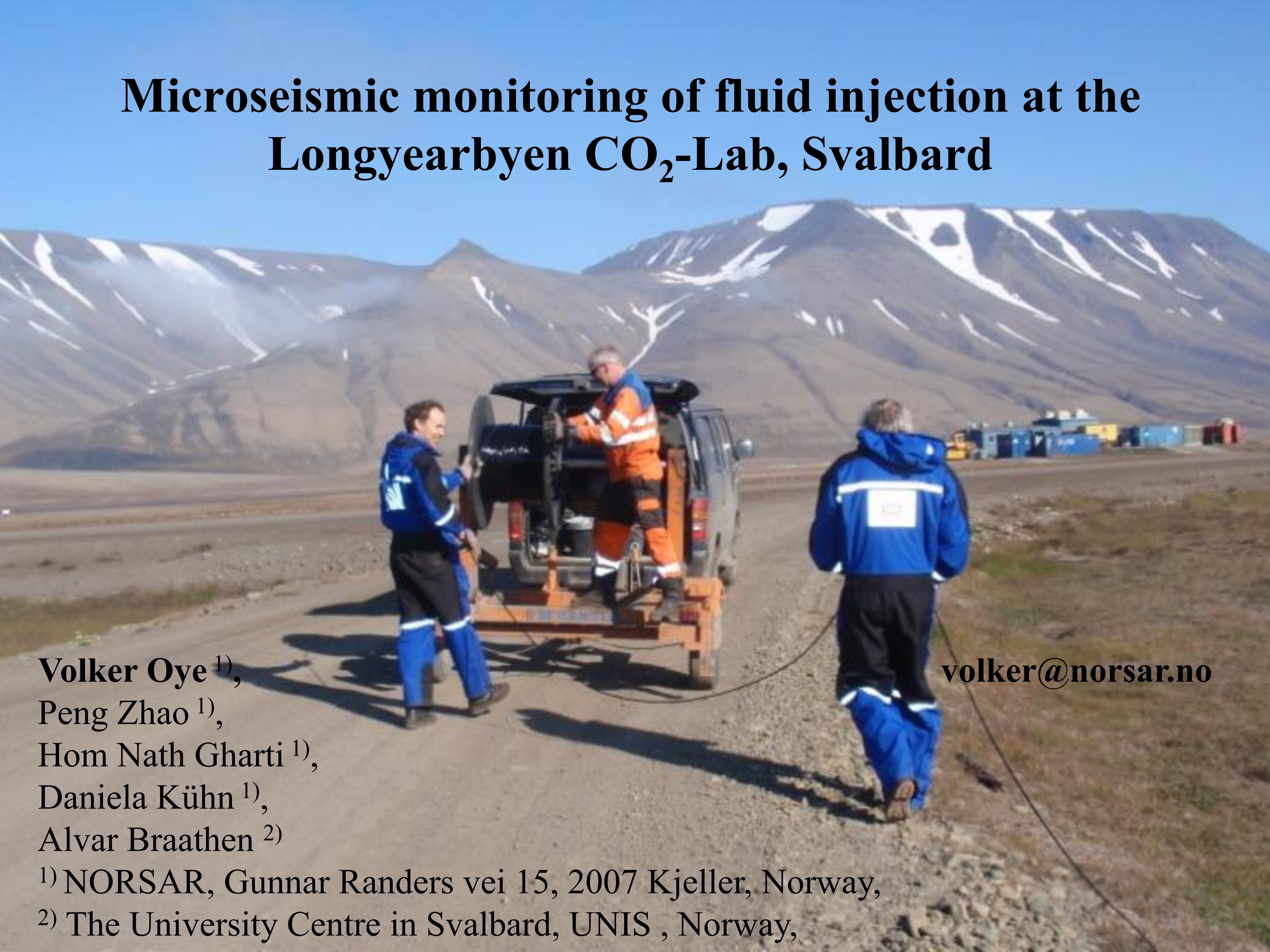
Microseismic monitoring of fluid injection at the Longyearbyen CO_2-Lab, Svalbard



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W130°
W150°
W170°
Antimeridian
W110°
E170°
W 90°
E150°
W 70°
E130°
W 50°
E110°
W 30°
N70°
E 90°
Polarsirkelen
W 10°
E 70°
Hovedmeridian
E 10°
E 50°
E 30°
N50°
N30°

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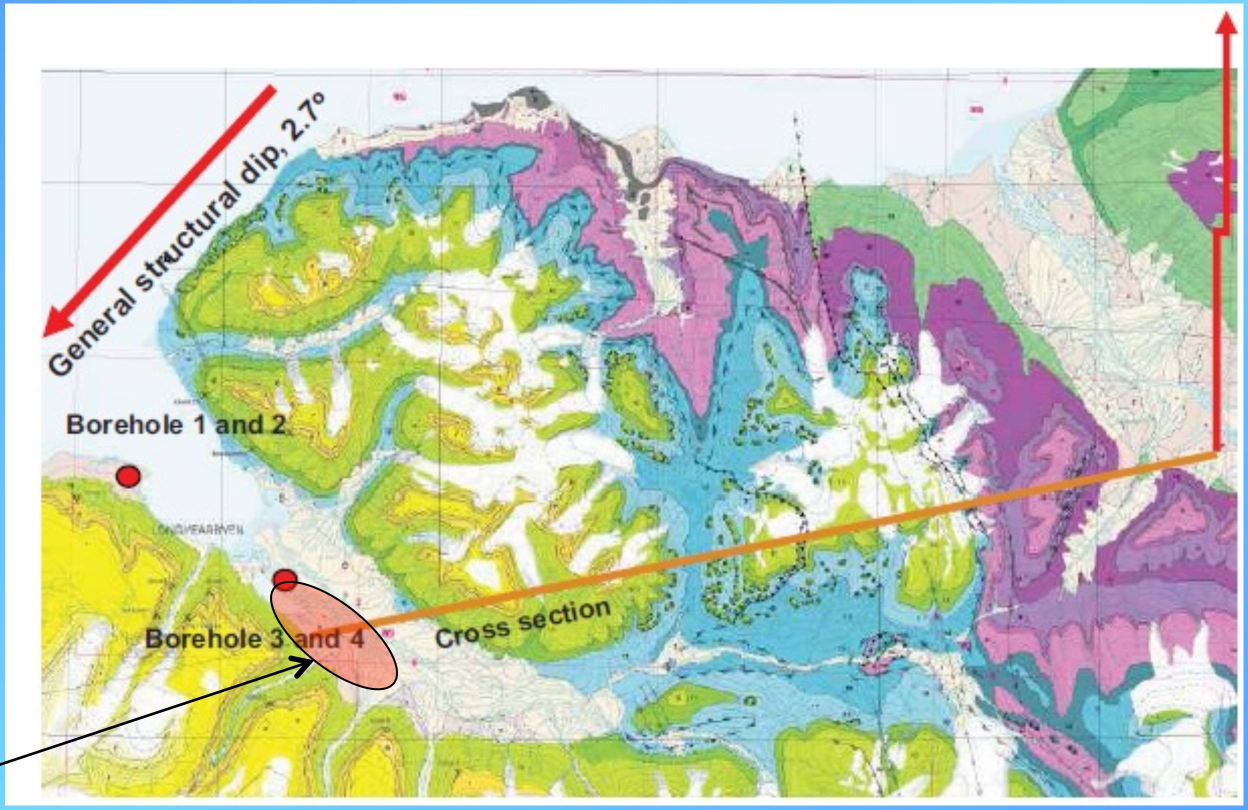
CO2LAB project

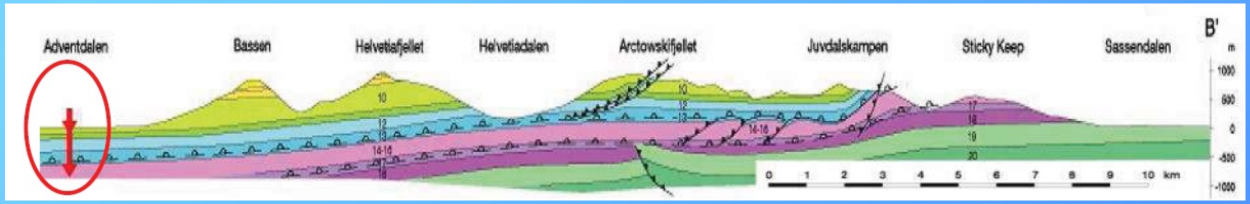
Project goals

The CO2LAB project has investigated that a sealing cap rock section exists around Longyearbyen, and it will proceed towards demonstration and monitoring studies of sub surface CO_2 storage over time. NORSAR's involvement in this project contains 3 main topics about:

1. Establish and improve the microseismic network in order to locate and improve microseismic event locations
2. compute changes of stress fields resulting from variations in the geometry and rock properties of the CO_2 storage
3. model changes in 4-D seismic response due to CO_2 injection/ propagation, i.e. model pre-stack depth migrated sections

Geological map of the Longyearbyen region





Area of installed microseismic network

Station network at Longyearbyen, Svalbard

Nordlysstasjon
GEODE central digitizer, PC, internet
Automatic FTP of data to NORSAR
Data processing at NORSAR

SH2

North
(sketch only,
not to scale)

Injection well

DH3, cable with 5 3C-geophones
Depth 94, 144, 194, 244, 294m
below surface

SH1, SH2, SH3:
One 3C geophone at ~12m
depth, distance to
Nordlysstatsjon ~500m

SH3

SH1

Nordlysstasjonen

Installation 5-level 3C geophone string in deep borehole (94 to 294 m depth, 50m distance)

Installation 5-level 3C geophone string in deep borehole (94 to 294 m depth, 50m distance)

Installation of single 3C geophones in shallow borehole stations (12m deep)

Installation at SH3

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Installation at SH1

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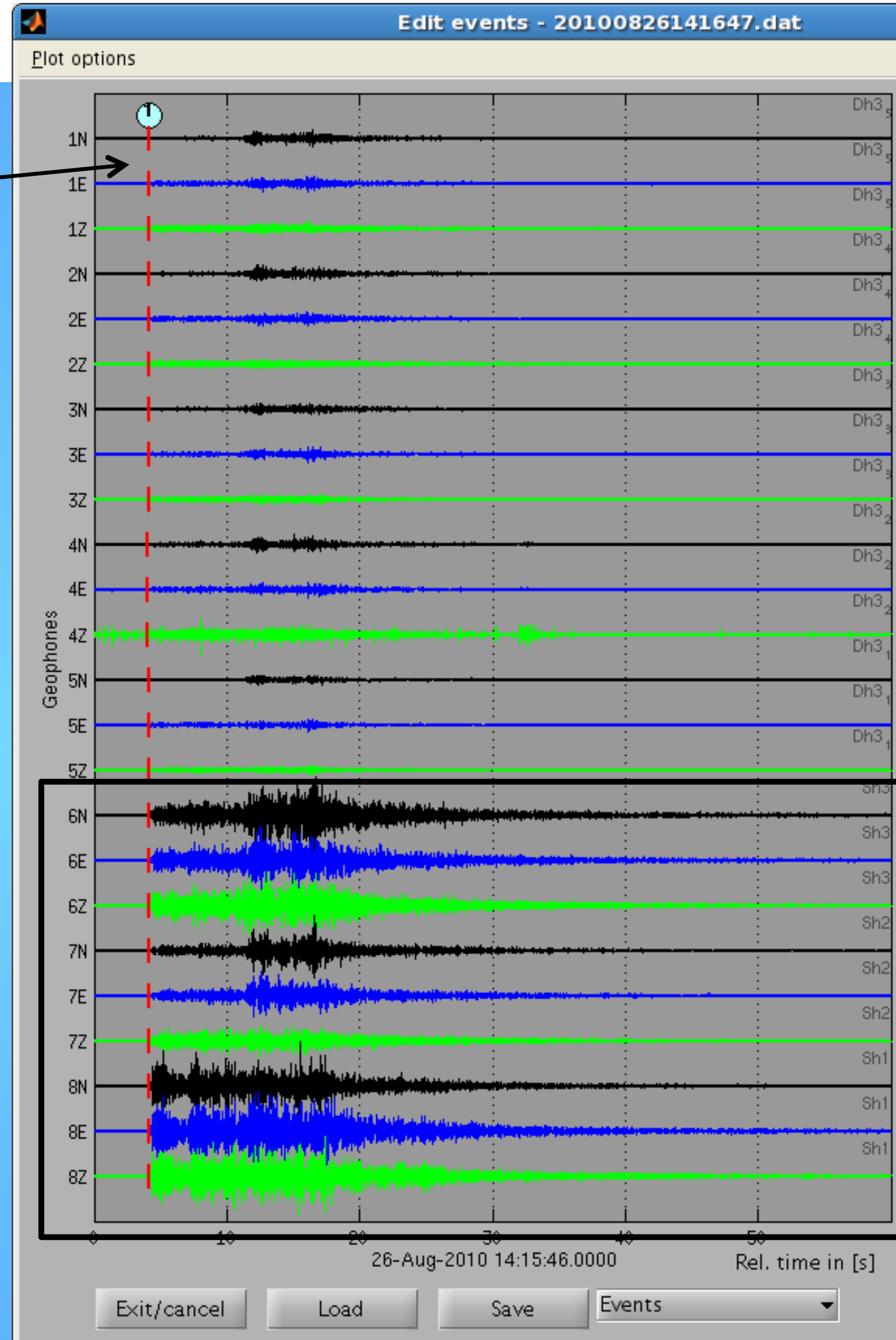
P-wave of earthquake from Storfjorden

In principle, the polarization of the earthquakes can be used to orient downhole sensors. However, it is difficult due to energy at low frequencies. We used also local events to get more consistency within geophone levels.



294m

244m

194m

144m

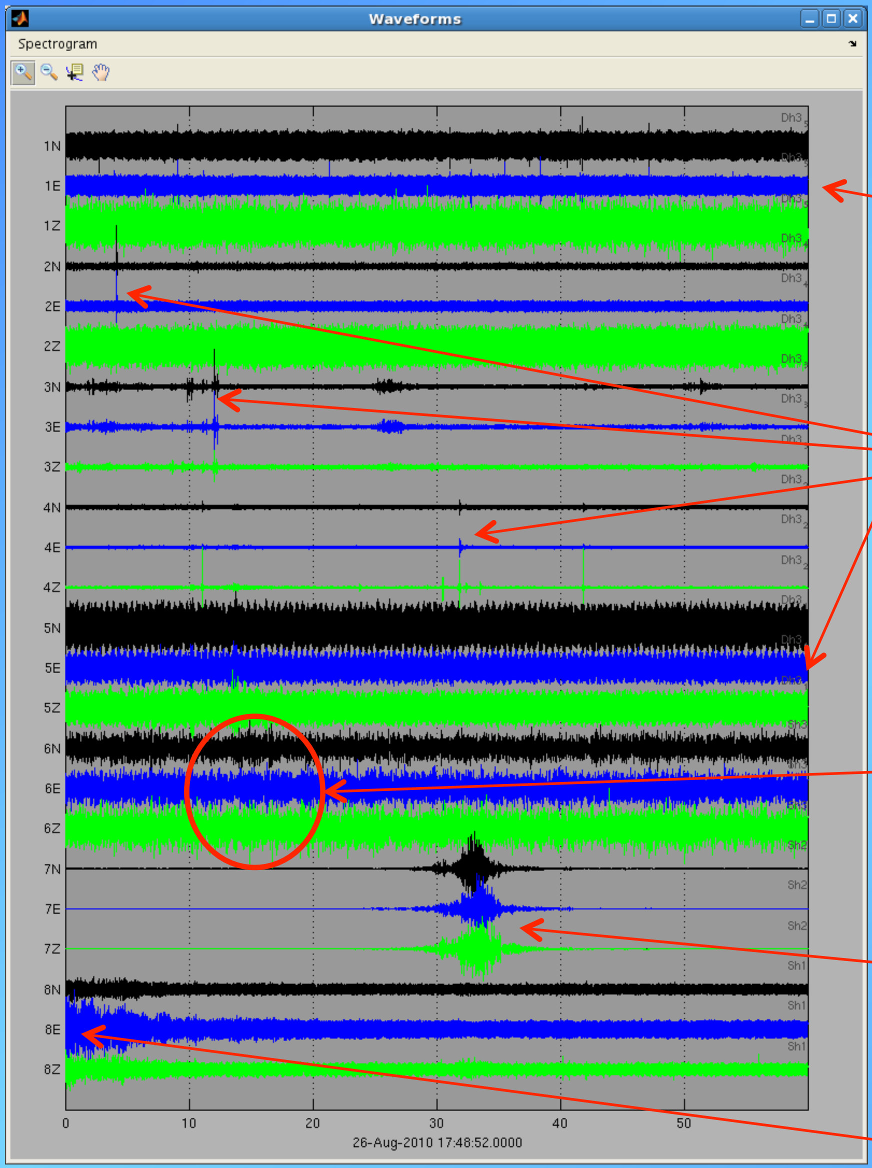
94m

SH3

SH2

SH1

Some typical recordings



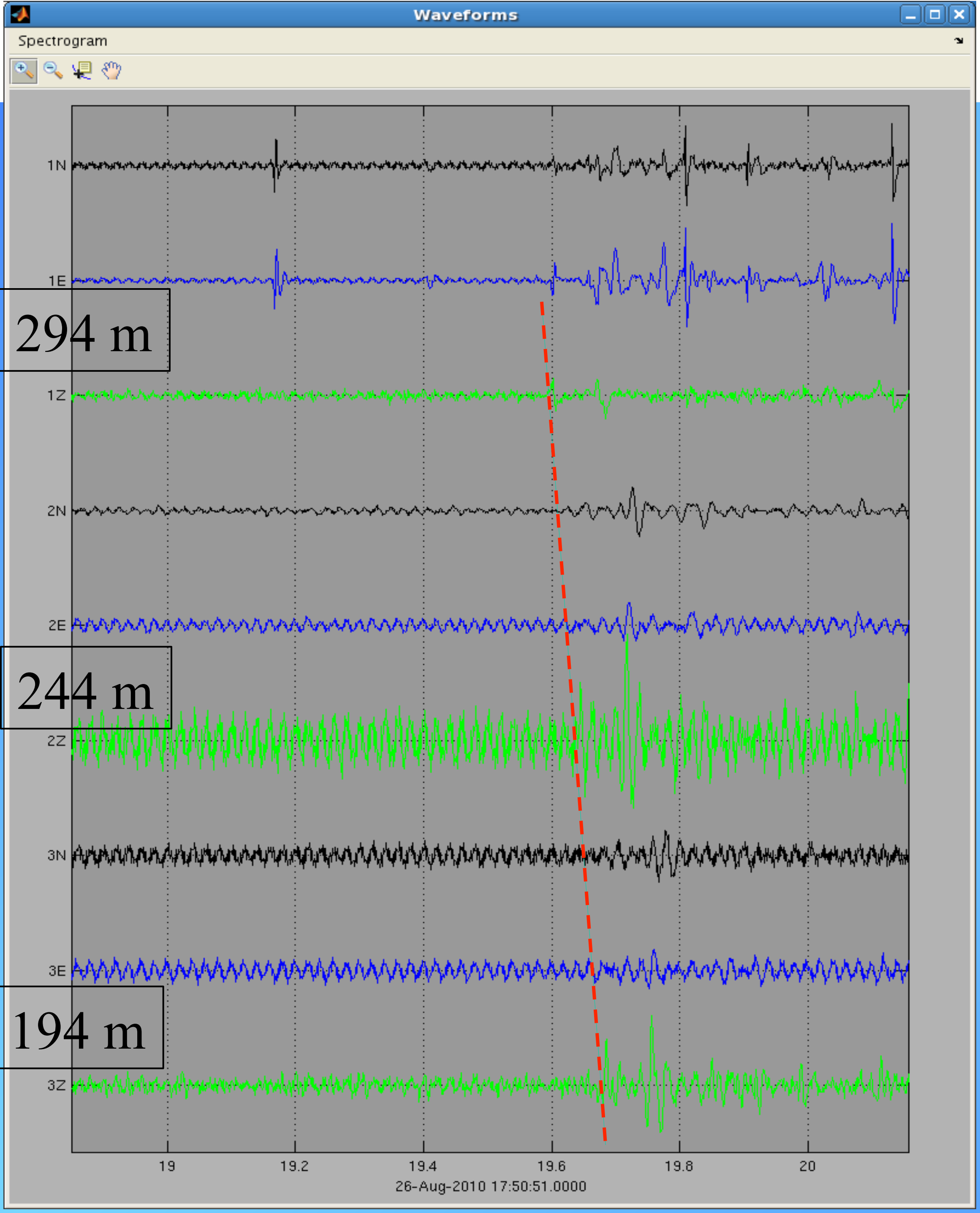
L5 and L1 are very quite, only constant background noise

L2 L3 and L4 show some spikes with local noise that peaks far above the constant background noise

Car driving by station SH3, too far a

Car driving by station SH2

Car drove by station SH1



Many automatic detections (about 1000/day) with apparent velocity of ~1000 m/s, only visible on the deepest 3 sensors, coming from depth.

Mud waves along the open hole section?

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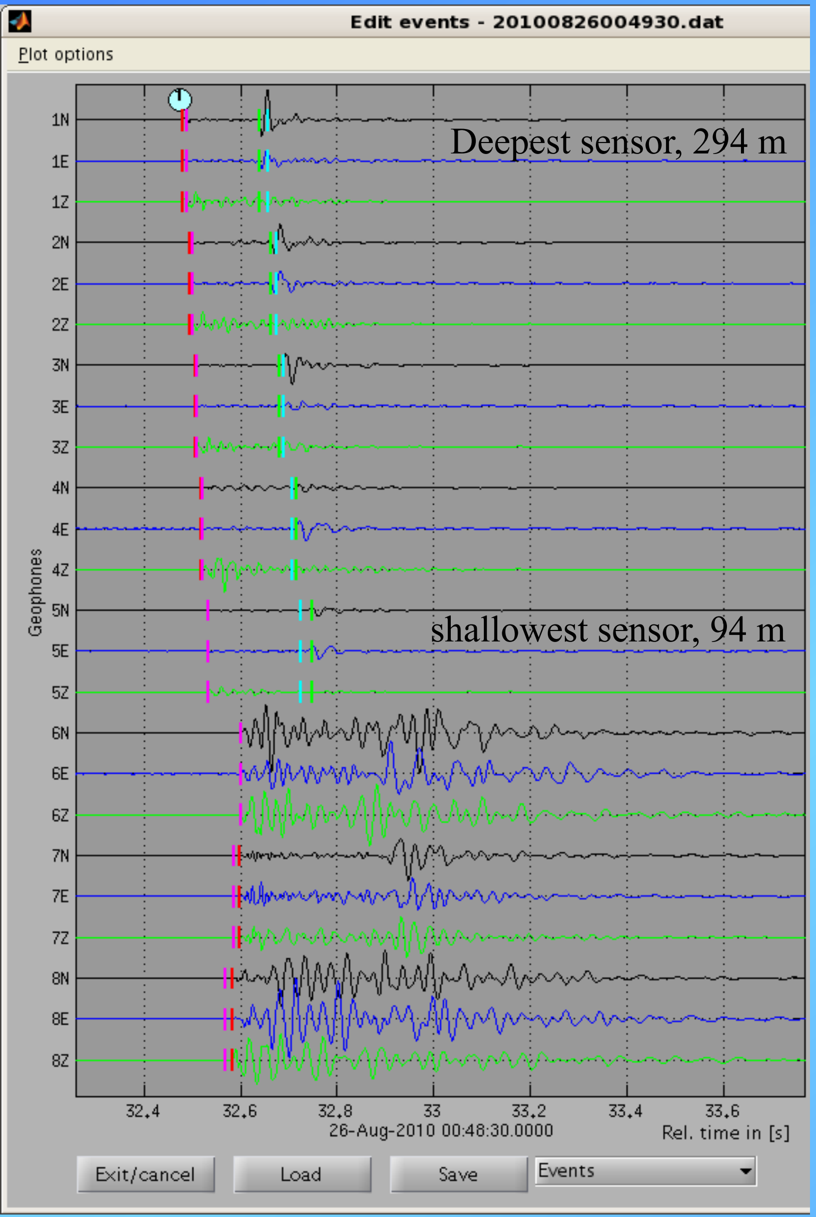
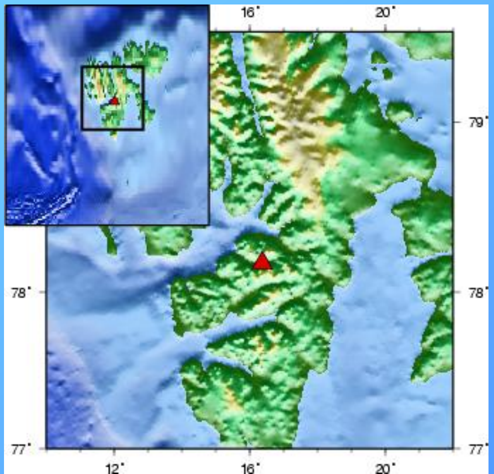
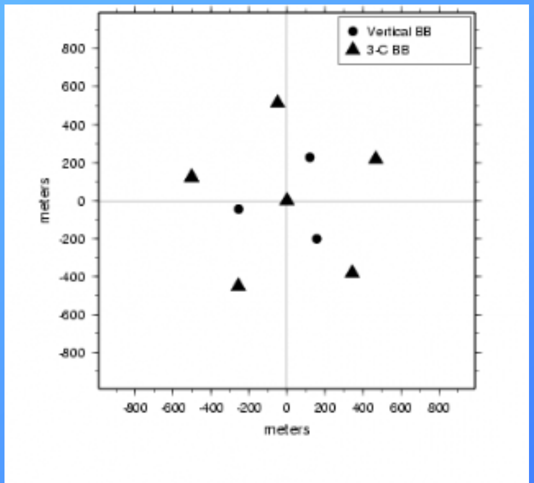


Event on 26th August at 00:49 GMT

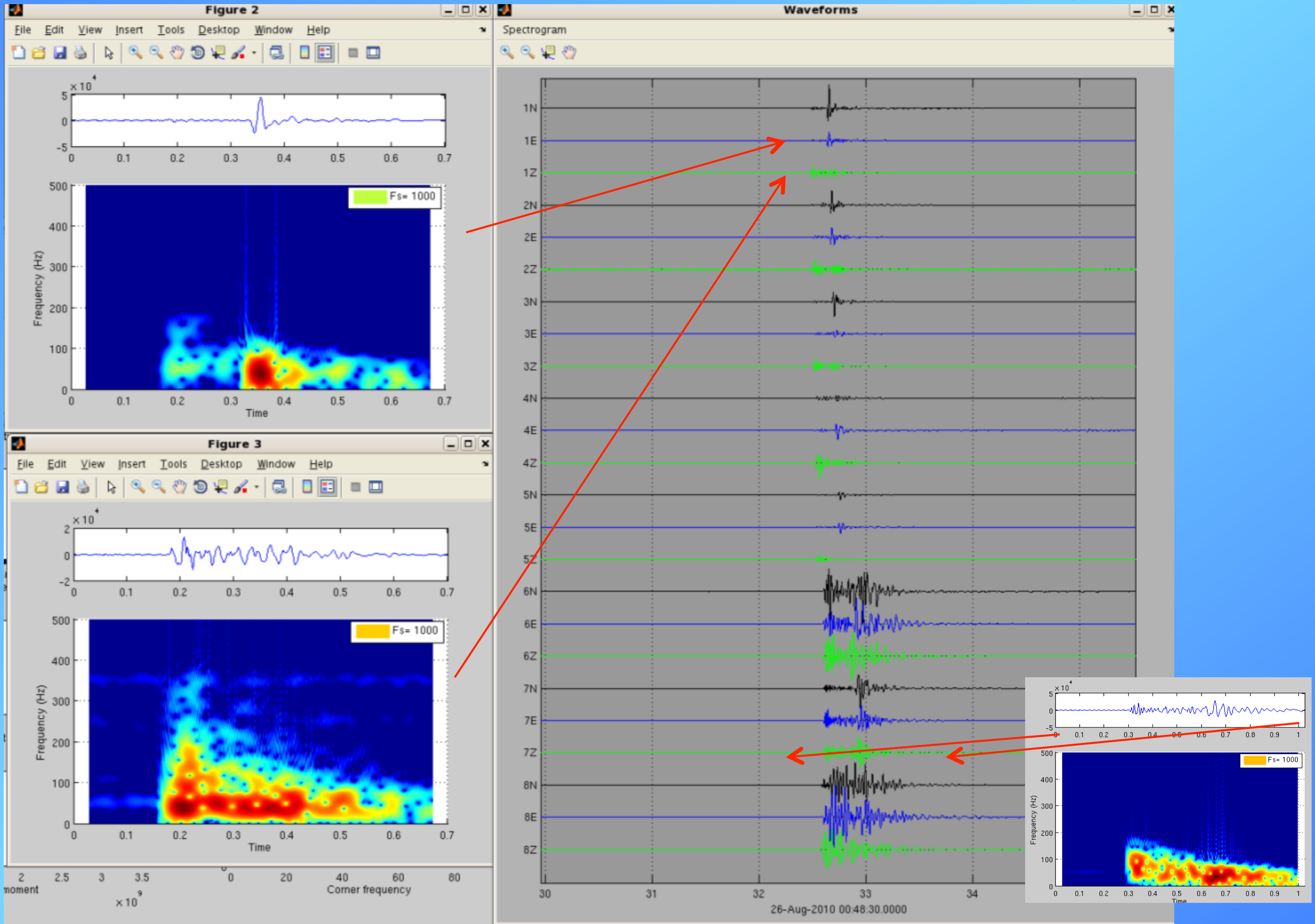
(26th 2:49 local time)

- strongest local event located so far, clearly seen on all stations, signal is far above noise-level.
- P and S phases can be clearly identified at downhole string, on shallow borehole stations P-wave arrivals are clear, but S-wave arrivals remain more difficult.
- location trade-off between depth and spatial position (direction North-East).
- signals are also found on all stations of NORSAR's array SPITS, about 12 km east of the injection site – will help to confine the location!

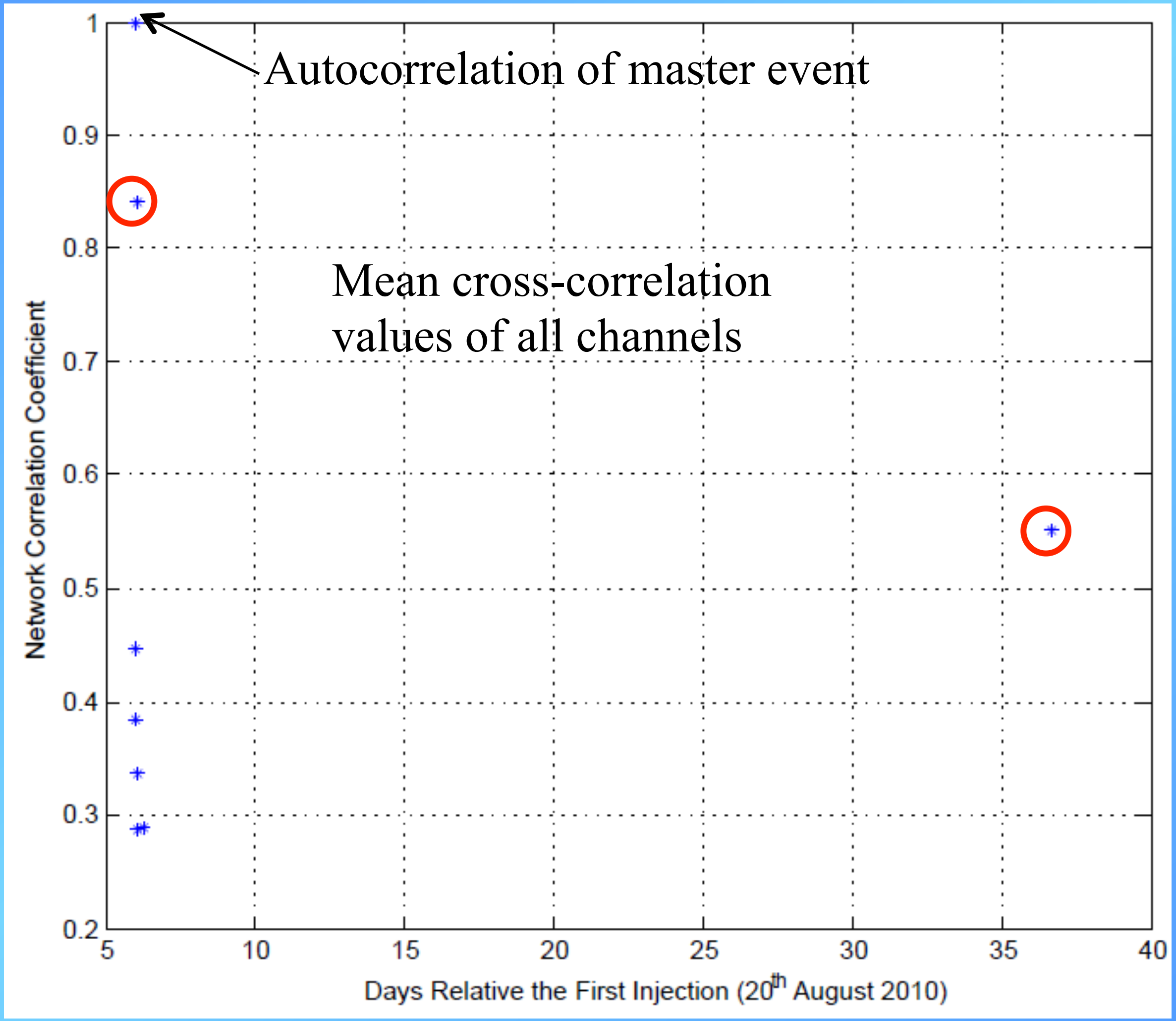




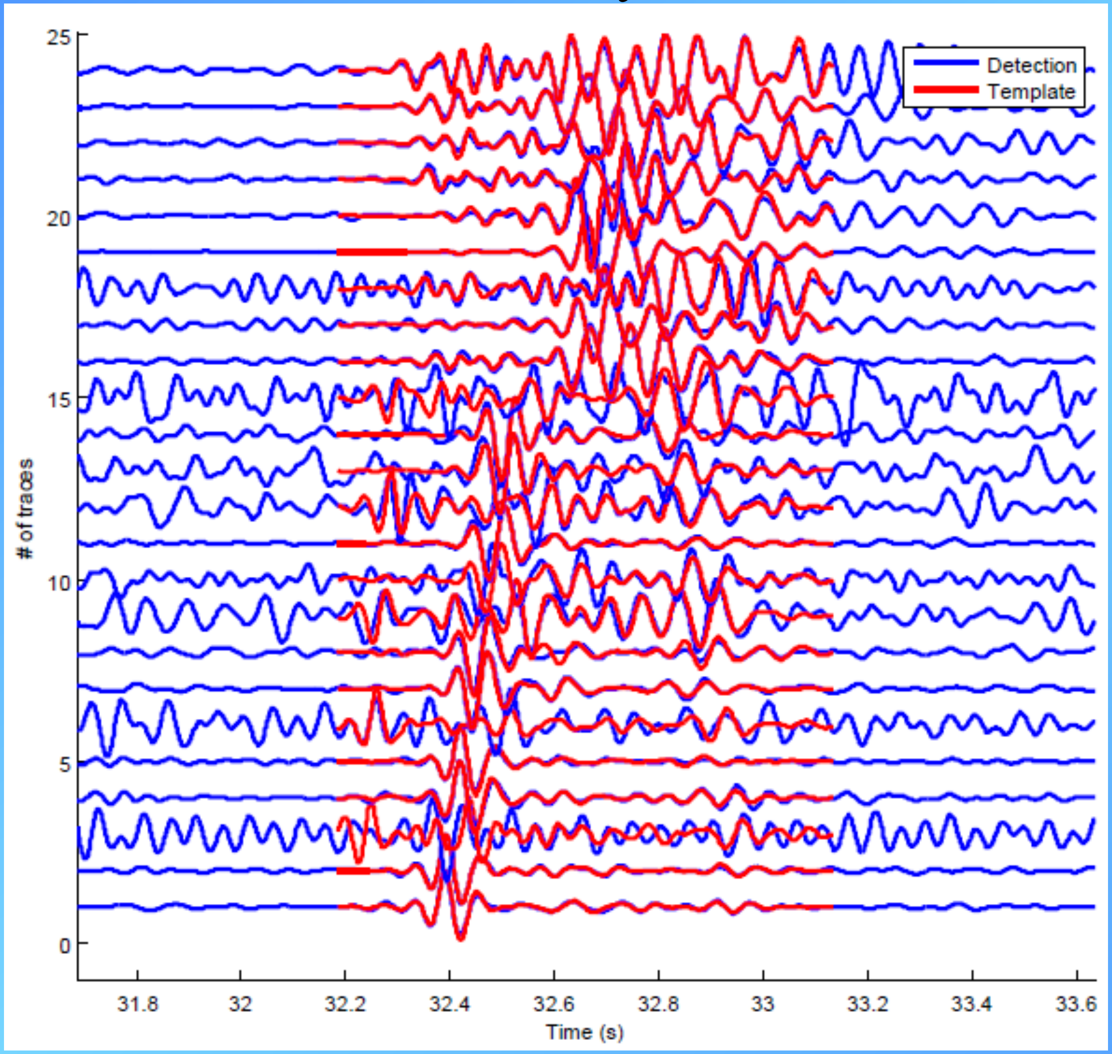
Event on 26th August at 00:49 GMT; spectrograms



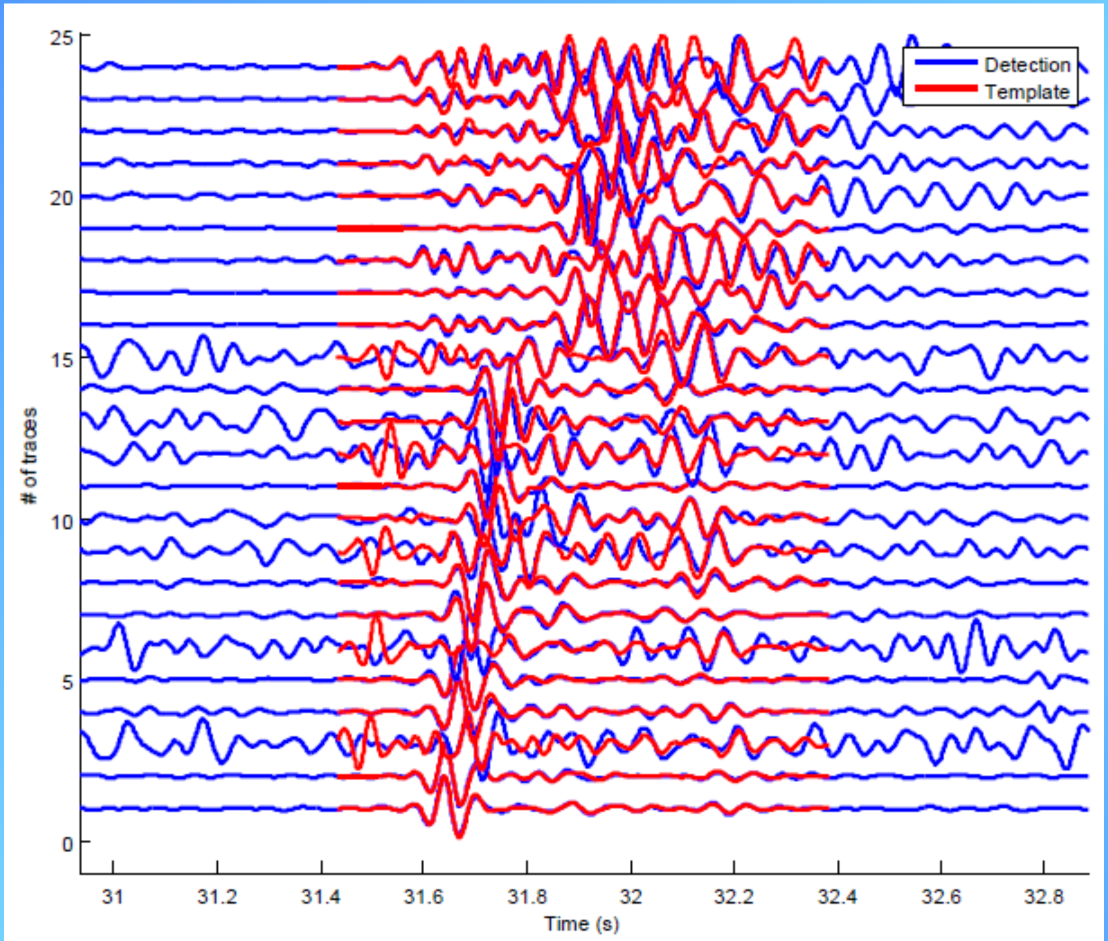
Network cross-correlation coefficients



- Same day cross-correlation event

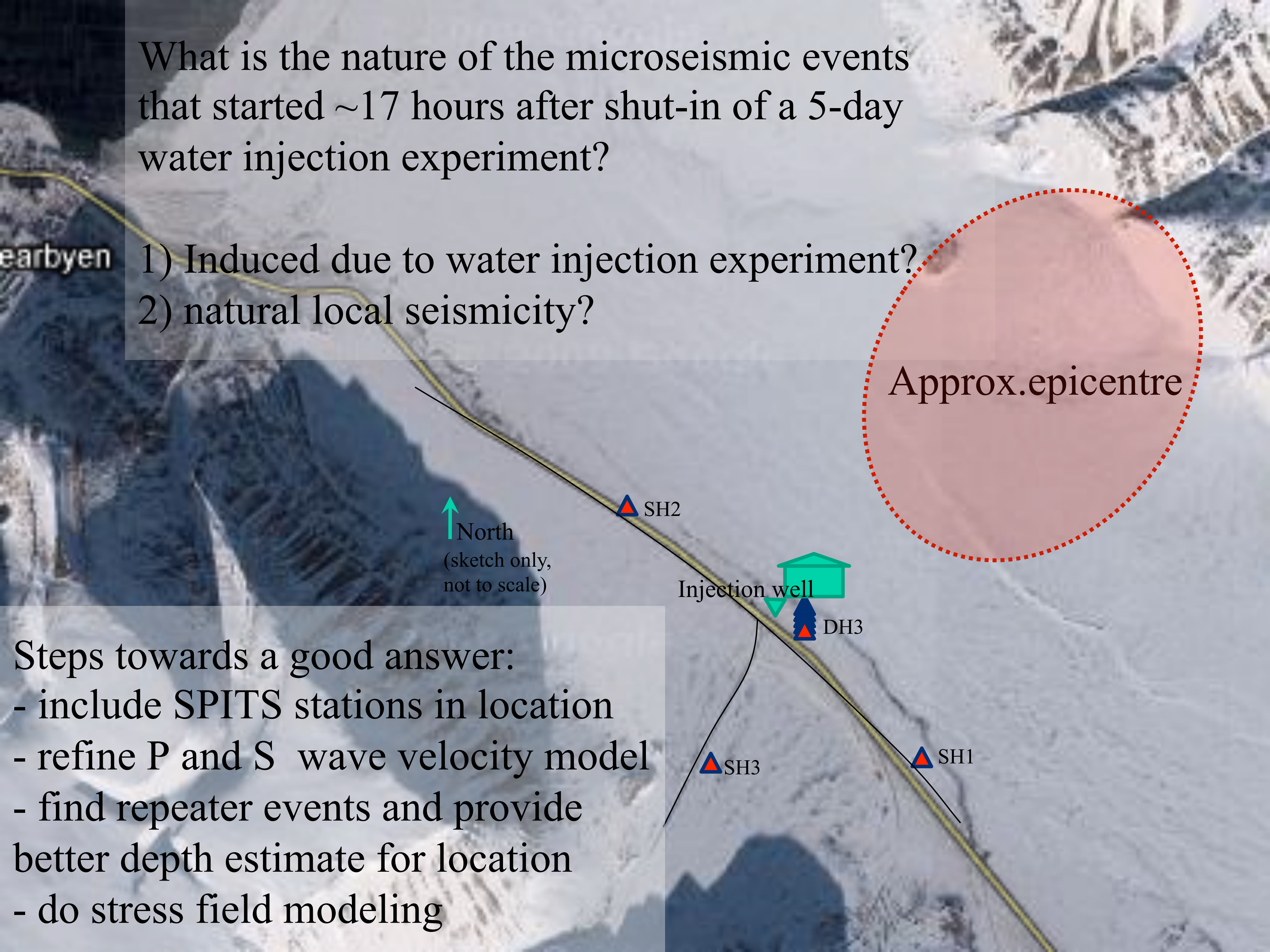


Detection 30 days later than main shock



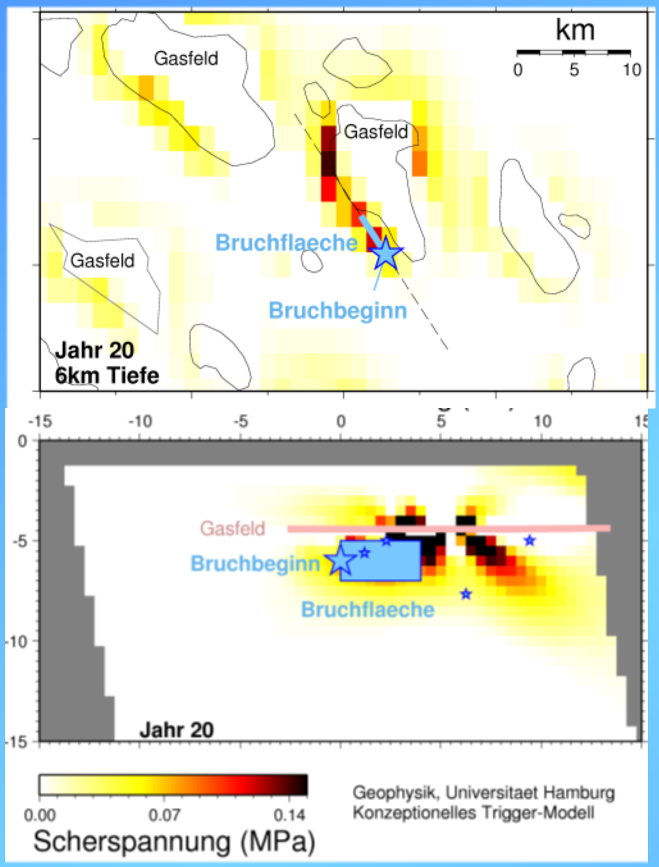
What is the nature of the microseismic events that started ~17 hours after shut-in of a 5-day water injection experiment?

1) Induced due to water injection experiment?
2) natural local seismicity?

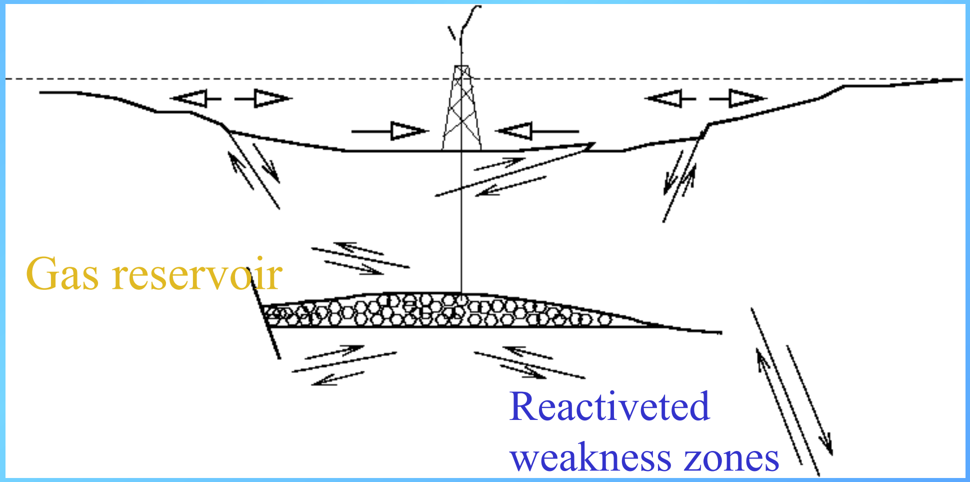


Steps towards a good answer:
- include SPITS stations in location
- refine P and S wave velocity model
- find repeater events and provide better depth estimate for location
- do stress field modeling

Calculation of stress field changes due to filling/draining of reservoirs



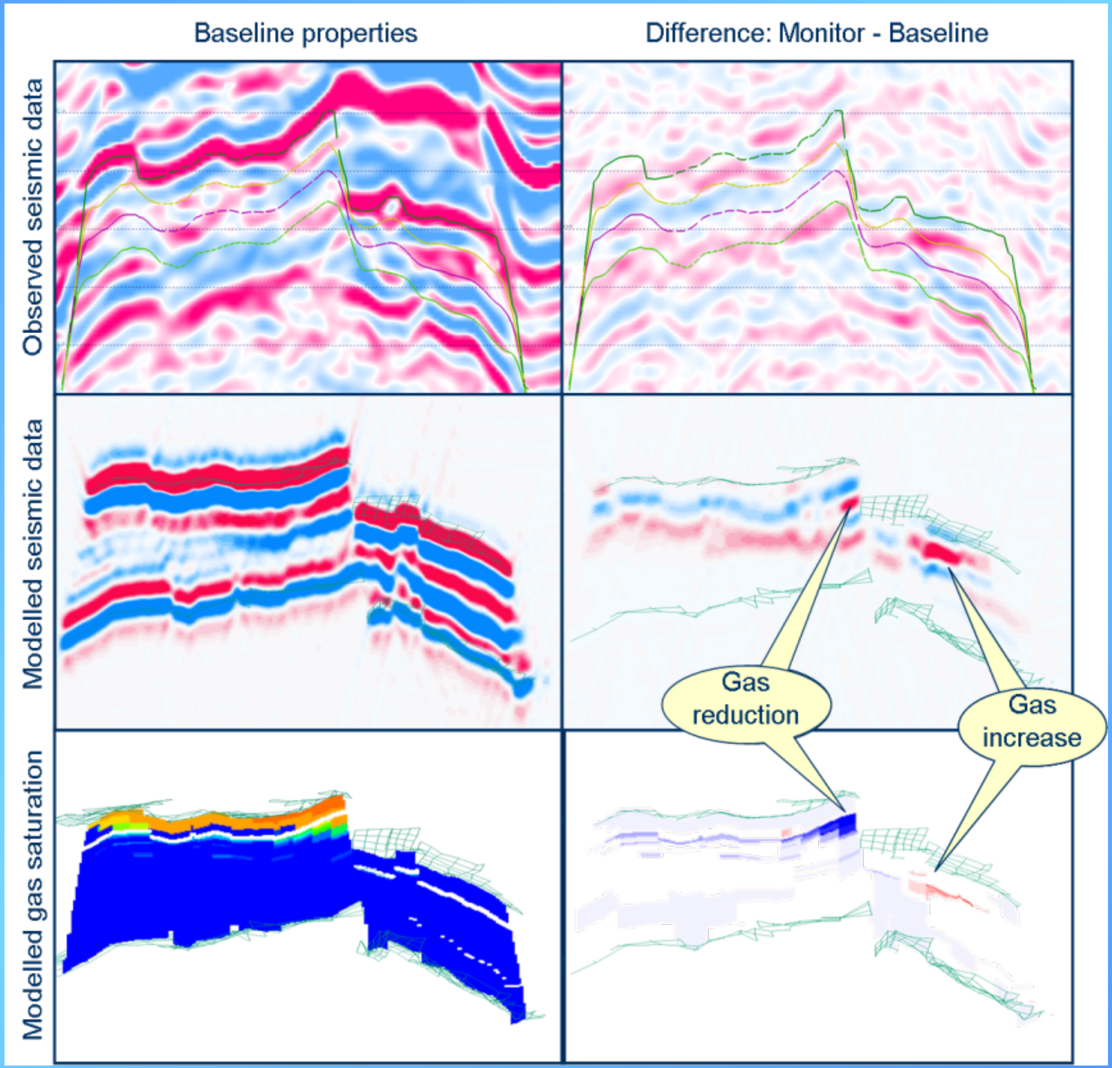
(Conceptual model from Dahm et al., 2010)



Schematic view after Segall et al., 1998

Shear stresses at
6 km Depth
and along fault
plane

4D seismic modeling to simulate behavior of migrated seismic sections on a time-lapse basis during long term CO_2 injection



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Conclusions

- The installed microseismic network is up and running, providing real-time data-flow.
- Continuous mode will soon be exchanged with triggered mode recording (low trigger threshold).
- Microseismic events occur at depth, direct correlation between events and injection test is likely, but needs to be further investigated.
- Not all data have been analyzed automatically, and visual/manual re-processing is inevitable. Need to work with automatic discarding of "false detections" to reduce dataset and do manual cross-check.

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Acknowledgements

- Thanks to NFR and industry partners ConocoPhillips, Lundin, OCTIO, READ and Statoil for financial support of the project
- E. Shalev, IESE and H. Johnson, UiB for help during the installation
- Collaboration with CO2LAB at UNIS

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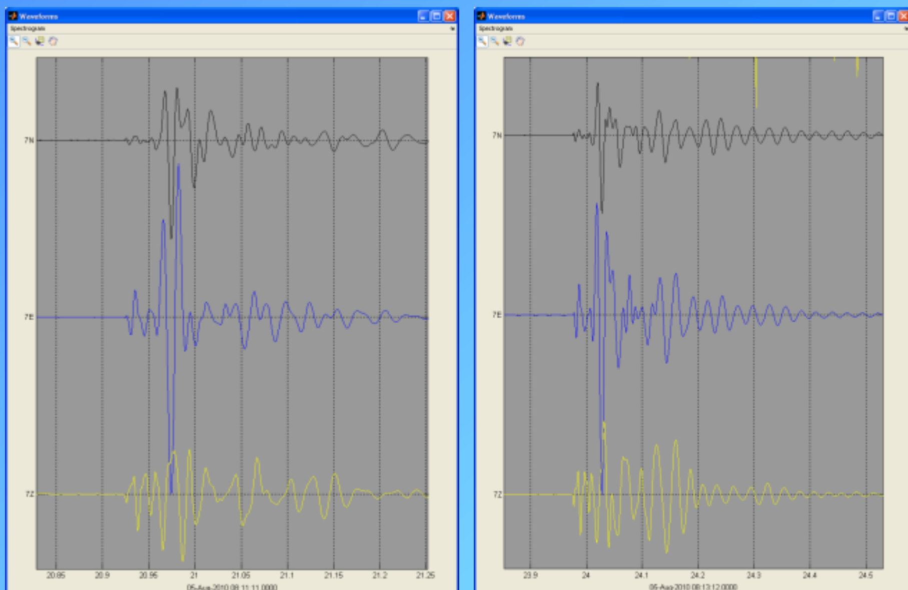
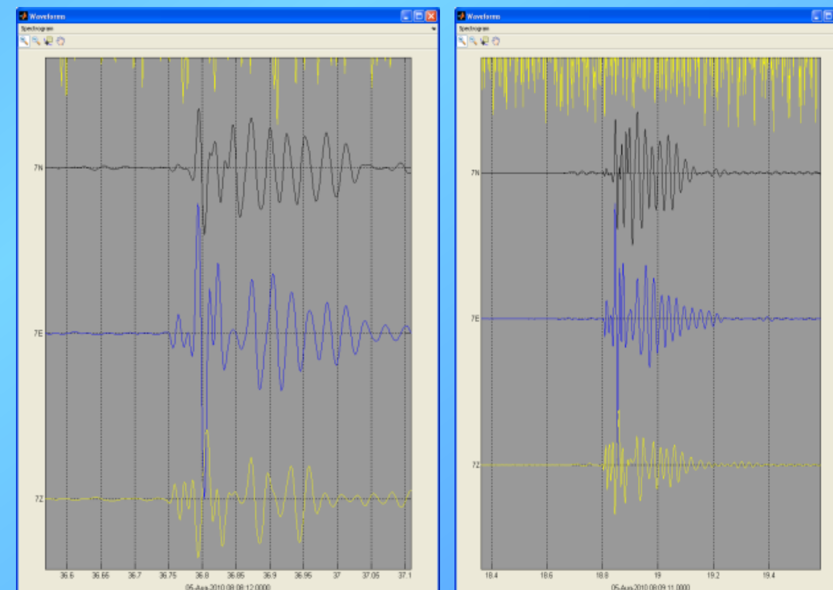
Example of hammer and ‘explosion’





Same site (SH2), with 1 repetition

Explosions

Hammer

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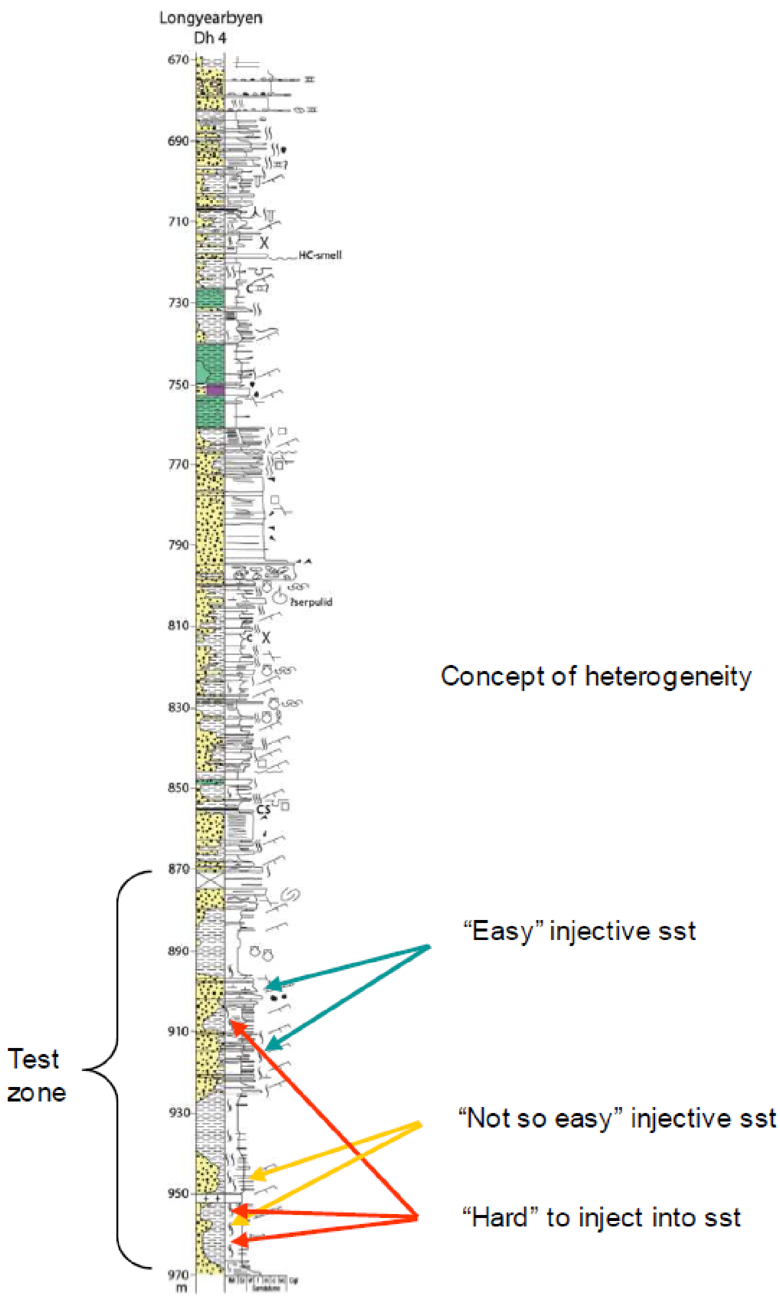
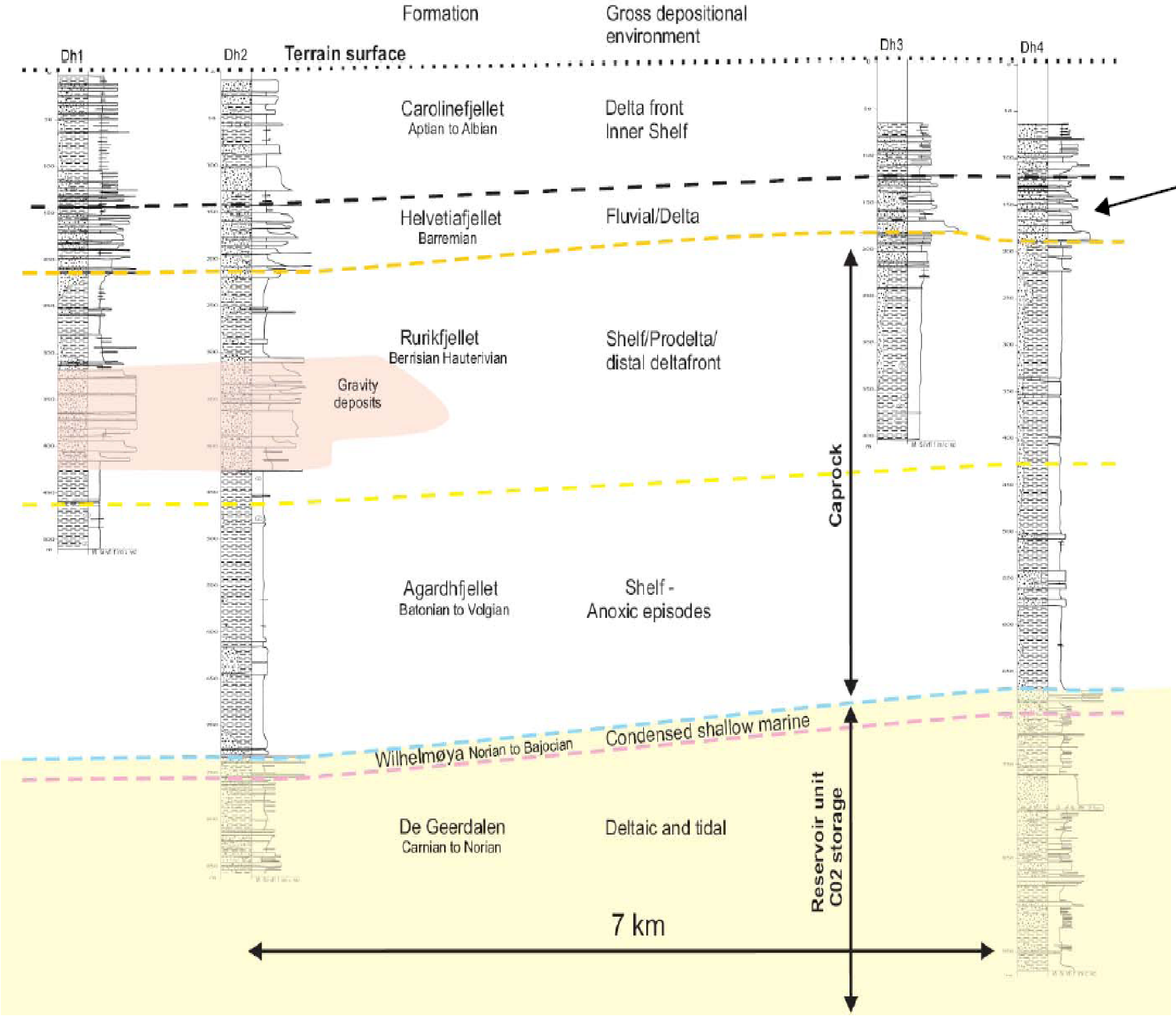
Concept of heterogeneity



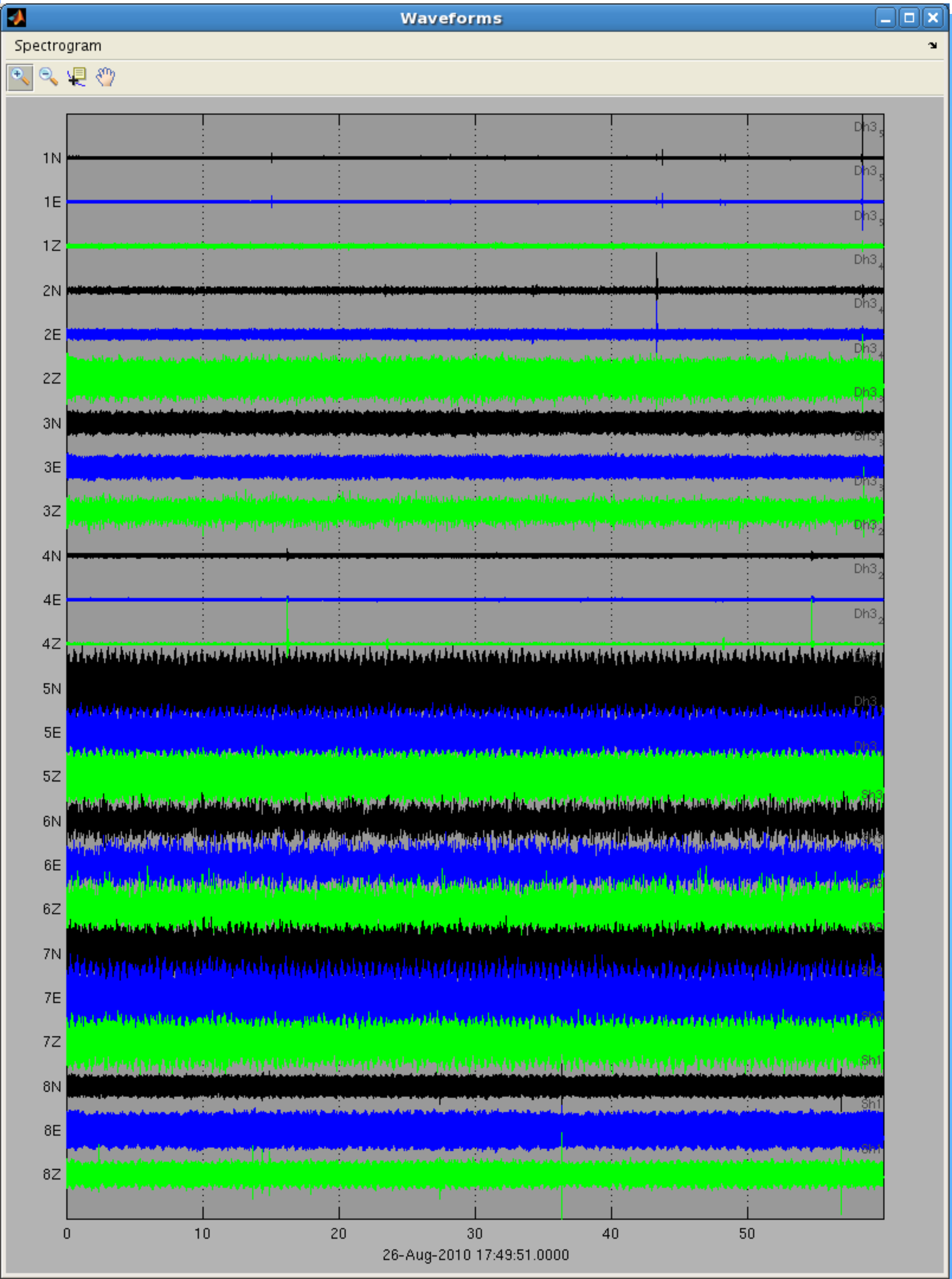
Well correlation Adventdalen



High pressured water (artisan water) Gas bearing higher up in Adventdalen. Permafrost as seal?

Concerning water and probably all fluids in liquid phase = shale is tight

30 bar under pressured



Following minute of data, no cars, different noise pattern on downhole geophones