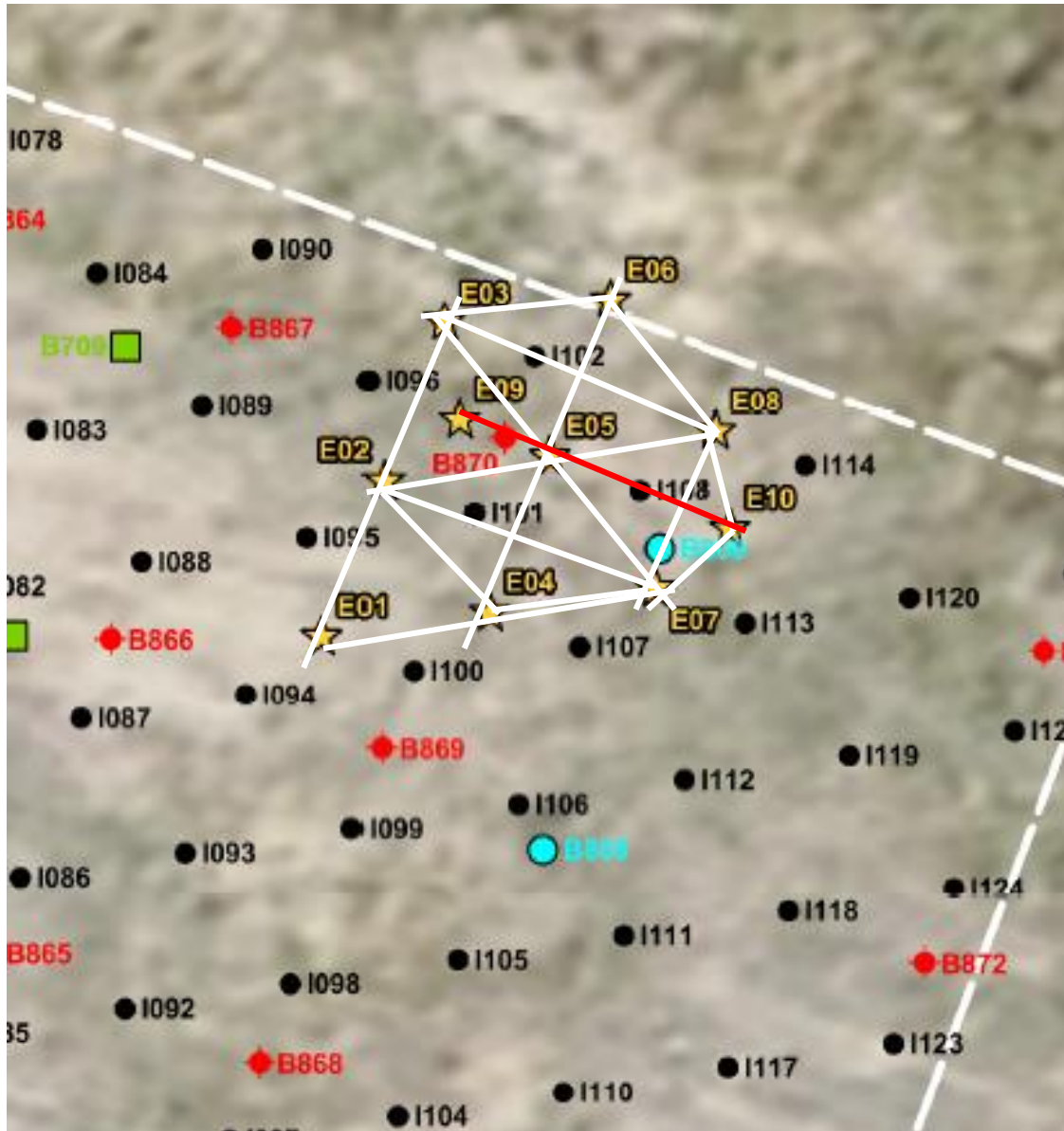
Kærgaard Klitplantage, grube 3



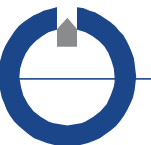
Kærgaard Klitplantage, grube 3



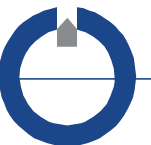
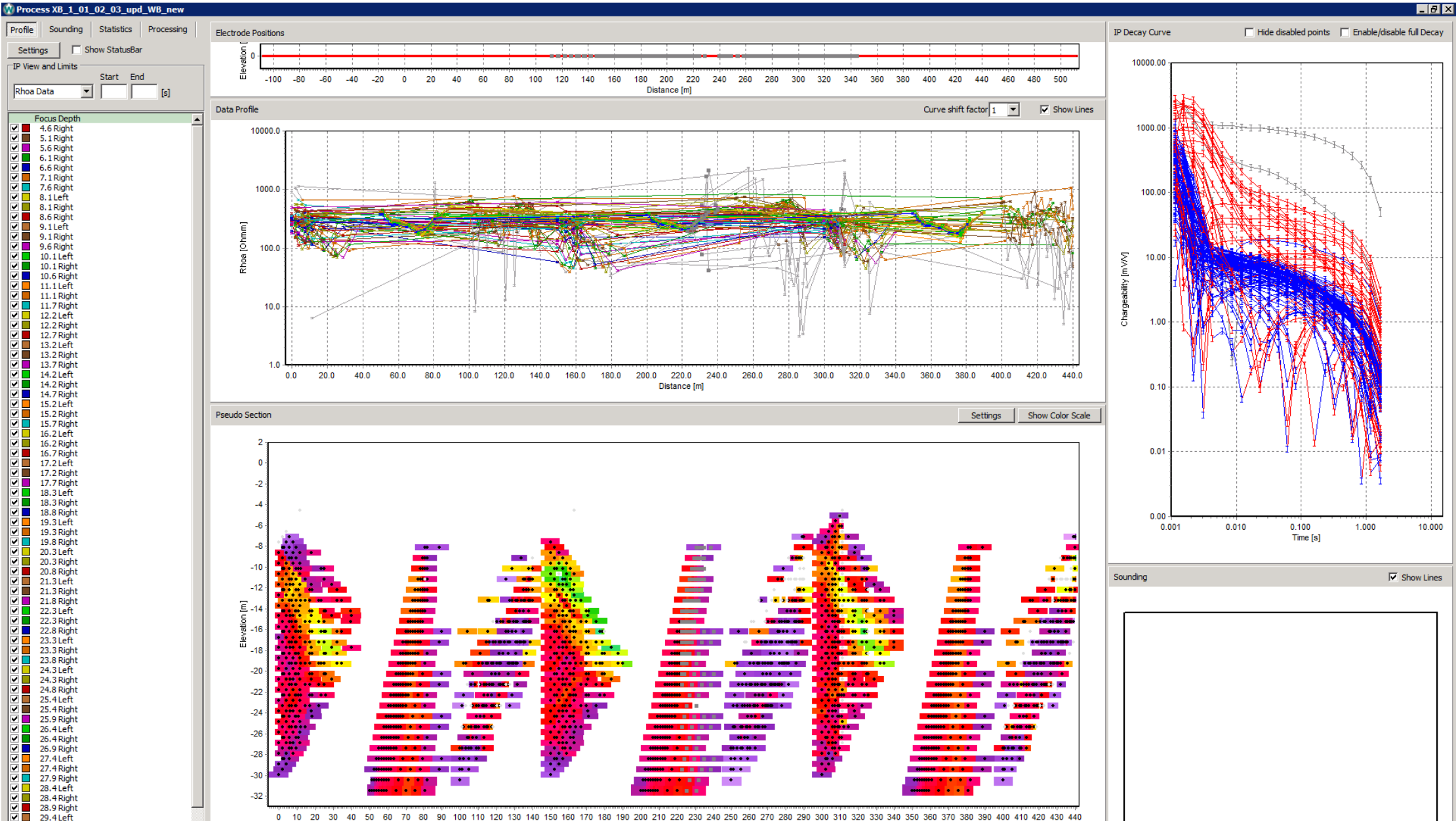
Kærgaard Klitplantage, grube 3



- 1: E01, E02, E03
- 2: E04, E05, E06
- 3: E07, E08, E10
- 4: E01, E04, E07
- 5: E02, E05, E08
- 6: E03, E06, E08
- 7: E02, E04, E07
- 8: E03, E05, E07
- 9: E09, E05, E10



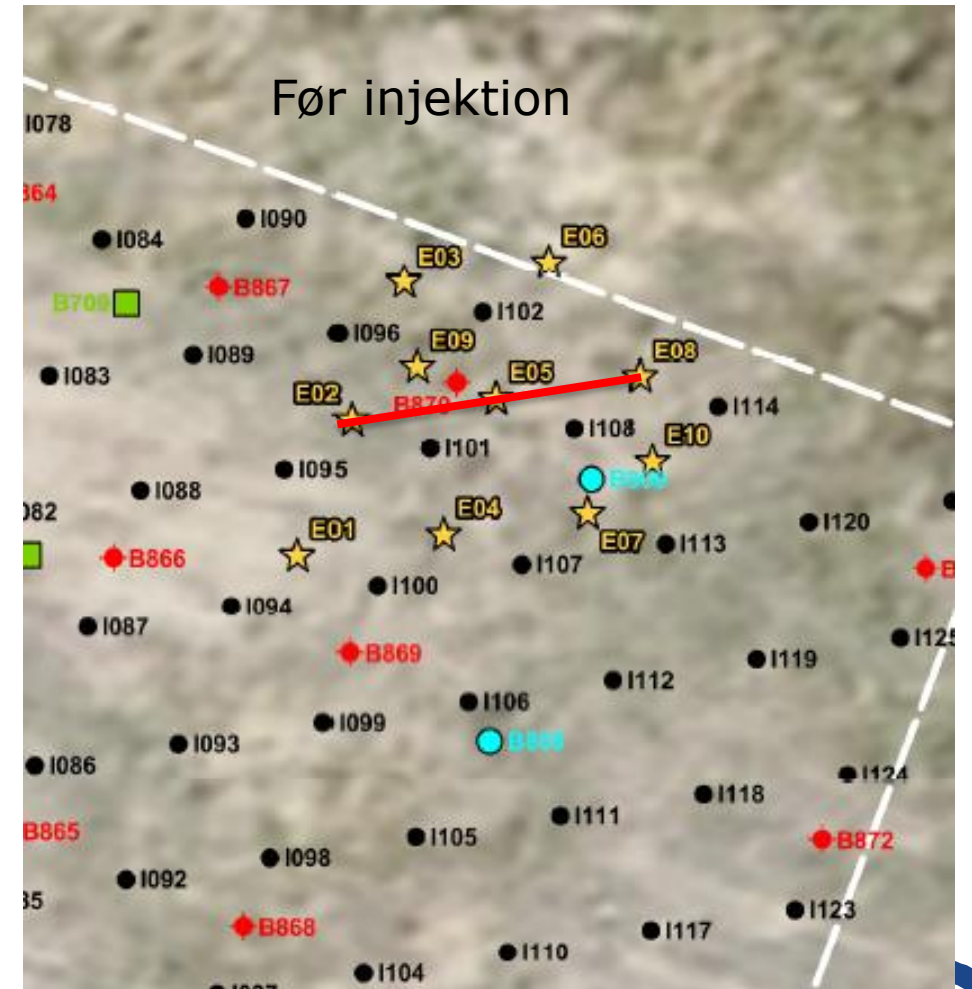
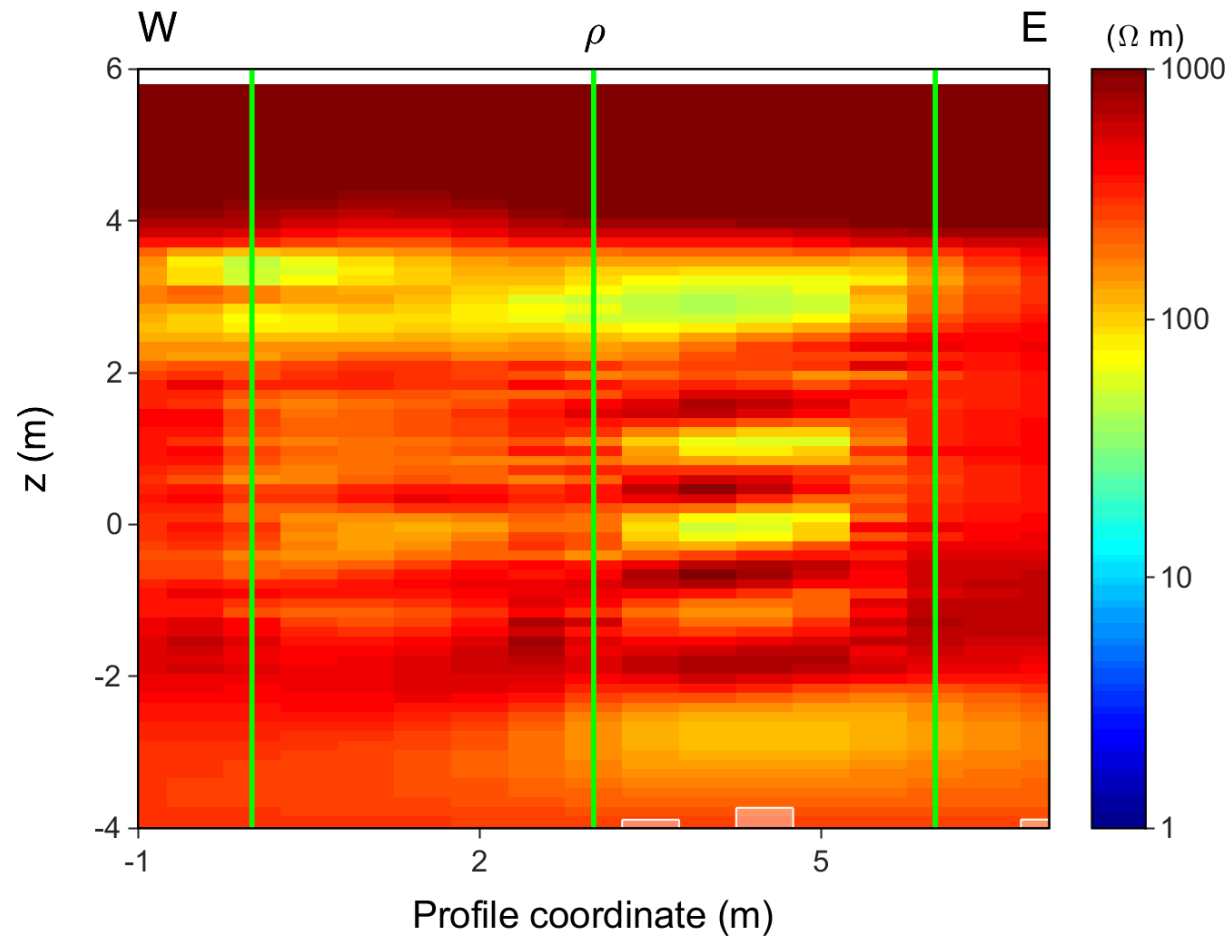
Kærgaard Klitplantage, grube 3



Kærgaard Klitplantage, grube 3

- Resultater

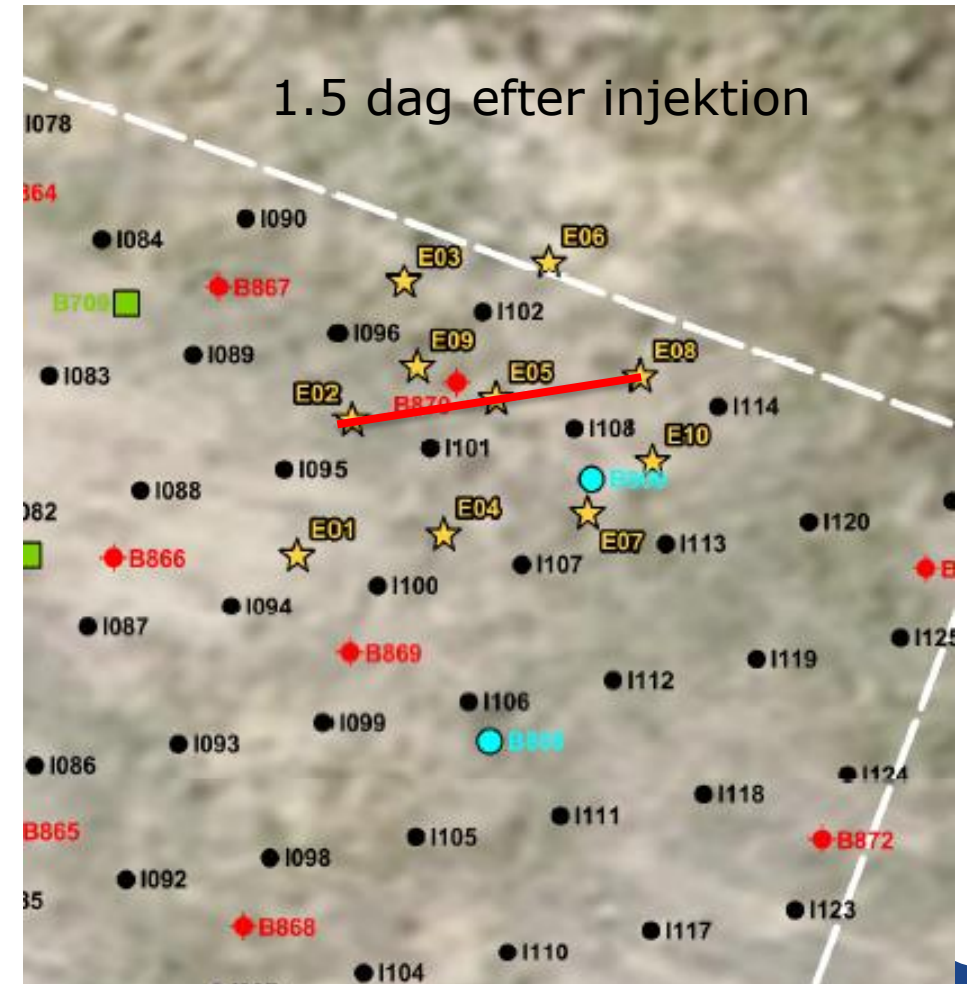
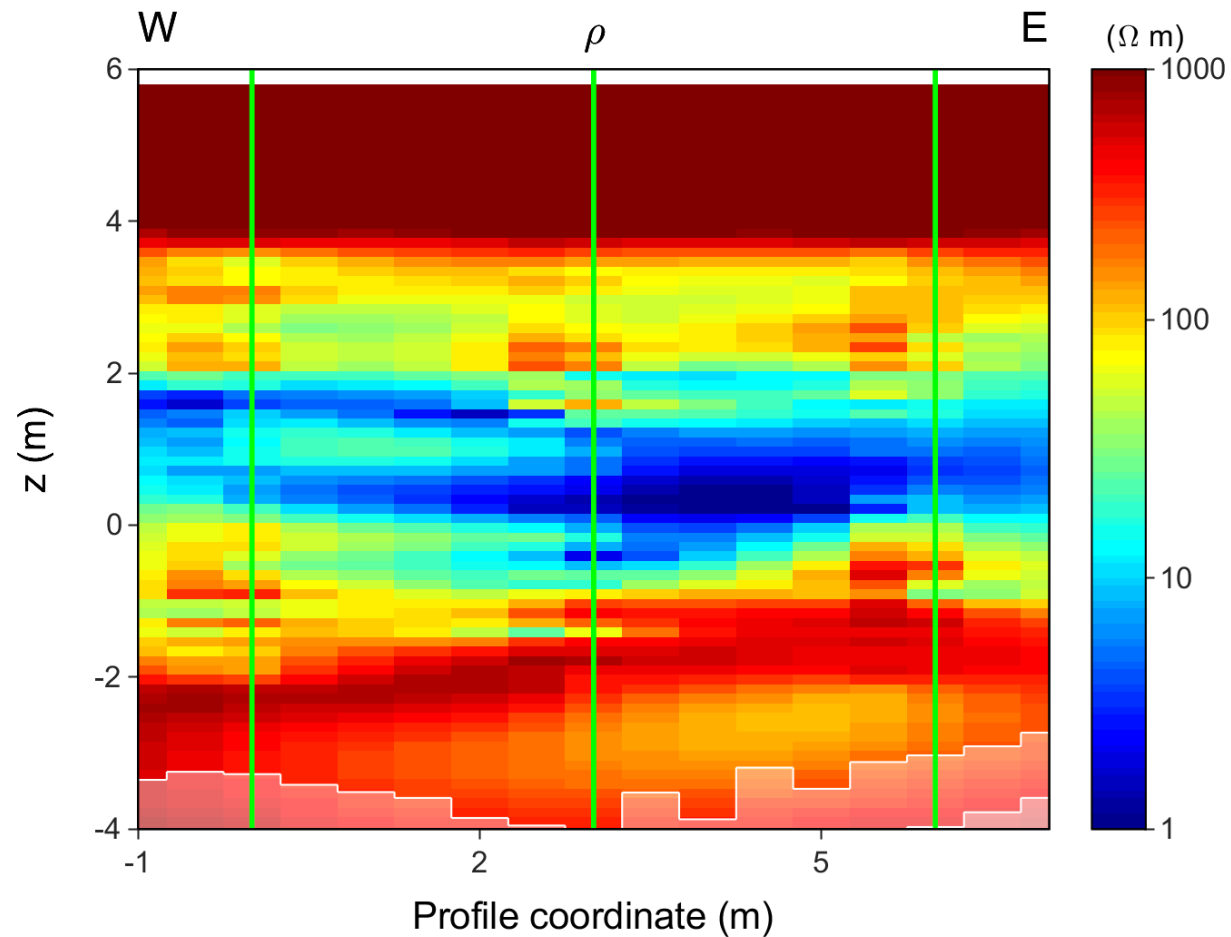
Round 2, E02 - E05 - E08



Kærgaard Klitplantage, grube 3

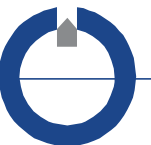
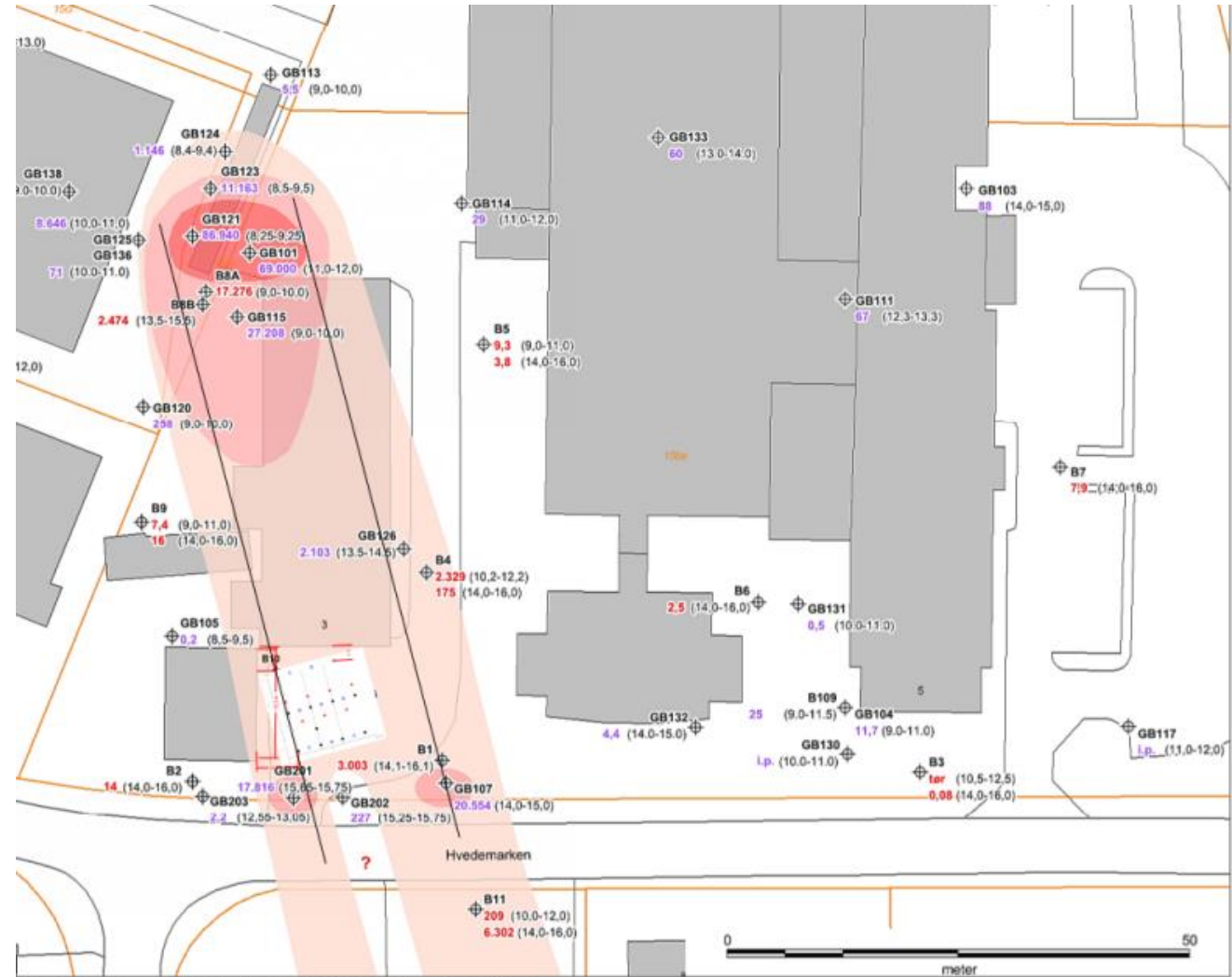
- Resultater

Round 3, E02 - E05 - E08



Hvedemarken, Farum

- 9 styk 20 m elektroderør
- 30 cm elektrodeafstand, (11-20 m)
- Installeret i PRB



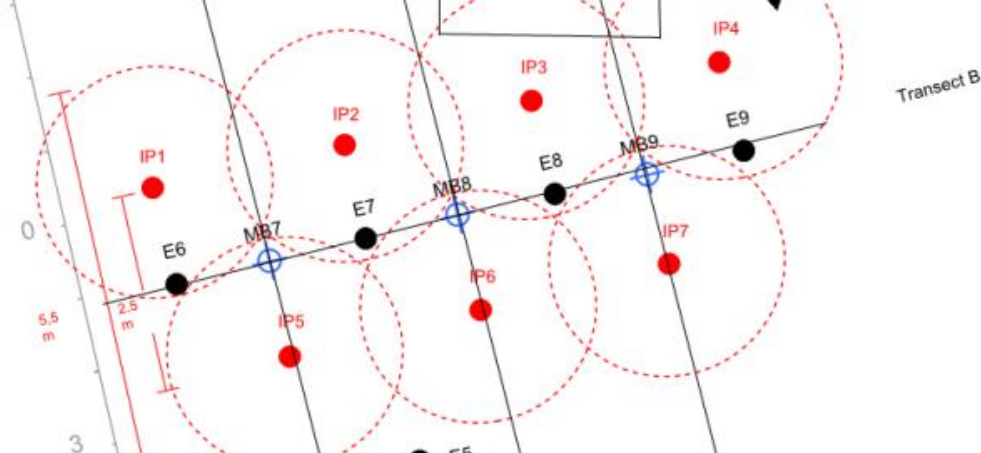
Hvedemarken, Farum

- Data indsamling

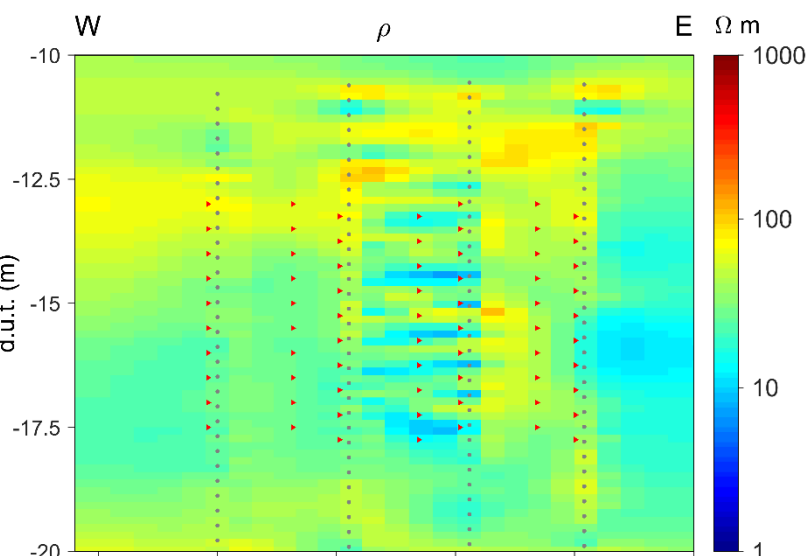


Hvedemarken, Farum

- Foreløbige resultater

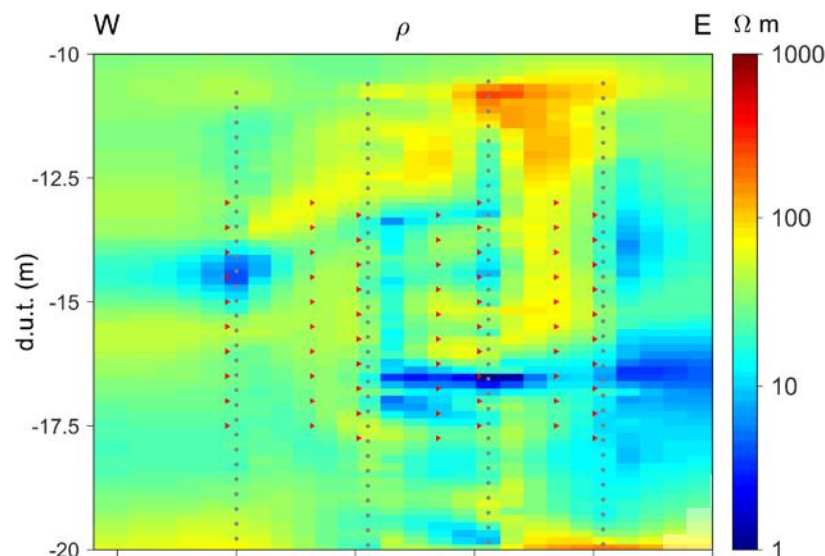


E6789 R1



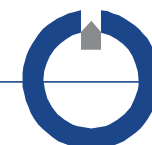
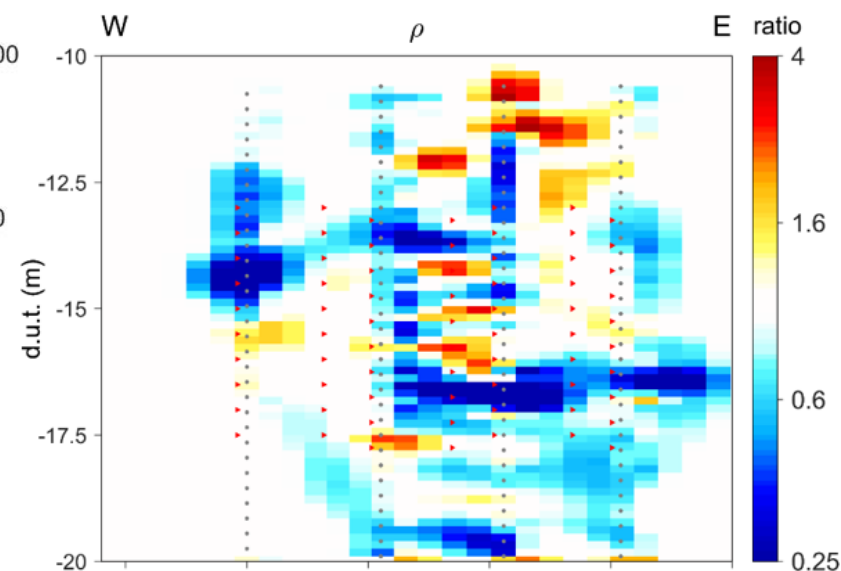
Før injektion

E6789 R4



Efter injektion

E6789 R4

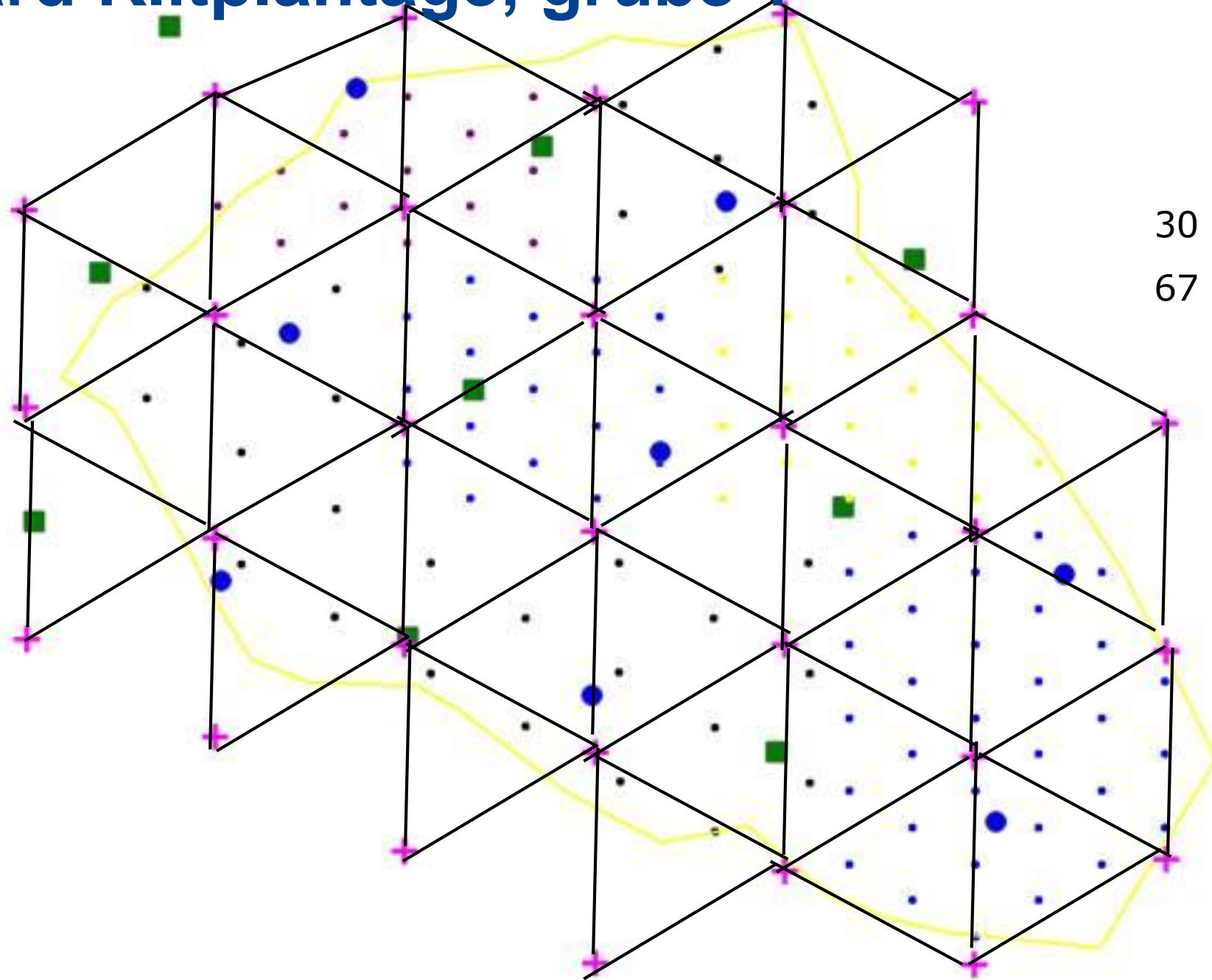


Kærgaard Klitplantage, grube 1

- 30 styk 8 m elektroderør



Kærgaard Klitplantage, grube 1

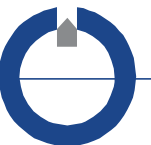


30 borehuller
67 linjestykker



Kærgaard Klitplantage, grube 1

- 30 styk 8 m elektroderør



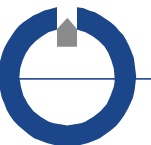
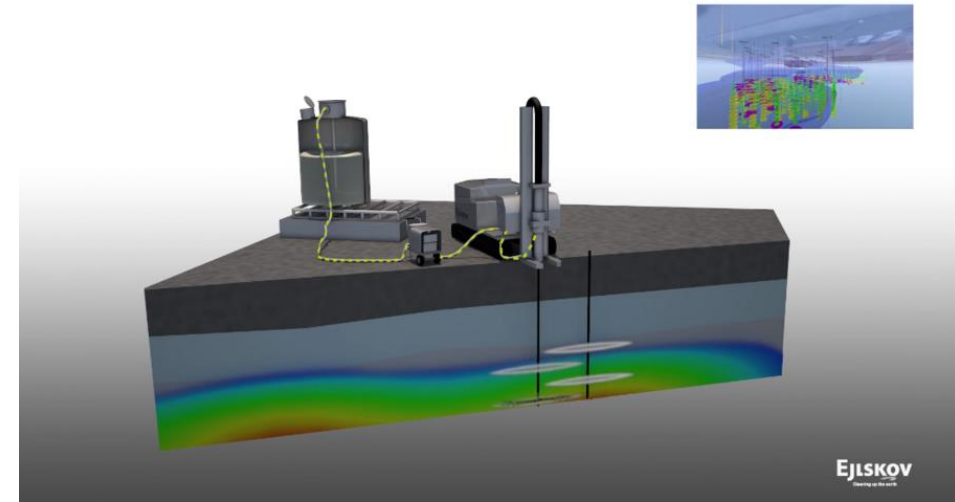
GIREM 2018-2022

- **Innovationsfond projekt**
- **Partnerskab med Ejlskov**
 - Udvikling af elektroderør
 - Injektionsmetodik

- **Instrumentudvikling**
 - Nye sendere og modtagere
 - Hurtigere og mere effektiv dataindsamling

- **Automatisk data processering**
 - Neurale netværk

- **3D DCIP AarhusInv**
 - Giver et 3D billede



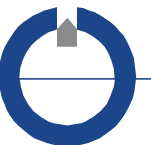
Lessons learned

- **Resultater**

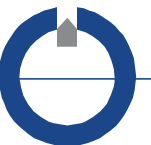
- Meget bedre opløsning end overflade målinger.
- Meget velegnet til time-lapse monitorering
- Kan med fordel bruges til at kortlægge konduktive injektionsvæsker
 - Men påvirker IP data kvaliteten negativt.

- **Udfordringer**

- God elektrode kontakt er kritisk, svært over gvs
- Konstruktion/installation af elektroderør: tidskrævende og omstændigt
- Meget store datamængder
- Processering af data mere komplekst end overflade data
- Inversion kan være hukommelsestungt (>100GB RAM)



Spørgsmål?



Fremtiden

- **3D DCIP AarhusInv**
 - Giver et 3D billede

- **Nye instrumenter**
 - Hurtigere og mere effektiv dataindsamling

- **Automatisk data processing**
 - Machine learning

