Hydraulic rock stress measurements with the LTU stress trailer

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Presentation at the NoRSTRESS seminar 2021,

Trondheim, Norway, 9 december 2021

Background

Photo: Daniel Ask, 2018

- 2012: The Swedish Research Council (VR) supports the proposal *A Stress Measurement System for SDDP* by Ask, M., Ask, D., Juhlin, Bjelm and Rosberg
- 2013-2018: Procurement, design and construction of Stress Trailer at LTU with partners from academia (University of Strasbourg) and industry (Geosigma AB and Fracsinus Rock Stress Measurement AB)
- 2018: Stress trailer is commissioned and in operation
- 2020: Stress trailer offered as 3rd party equipment by the International Continental Scientific Drilling Program, ICDP
- 2023: the LTU stress trailer is part of the *Riksriggen* infrastructure, i.e. infrastructure of national importance according to VR (decision 2021-11)

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Design goals

Photo: Daniel Ask, 2018

1. Compatible with boreholes drilled by the national infrastructure *Riksriggen* with respect to depths and borehole dimensions
2. Maximize precision and minimize measurement-related uncertainties
3. Redundancy in data collection to allow validation of results

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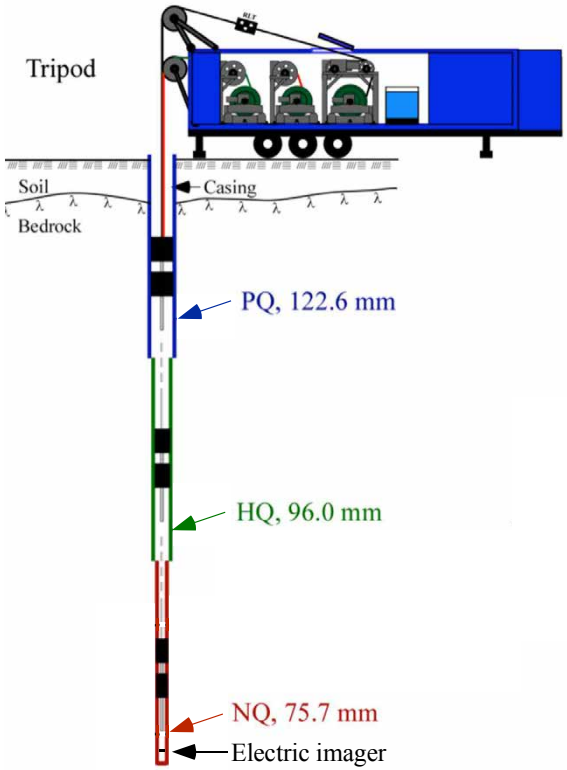
Technical specifications



- Wireline-activated integrated borehole equipment
  Straddle packer and electric imager mounted together
- Depth capacity: 0.1 - 3 km
- Borehole dimensions: PQ, HQ, NQ (123, 96, 76 mm)
- Maximum system pressure: 650 – 1378 bar (3 km – surface)
- Testing temperature: 85°C
- Reduced uncertainties
  - Digital data acquisition
  - High resolution data collected, ~40 channels
    - On surface: pressure sensor, flow-meter, length, speed, cable tension
    - In borehole: electrodes, pressure sensors, orientation sensors, temperatures
- Advanced data collection & analyses
  - Collected data are integrated using a Python interface
  - Analyses and stress calculations are made in Matlab

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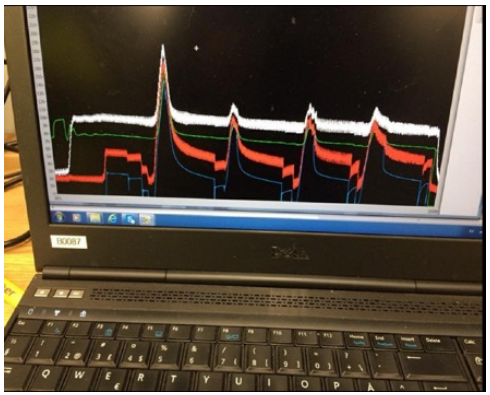
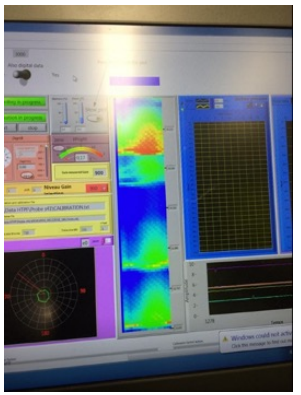
The surface unit of the stress trailer





- Storage and transport
- Control center during testing
- Workshop

Photos: Maria Ask, 2016; Daniel Ask, 2018

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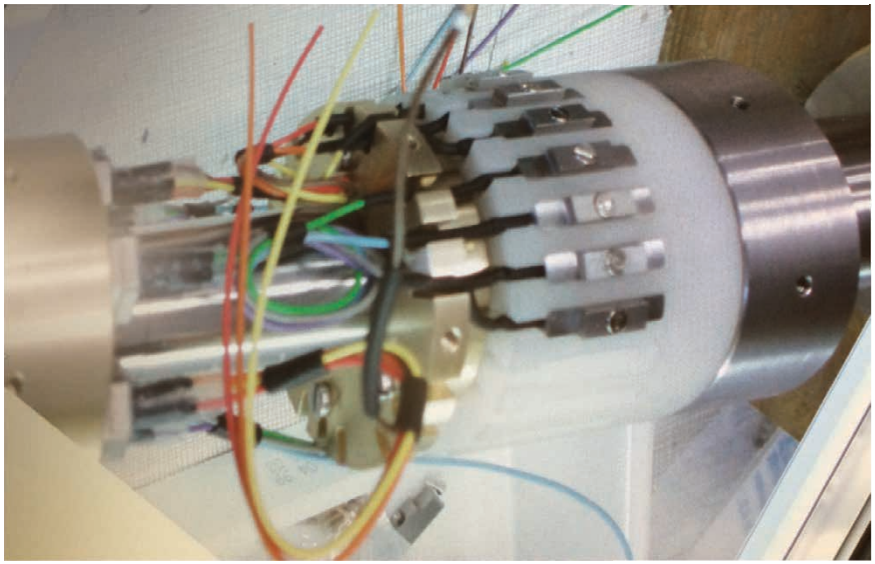
Downhole unit



Photos: Maria Ask, 2014, 2016; Daniel Ask, 2018

- Straddle packers for NQ, HQ, PQ (76, 96, and 123 mm) borehole diameters
- Electric imager with adapters
- Require good quality of borehole

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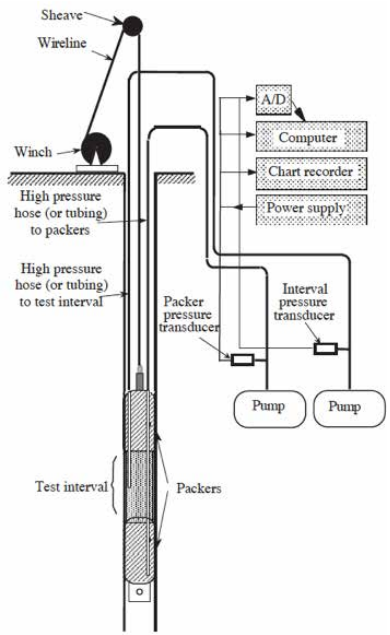
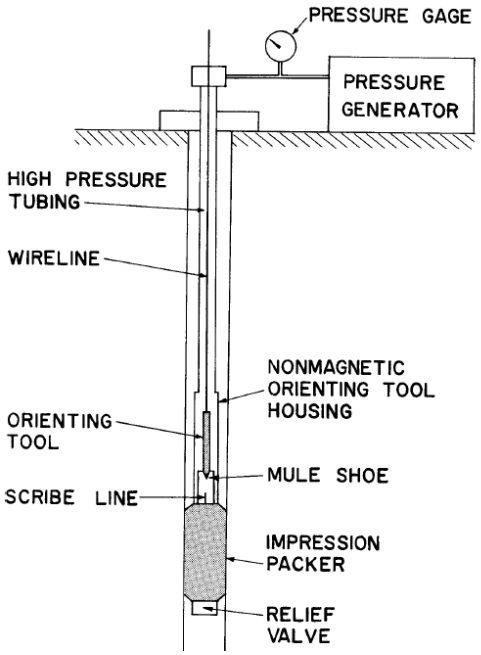
Methods and standards



(ISRM 2003)



(ASTM D4645-08)

- Hydraulic fracturing, **HF**
  (*Hubbert & Willis 1957*)
- Sleeve fracturing, **SF**
  (*Stephansson 1983*)
- Hydraulic tests on pre-existing fractures, **HTPF**
  (*Cornet & Valette 1984, Cornet 1986*)

- Active standard:
  HF, HTPF: ISRM 2003
  (*Haimson & Cornet*)
- Withdrawn/Historical standard:
  HF: ASTM 2008 D4645-08
  ASTM 2004 D4645-04

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LuTH/LTU's past & present equipment

Range: 0 - 500 m
Multihose (soft)
ϕ: 56, 76 mm
Pressure limit: 280/350 bar
Impression packer
Separate measurements
Early 1980ies

The truck (Lastbilen)

Range : 0 - 1 000 m
Multihose (soft)
ϕ: 56, 76 mm
Pressure limit : 320/380 bar
Impression packer
Separate measurements
1985-2004

The stress trailer (Spänningstrailern)

Range : 0 - 2 850 m
Wireline (stiff)
ϕ: 76, 96, 123 mm
Pressure limit : 650/1 380 bar
Electric imager
Integrated measurements
2018-

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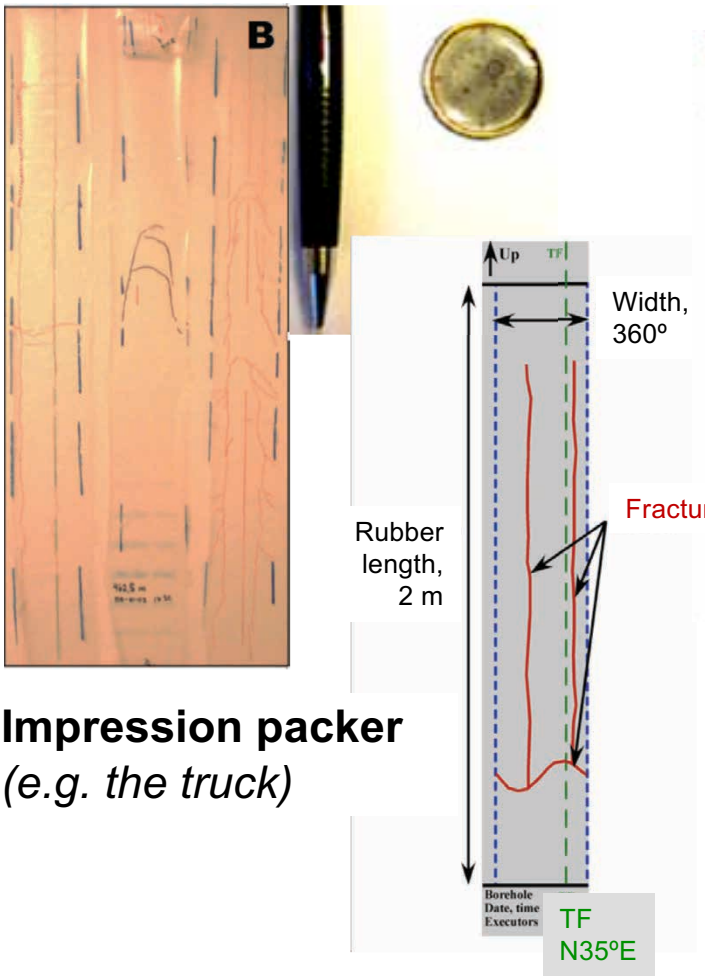
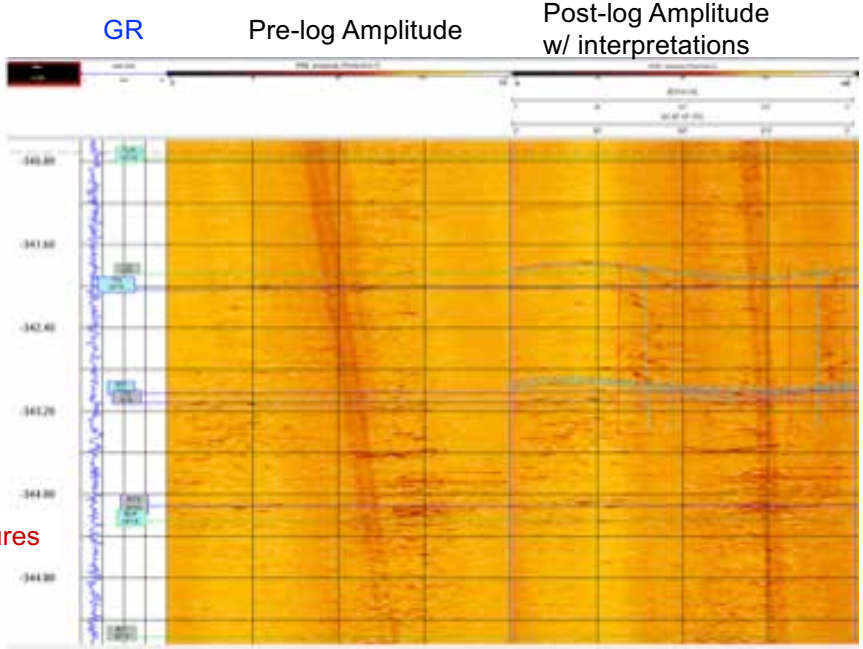
Methods for fracture detection

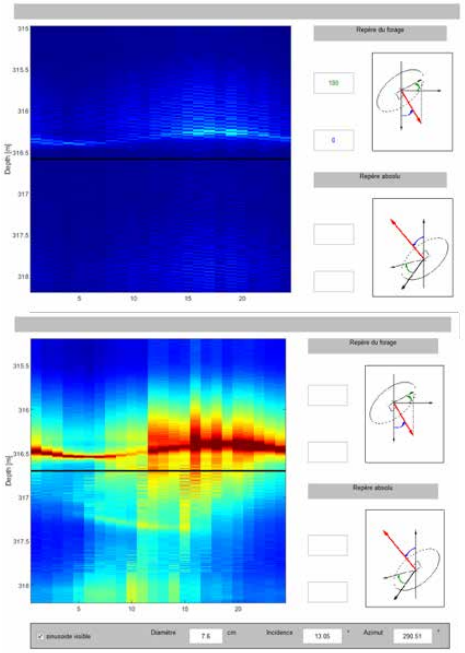


Impression packer
(e.g. the truck)



Borehole televiewer

Electric imager
(i.e. *the stress trailer)*



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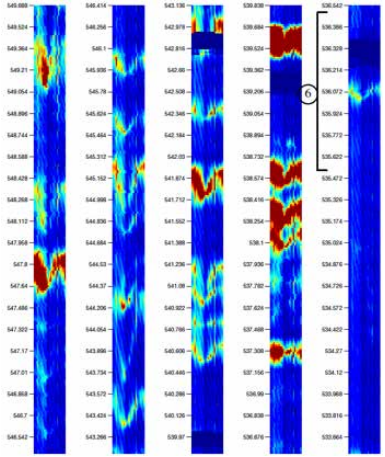
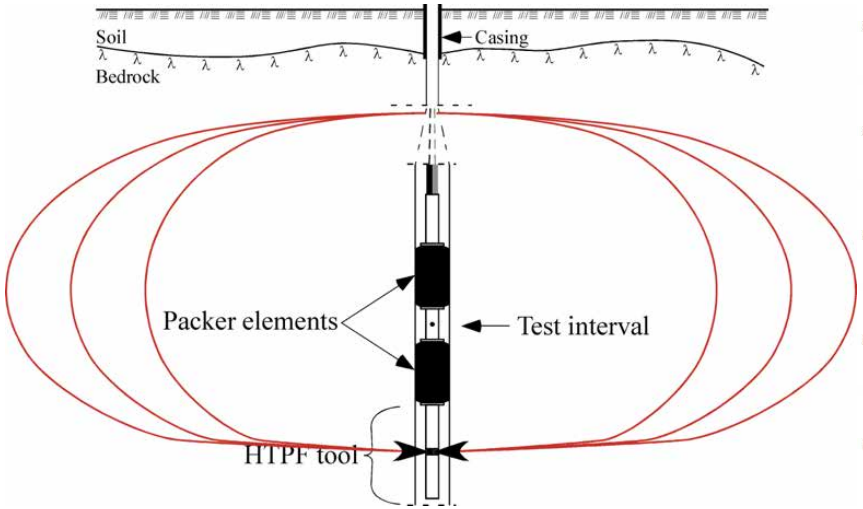
Data collected with the stress trailer – a three-step test sequence

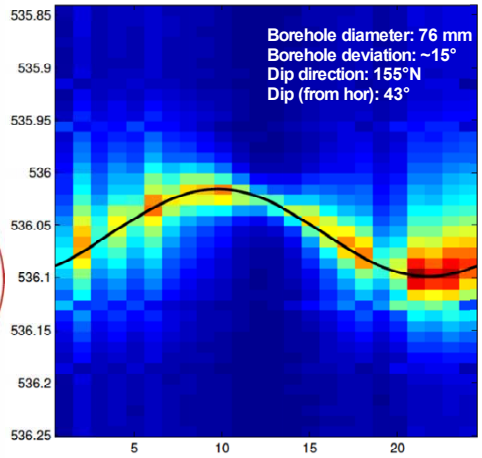
Pre-test logging



Pressure testing



Post-test logging



Note: before test sequence, borehole ishould be logged with borehole televiewer to identify enlarged sections and with dummy (weight with same dimensions as downhole equipment) to reduce risk for tool stuck.

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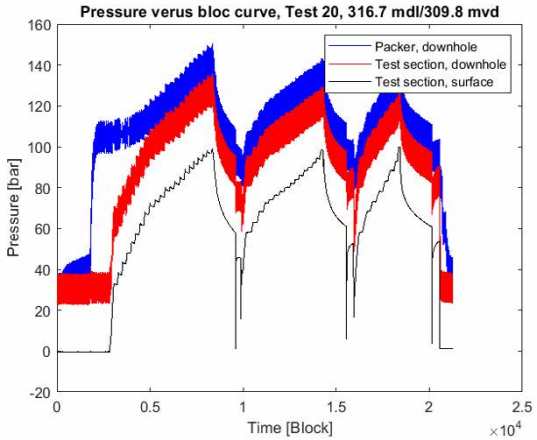
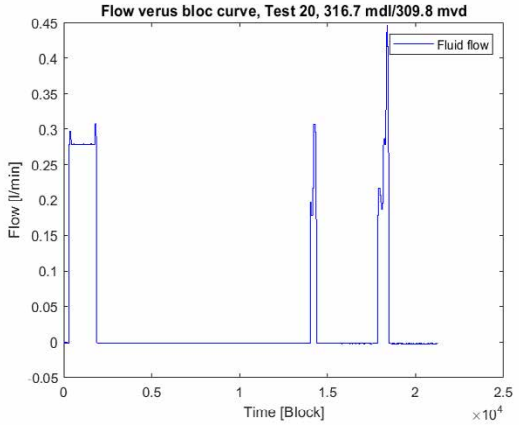
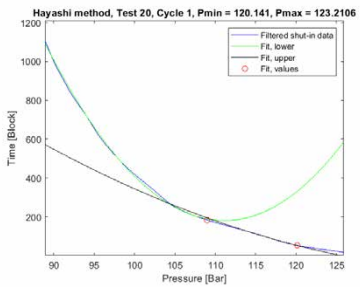
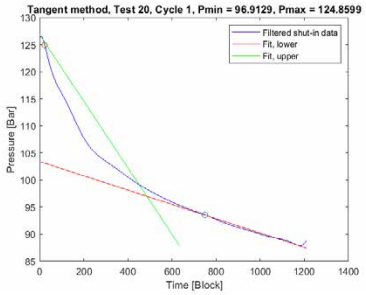
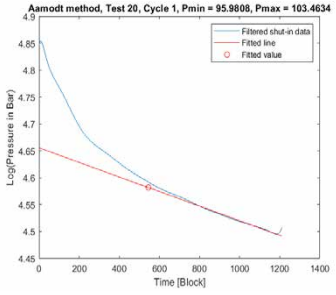
Stress data and analyses





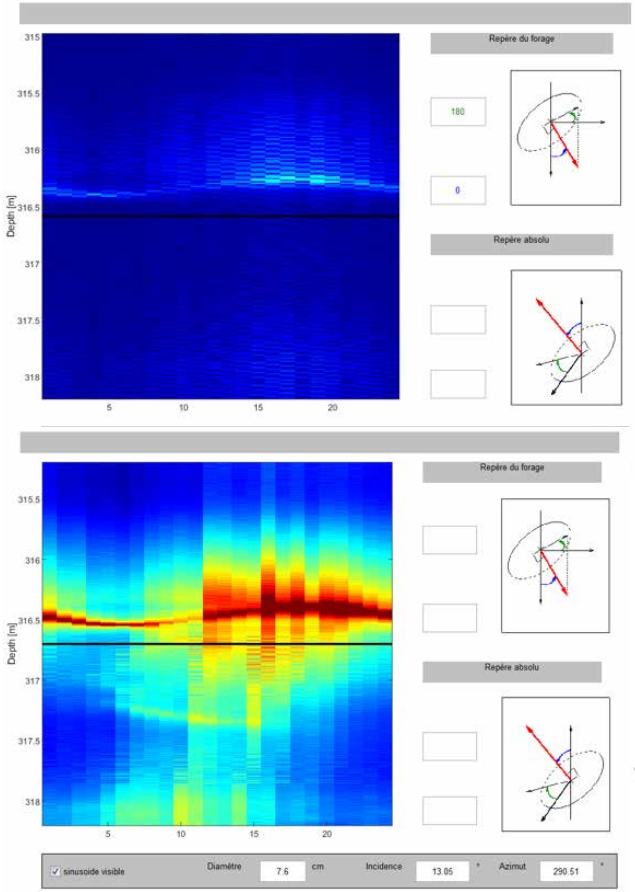






Shut in pressure analyzed according to ISRM standard
i.e., the Hayashi,Tangent and Aamodt methods

Pre- and post log



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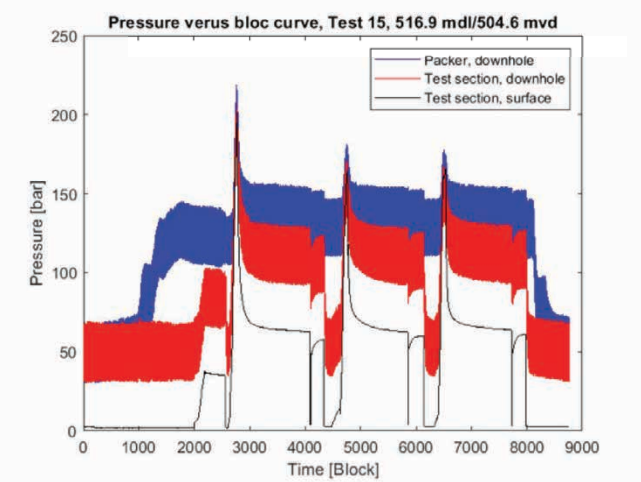
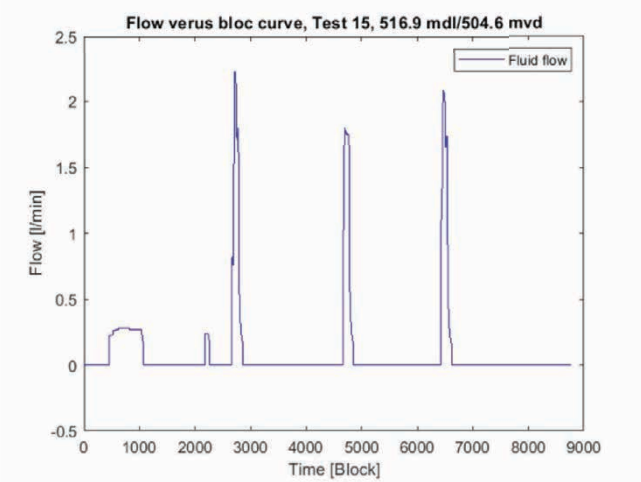
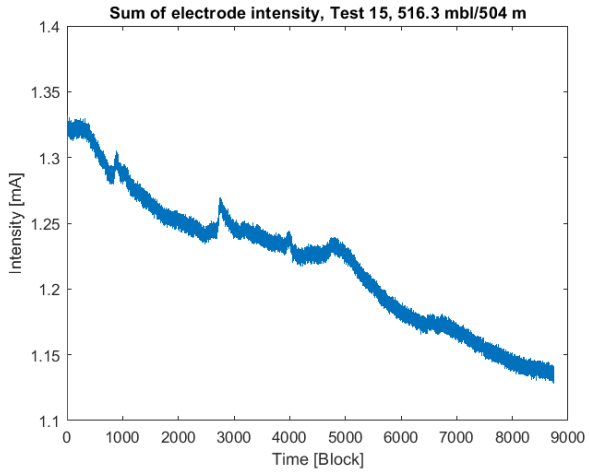
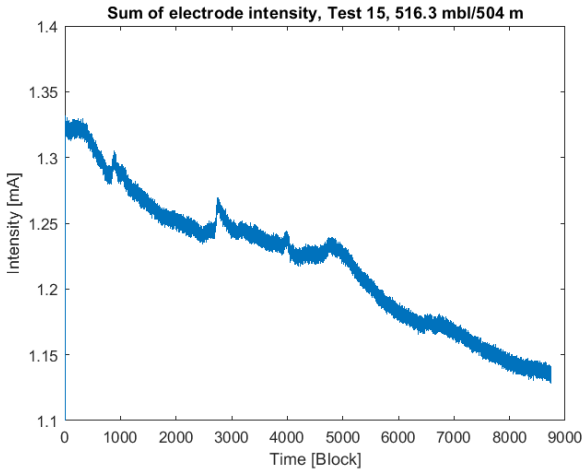
Electrodes may be used for independent pressure validation









Cornet et al. (2003) demonstrated that electrodes support evaluation of pressure data for an electric imager mounted within the test section.

Apparently, electric imager data from below the straddle packer also may be used evaluate pressure data!

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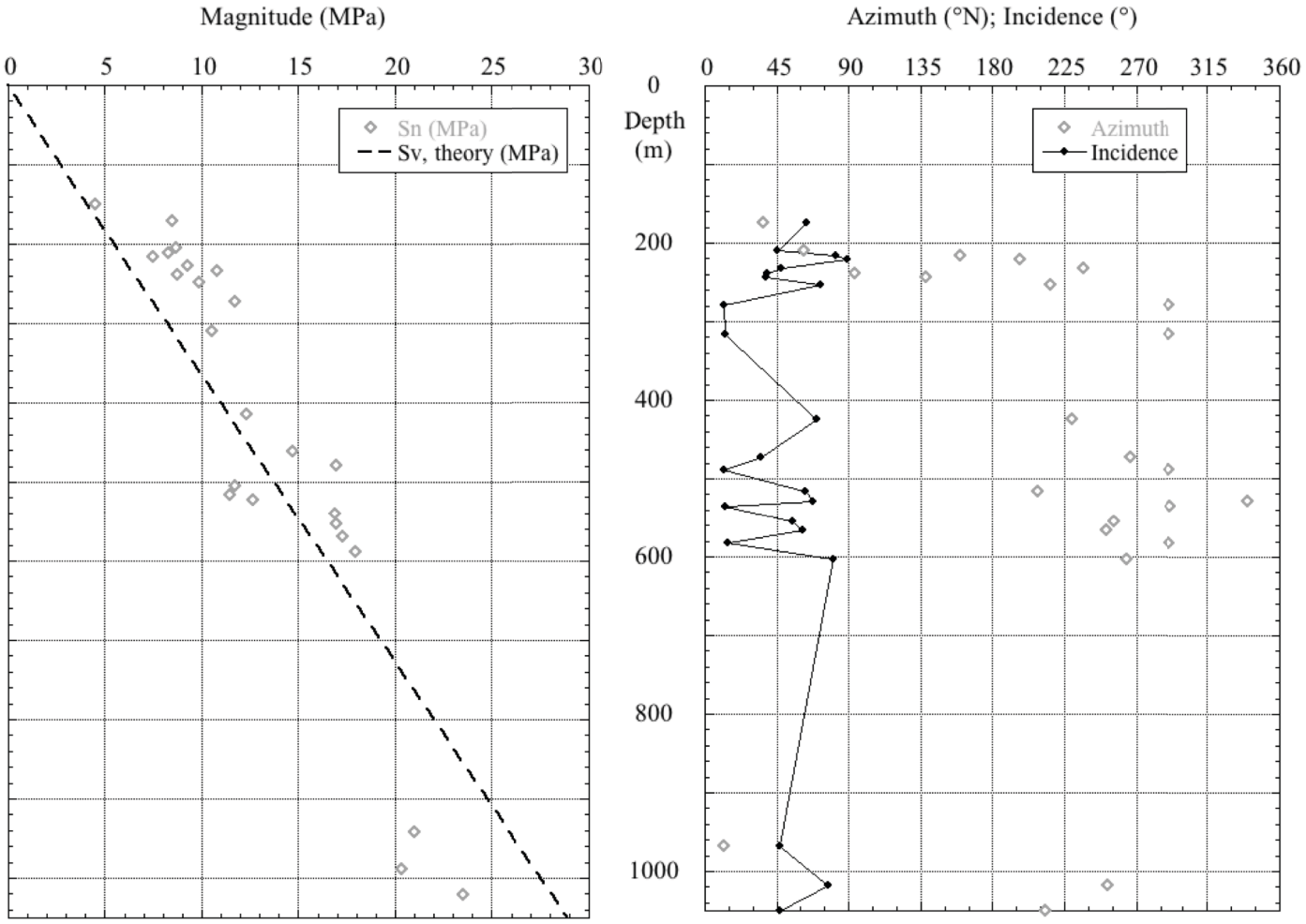
Results



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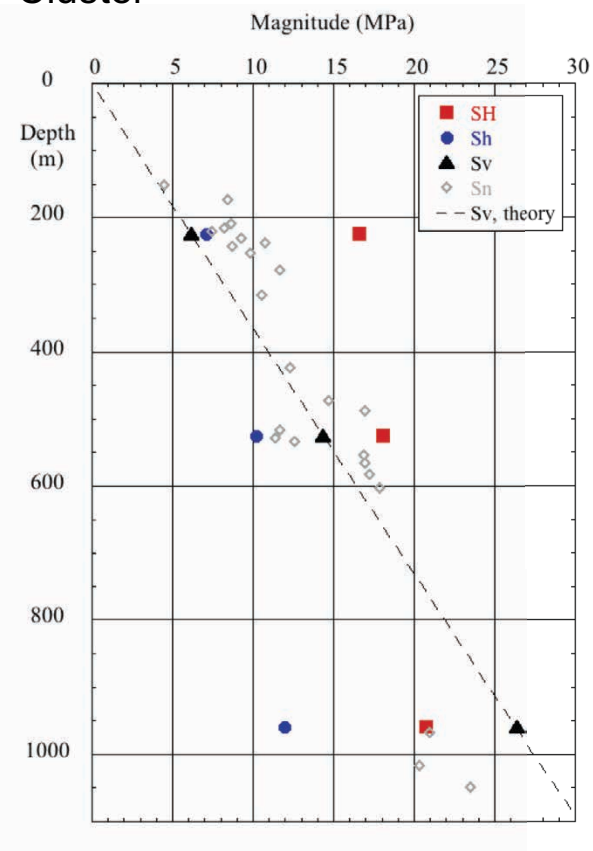
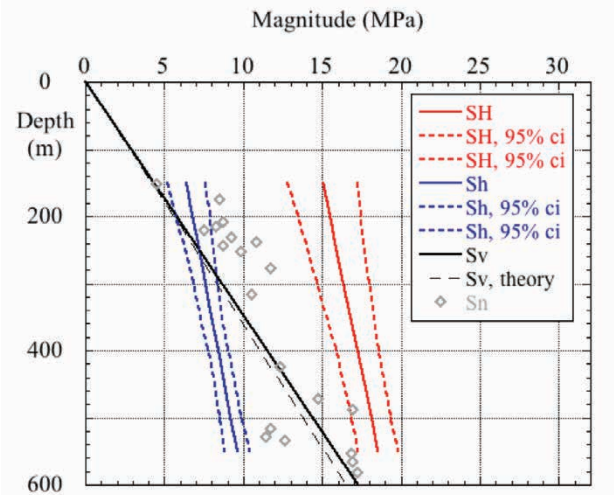
Stress calculations

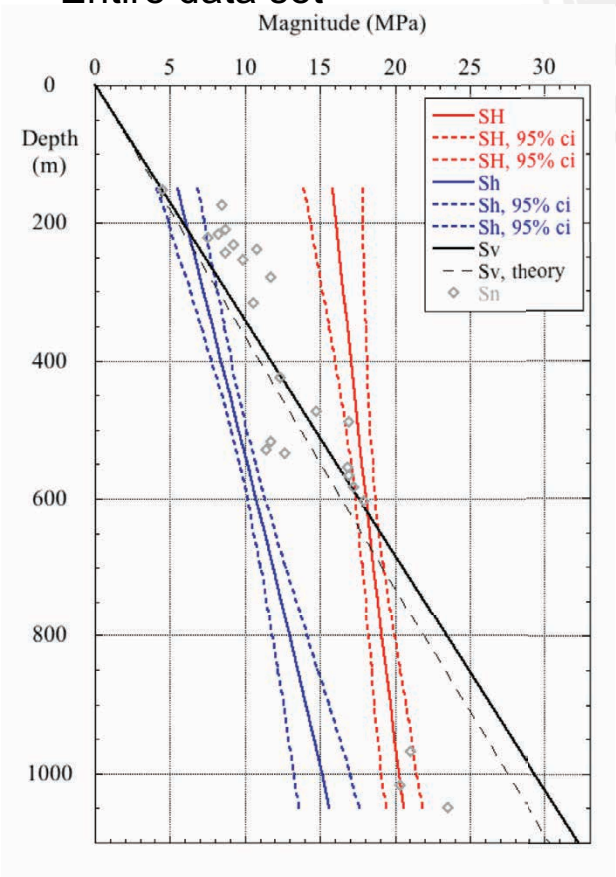
Cluster



Shallow data set



Entire data set



Step-wise interpretation:

- HF versus HTPF
- Cluster and increased data sets

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Our team

- Design: Daniel Ask[1,2], Francois H. Cornet[3], Tommy Nilsson[1]
- Construction: Daniel Ask[1,2], Francois H. Cornet[3], Tommy Nilsson[1], Miloud Talib[3], Jan Sundberg[4], Christer Ahlbäck[1], Fredrik Nilsson[1], Tobias Svanberg[1], Martin Lund[1]

  [1]*Luleå university of Technology (LTU)*

  [2]*FracSinus Rock Stress Measurements AB*

  [3]*Universitetet i Strasbourg (Frankrike)*

  [4]*Geosigma AB (Uppsala)*
- Design and construction of synchronized winches: István Lazányi, VOX Automatika Kft and Árpád Àtkari, Tek-Szol Kft, Hungary

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GEOSIGMA

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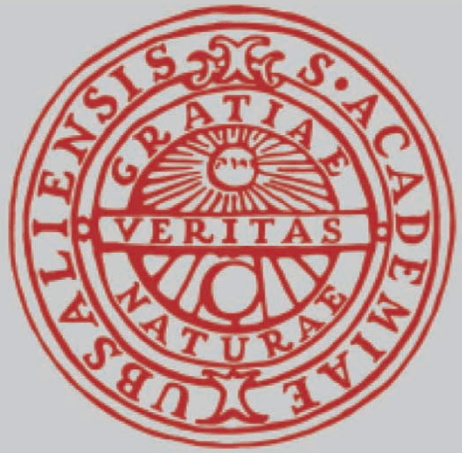

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