NoRSTRESS Seminar 09.12.2021
Joachim Schneider-Glötzl

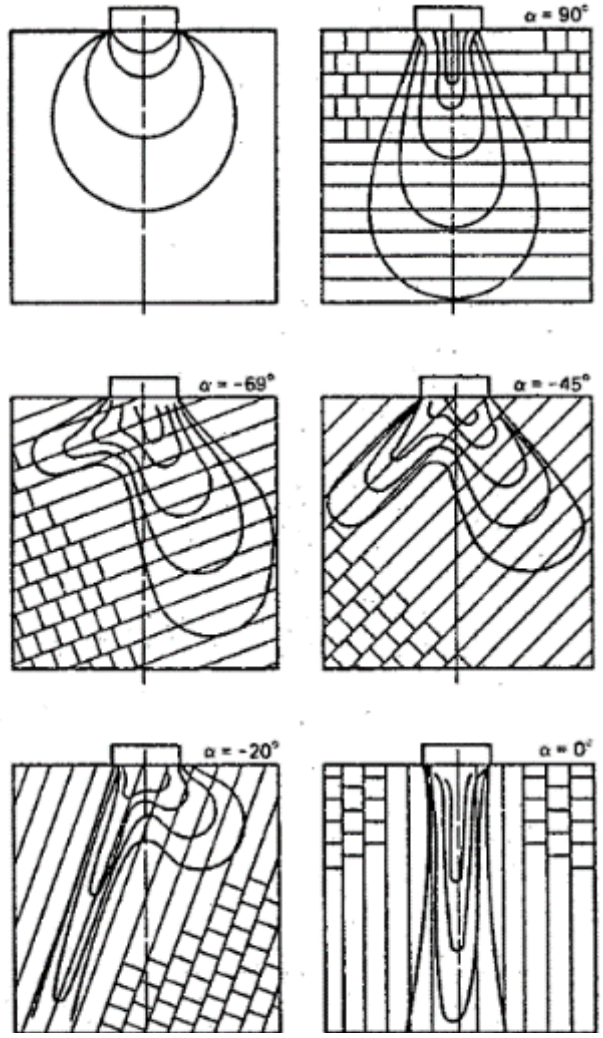
Multi-directional measurement of stress

NoRSTRESS

GLÖTZL

Motivation

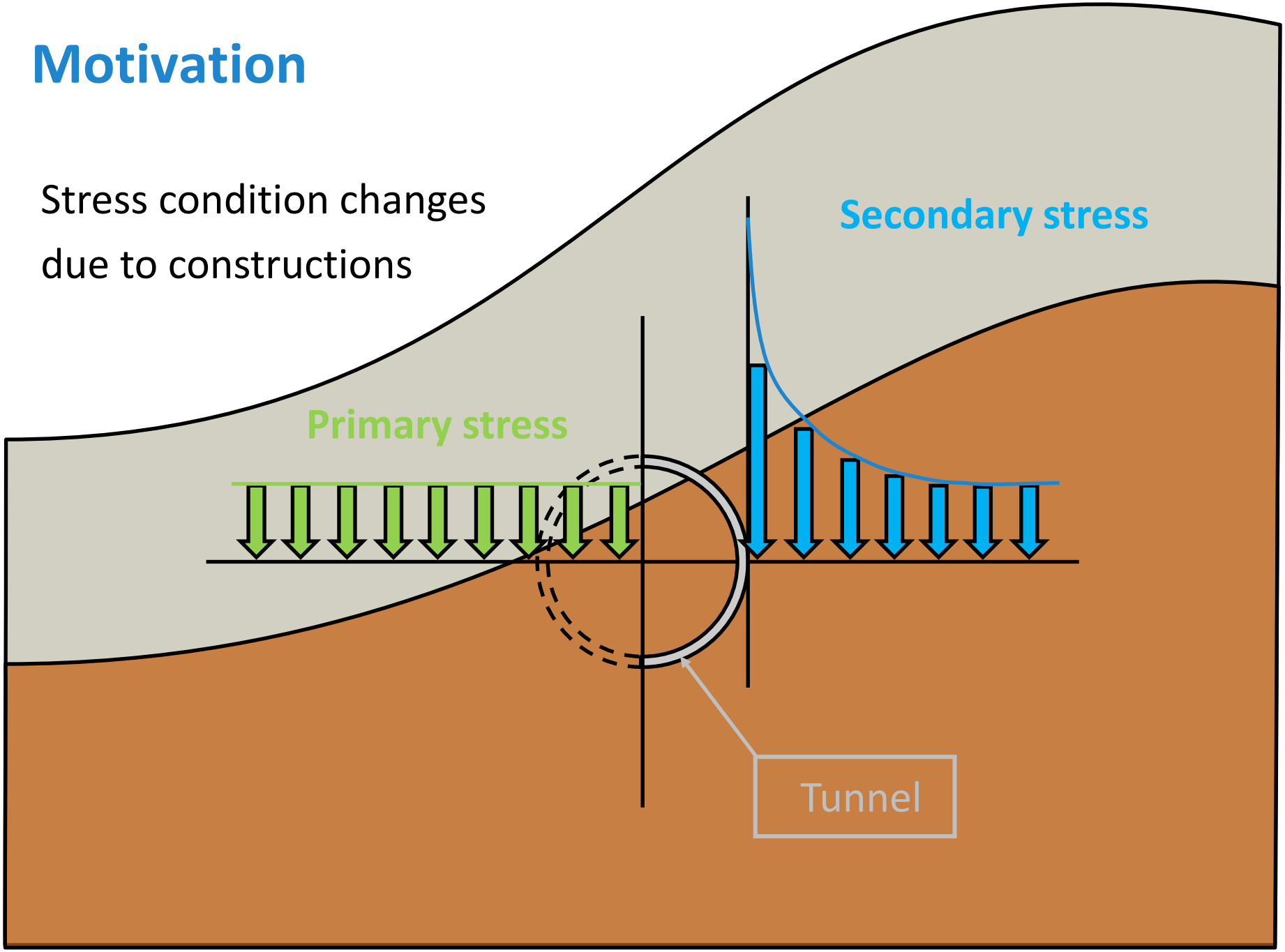
Stress condition depends on geology and tectonics



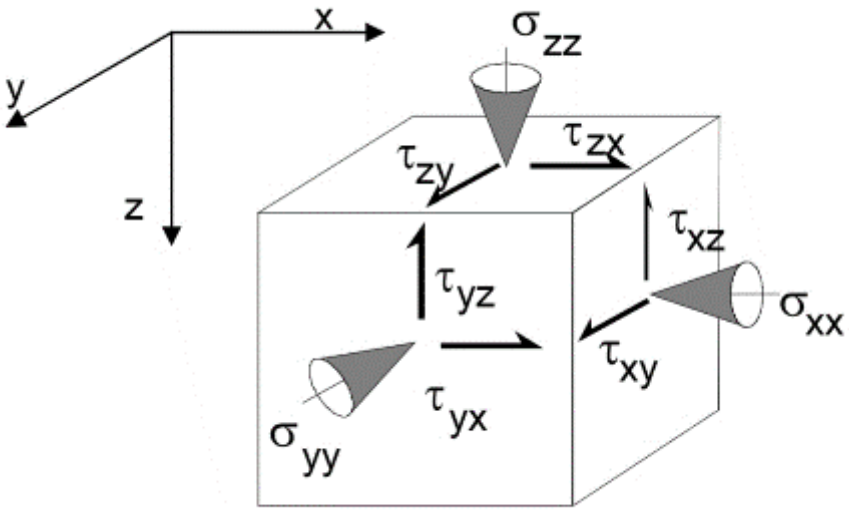
Lines of equal stress by Graziev and Erlikhman (1971)

Motivation

Stress condition changes due to constructions



Stress Analysis



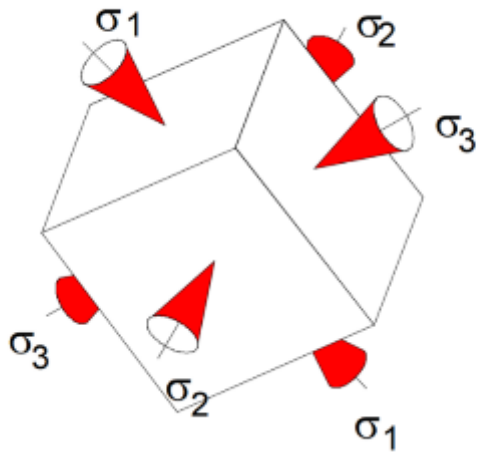
Stress tensor

$$\begin{bmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{bmatrix}$$

Points of interest

! Magnitude

! Direction



Principle stress

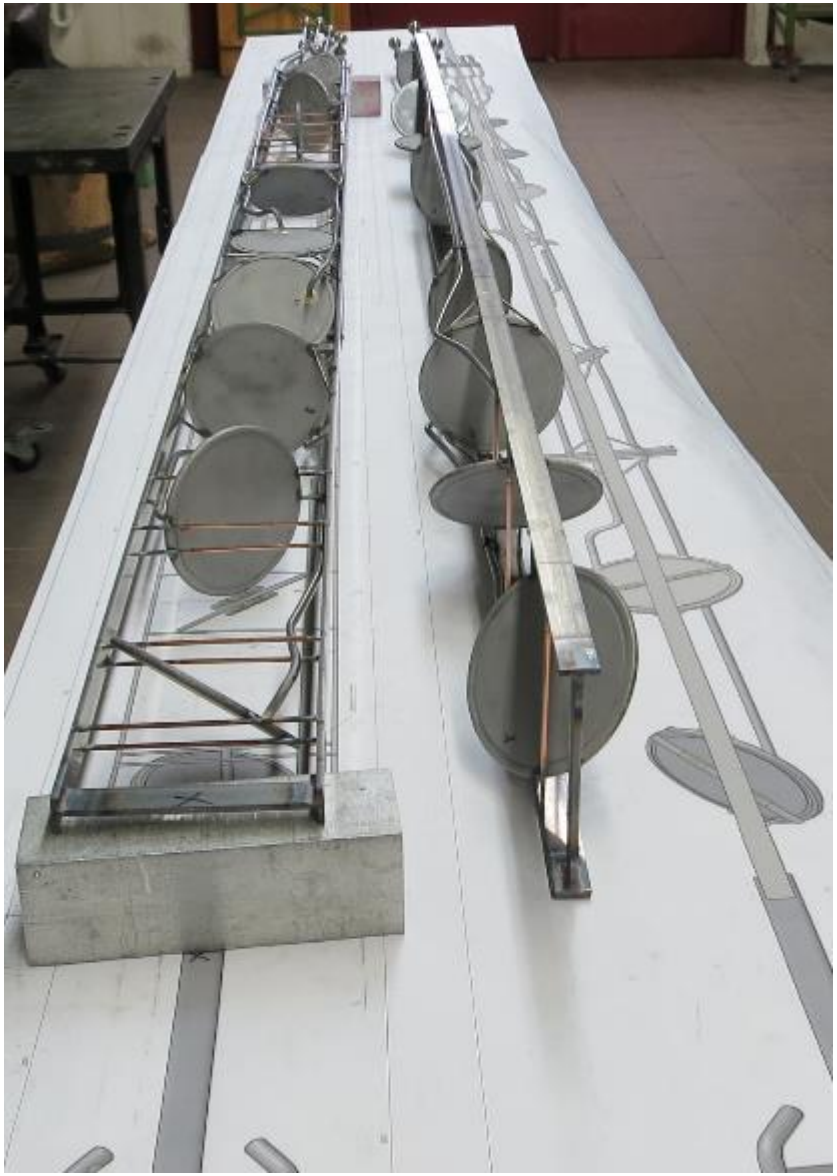
$$\begin{bmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{bmatrix}$$

Borehole Inclusion Method

to measure stress changes

GLÖTZL

Stress Monitoring Station

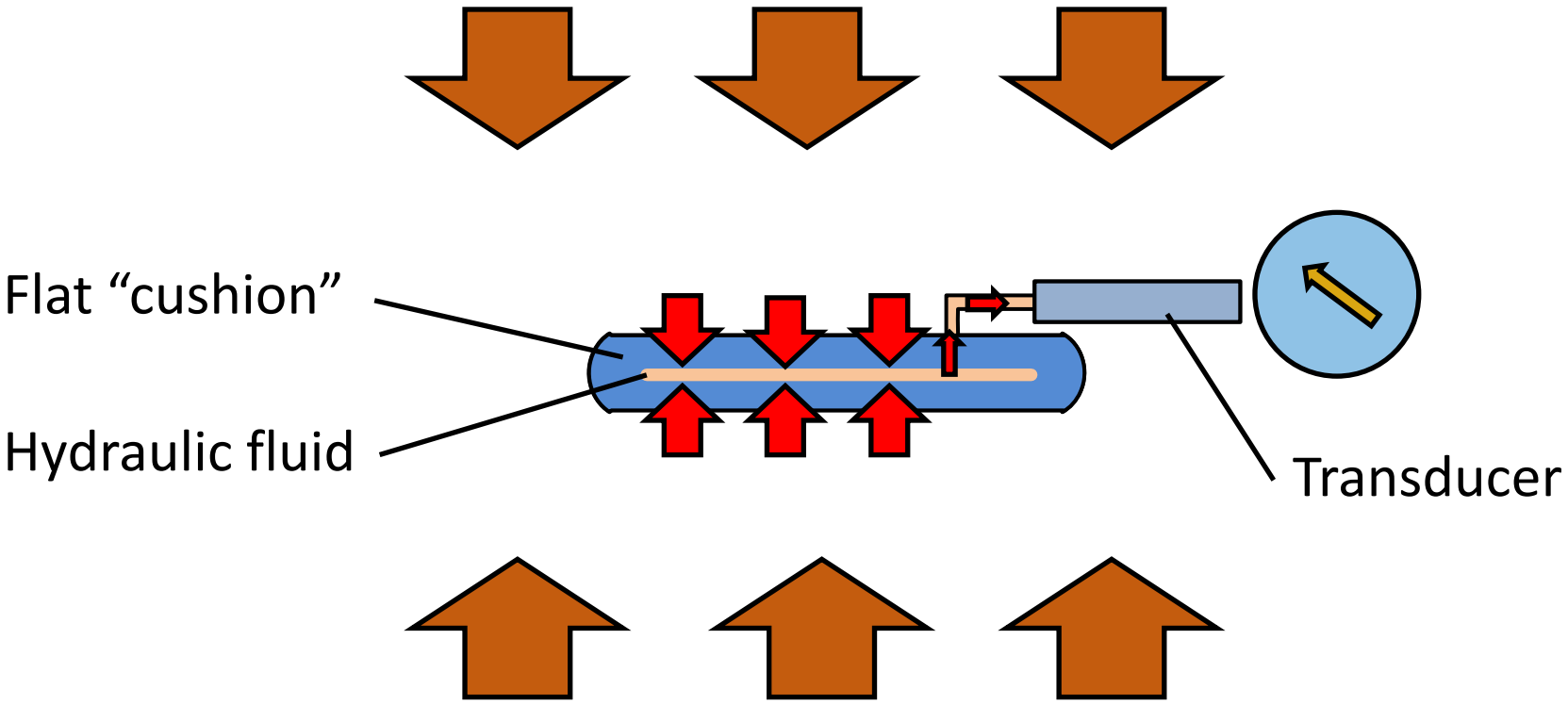


Multiple pressure cells

with different orientations

GLÖTZL

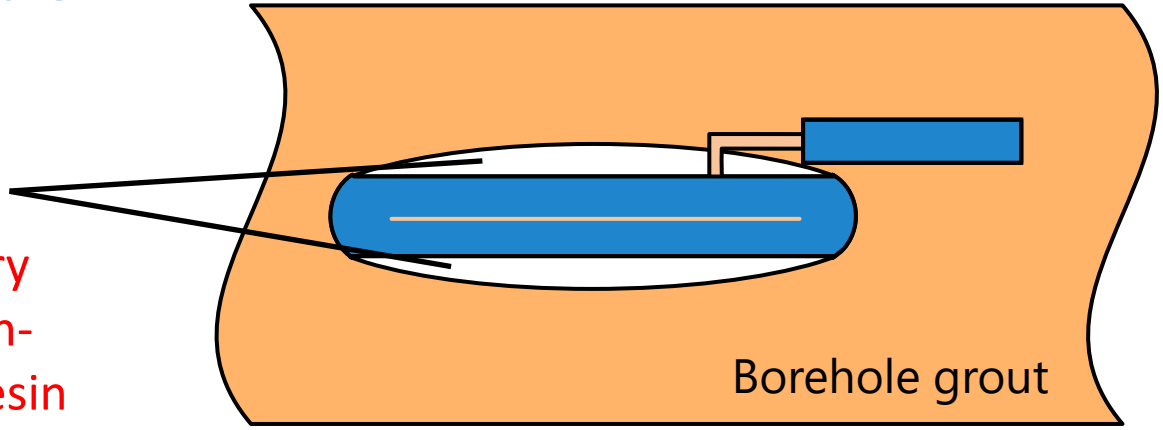
Principle of a “Pressure Cell”



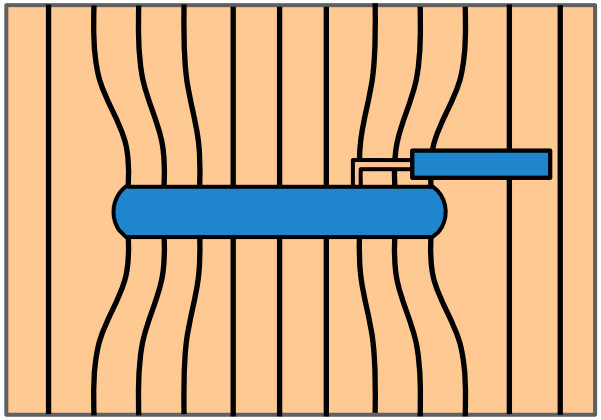
Effects to Consider

Missing contact

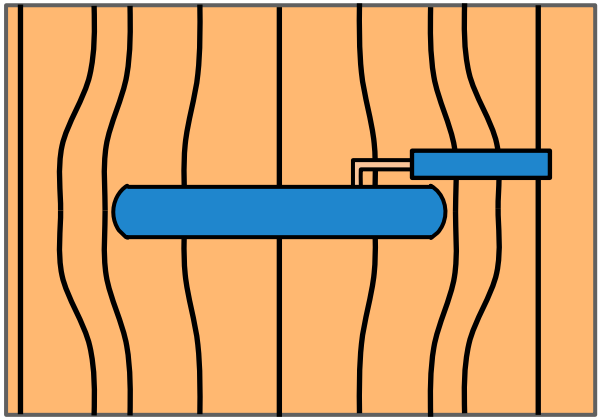
=> Need for secundary grouting using non-shrinking epoxy resin

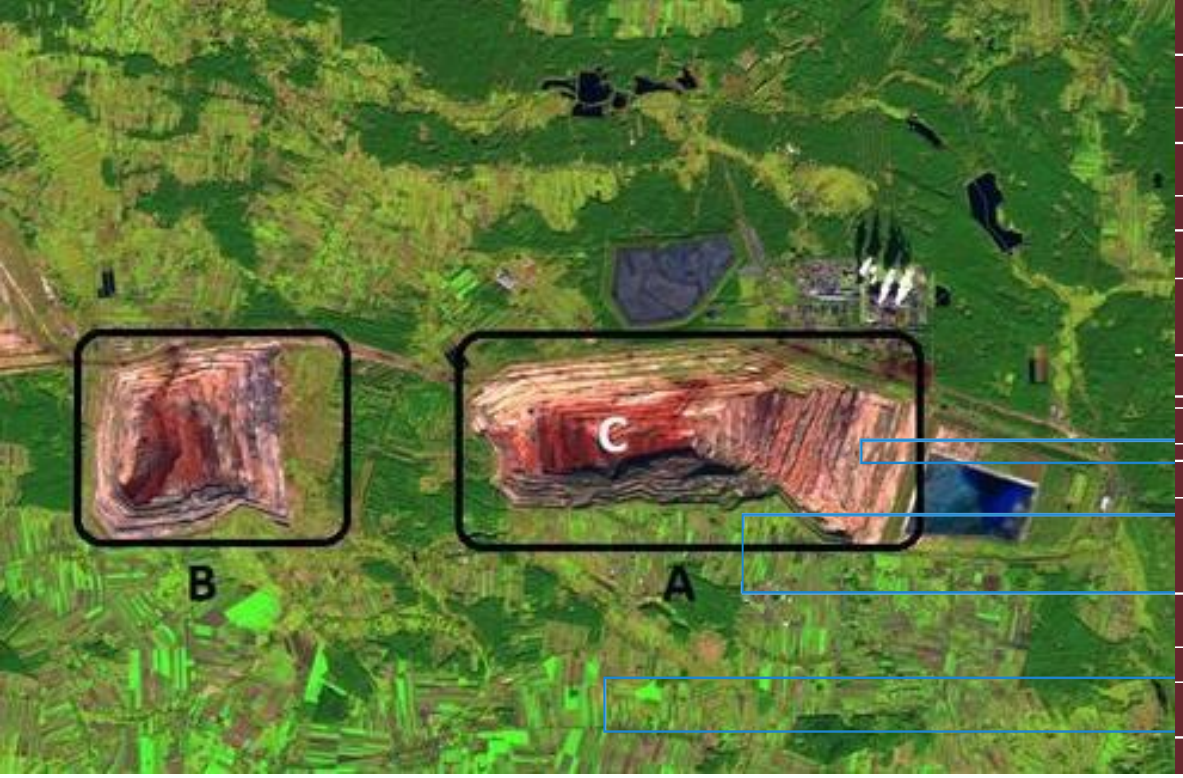


Hard inclusion



Soft inclusion



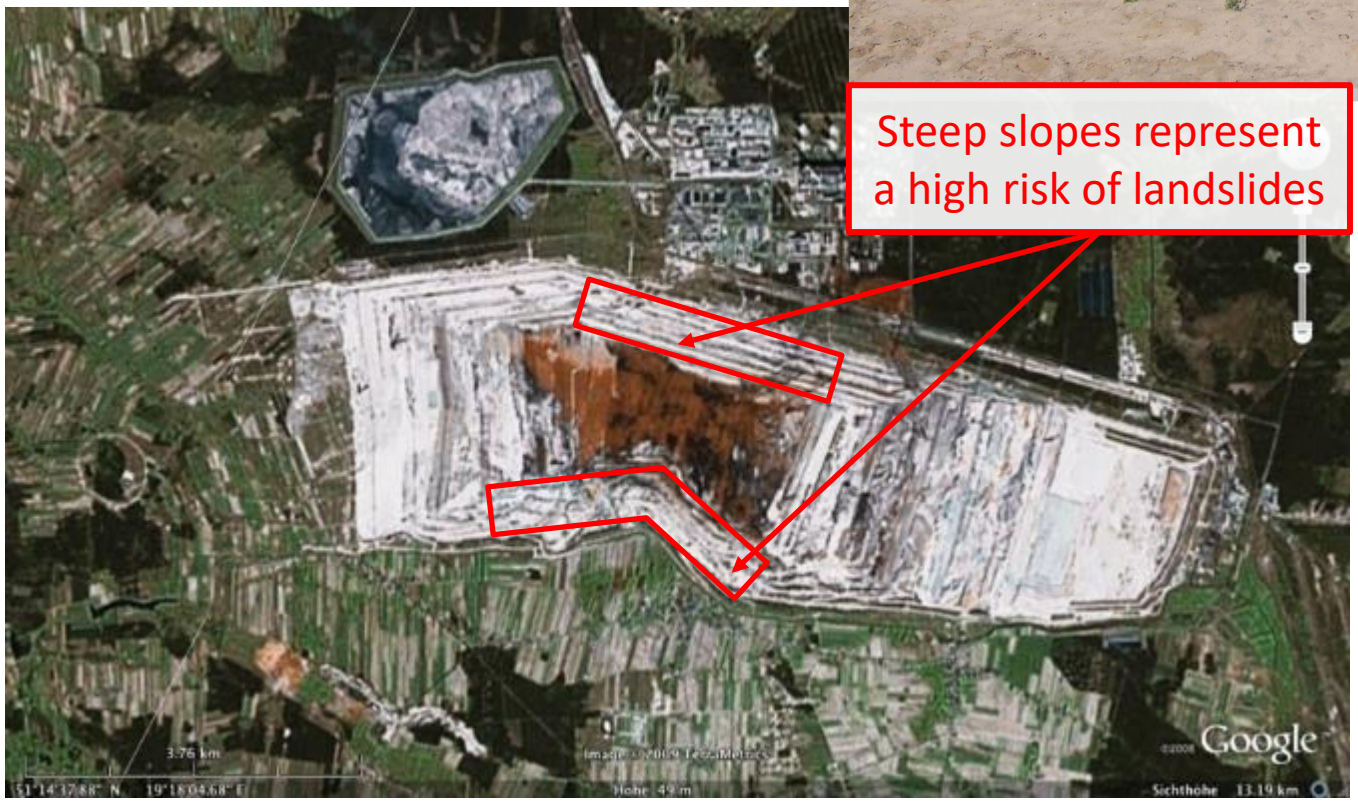


Application

Open-pit Mine

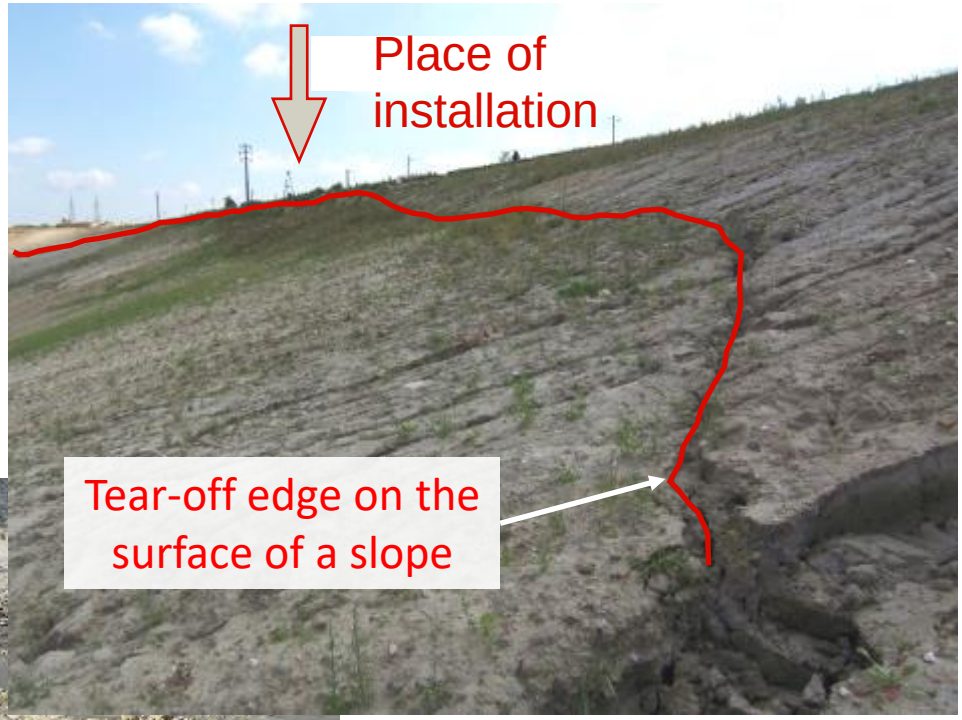
GLÖTZL

Lignite Mine Belchatow, Poland

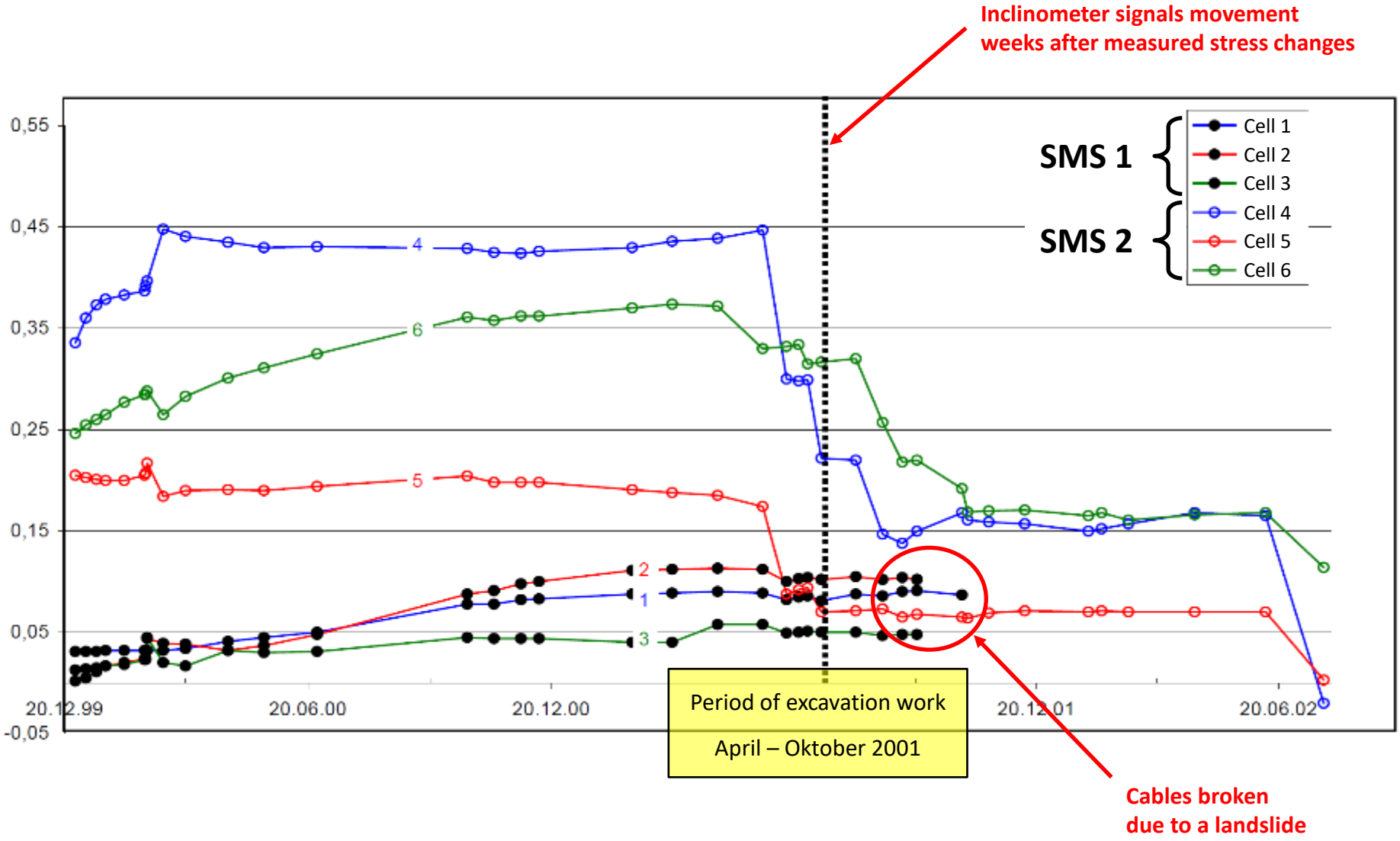


SMS with 3 cells

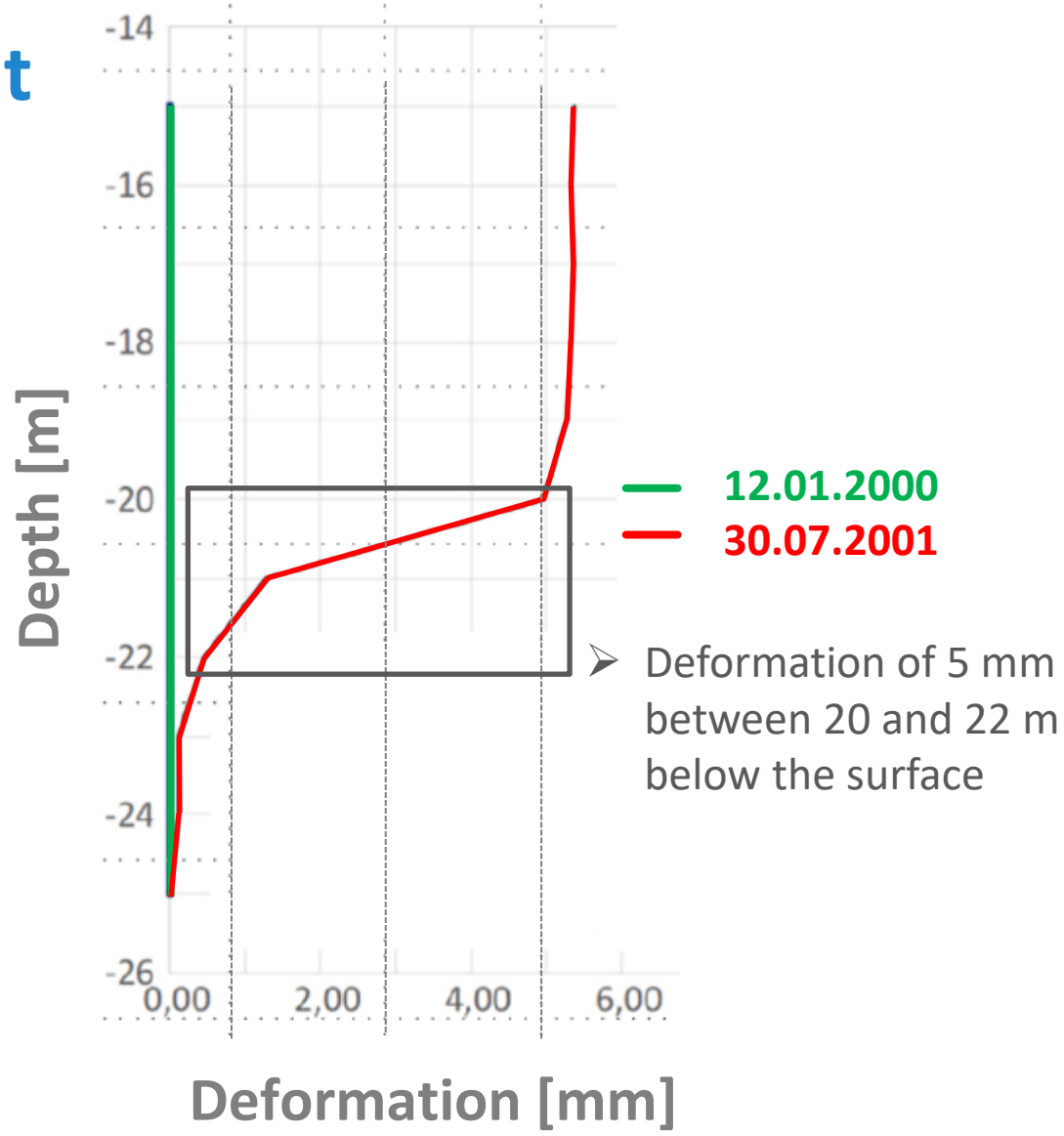
horizontal 0°120°240°



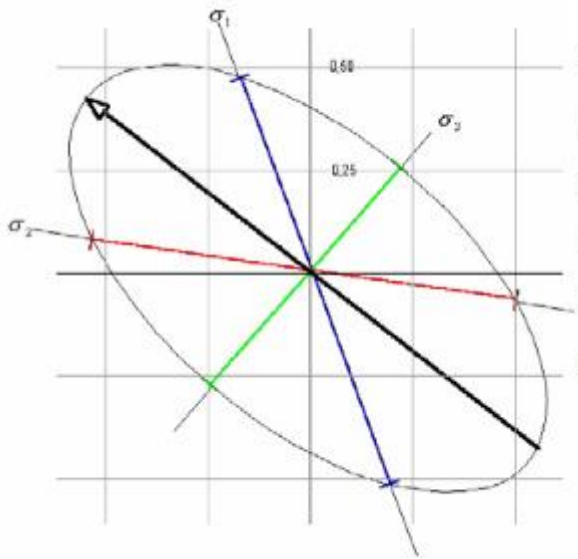
Stress Development



Inclinometer Measurement



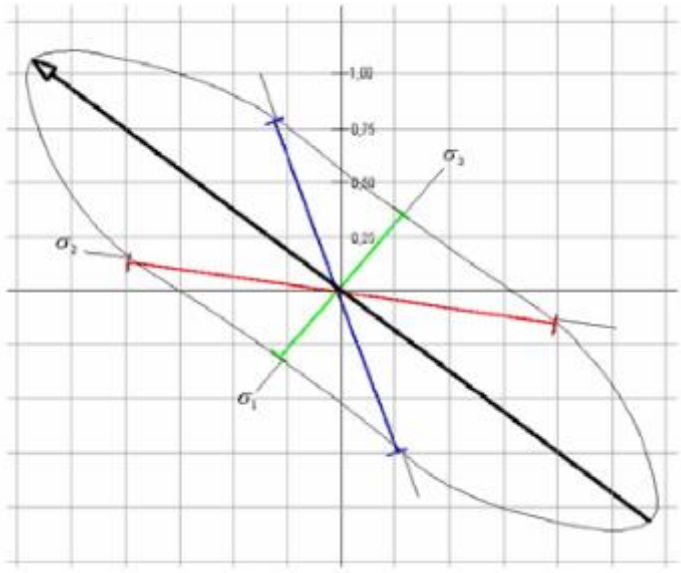
SMS 1
installed in lignite



SMS 1

26.06.00

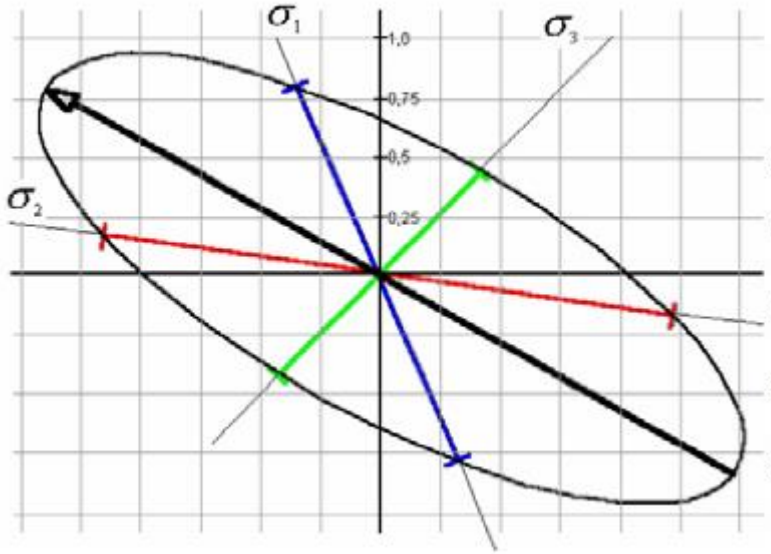
σ_1	0,50 *bar*
σ_2	0,48 *bar*
σ_3	0,31 *bar*
σ_m	0,72 *bar*
α_m	311°



SMS 1

11.12.00

σ_1	0,83 *bar*
σ_2	0,99 *bar*
σ_3	0,45 *bar*
σ_m	1,75 *bar*
α_m	306°



SMS 1

28.05.01

σ_1	0,88 *bar*
σ_2	1,12 *bar*
σ_3	0,55 *bar*
σ_m	1,5 *bar*
α_m	303°

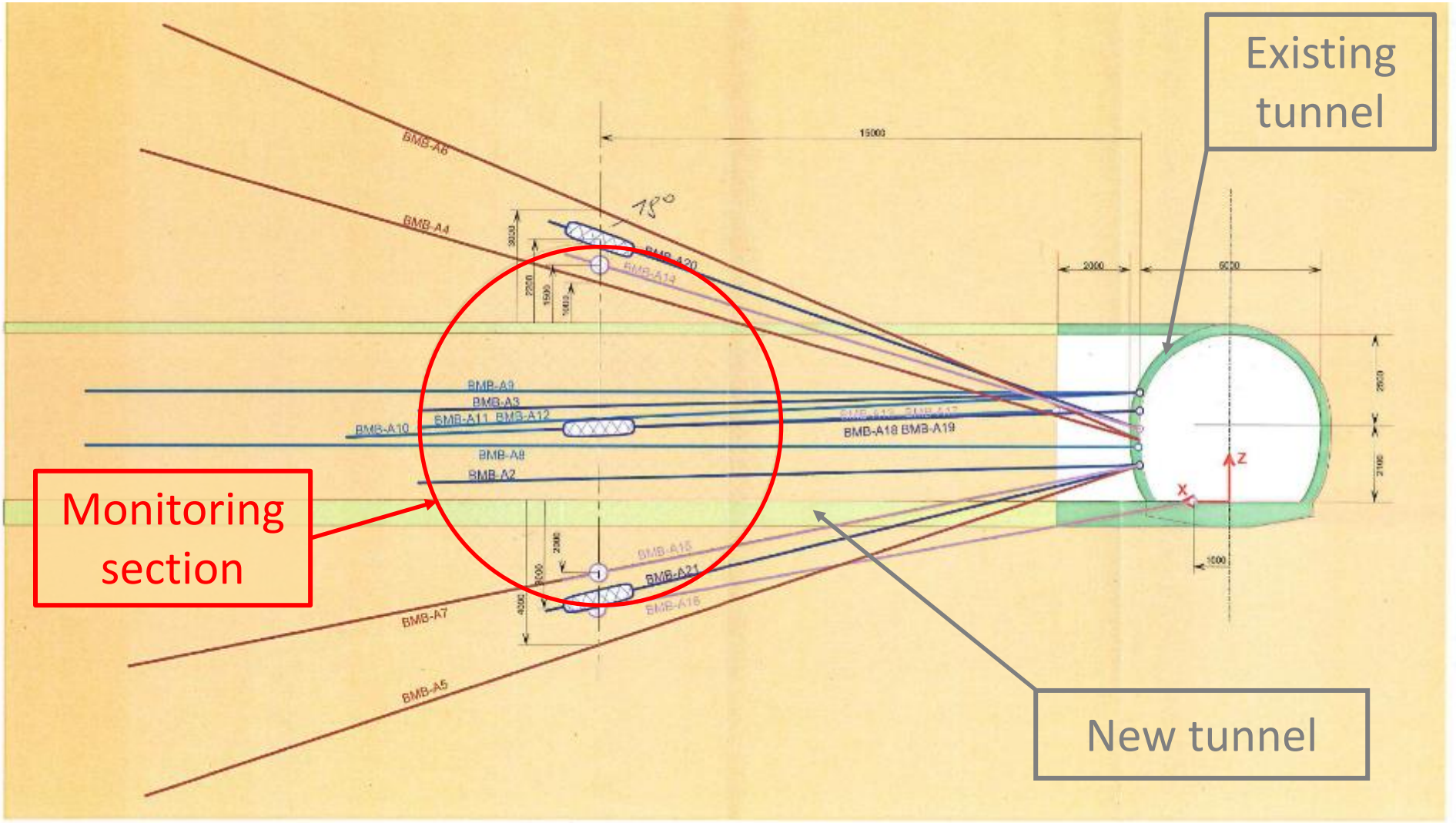
Principal stress changed due to excavation work

Application

Underground Laboratory

GLÖTZL

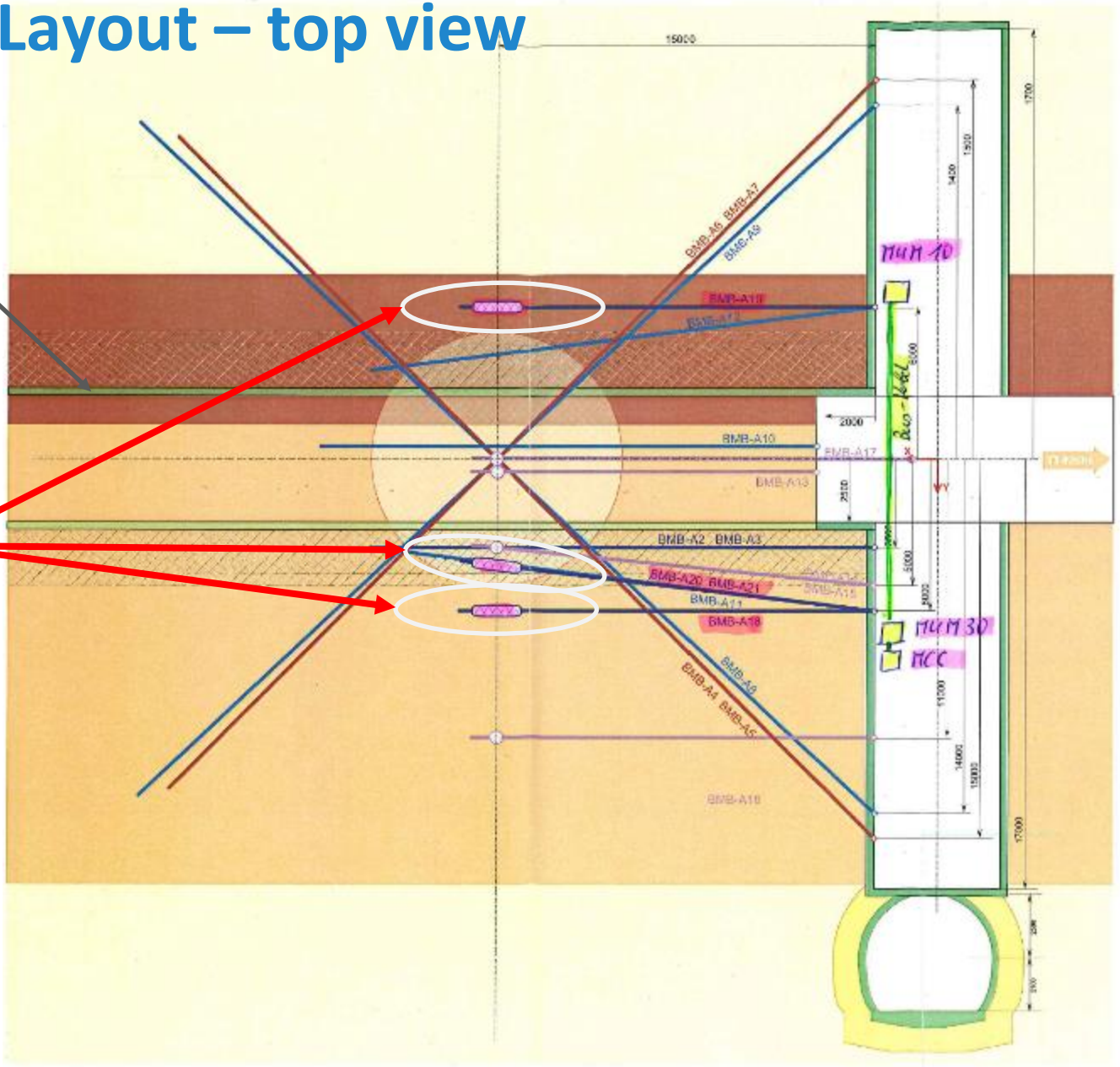
Monitoring Layout – sectional view



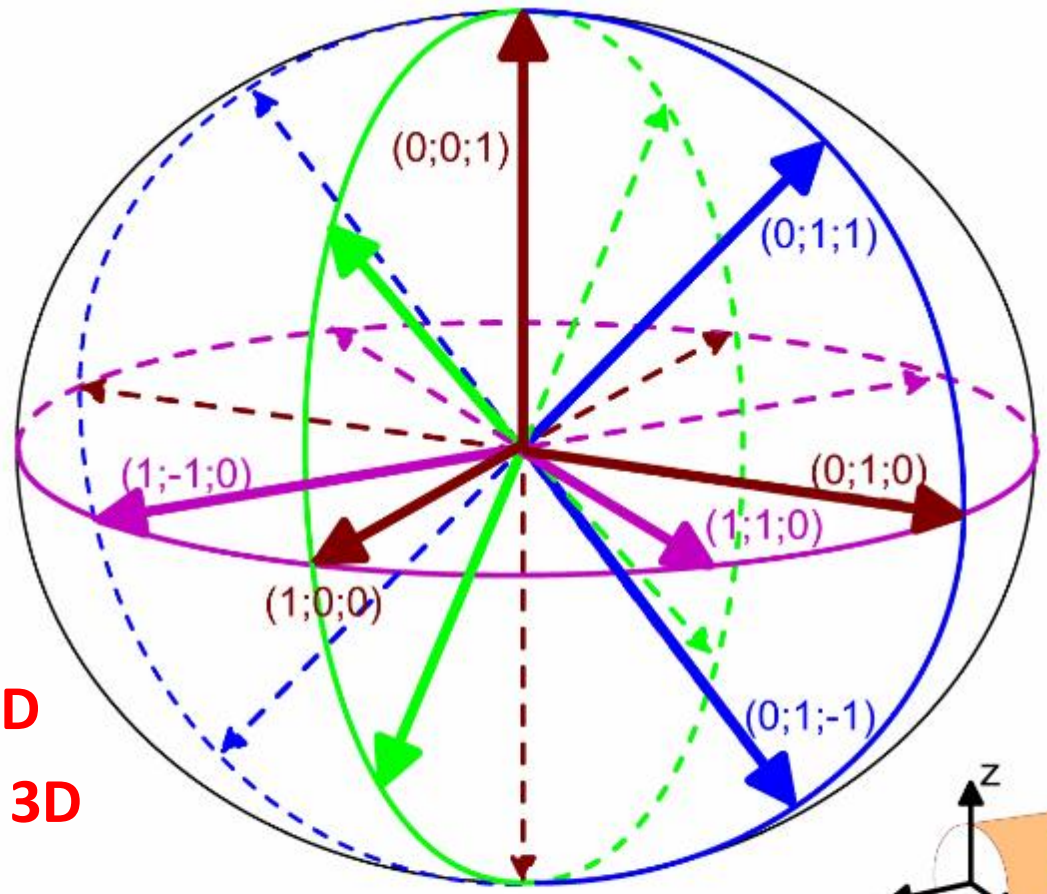
Monitoring Layout – top view

New tunnel

4x SMS
à 9 cells



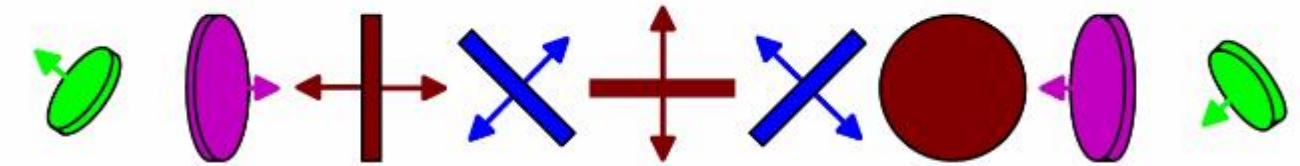
Measuring Directions



9 directed cells

⇒ 3 stress elipses 2D

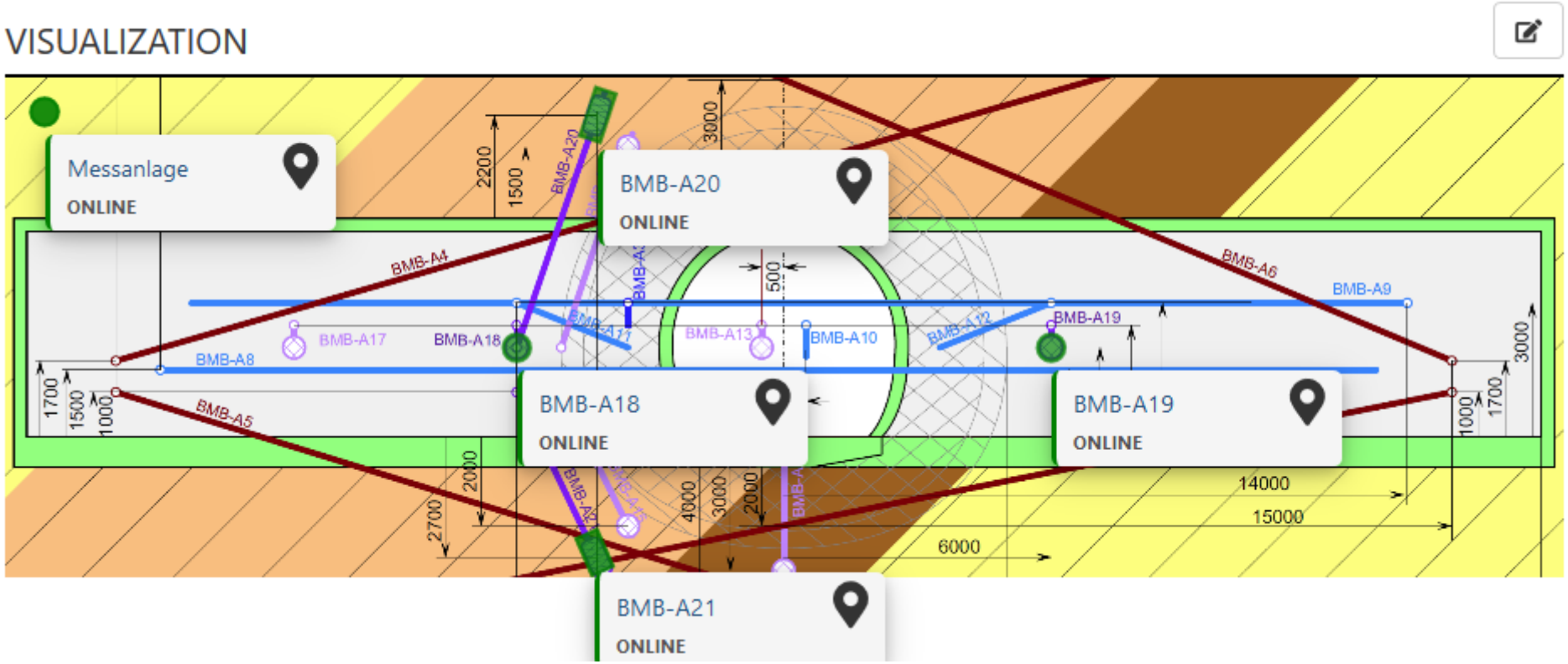
⇒ 1 stress ellipsoid 3D



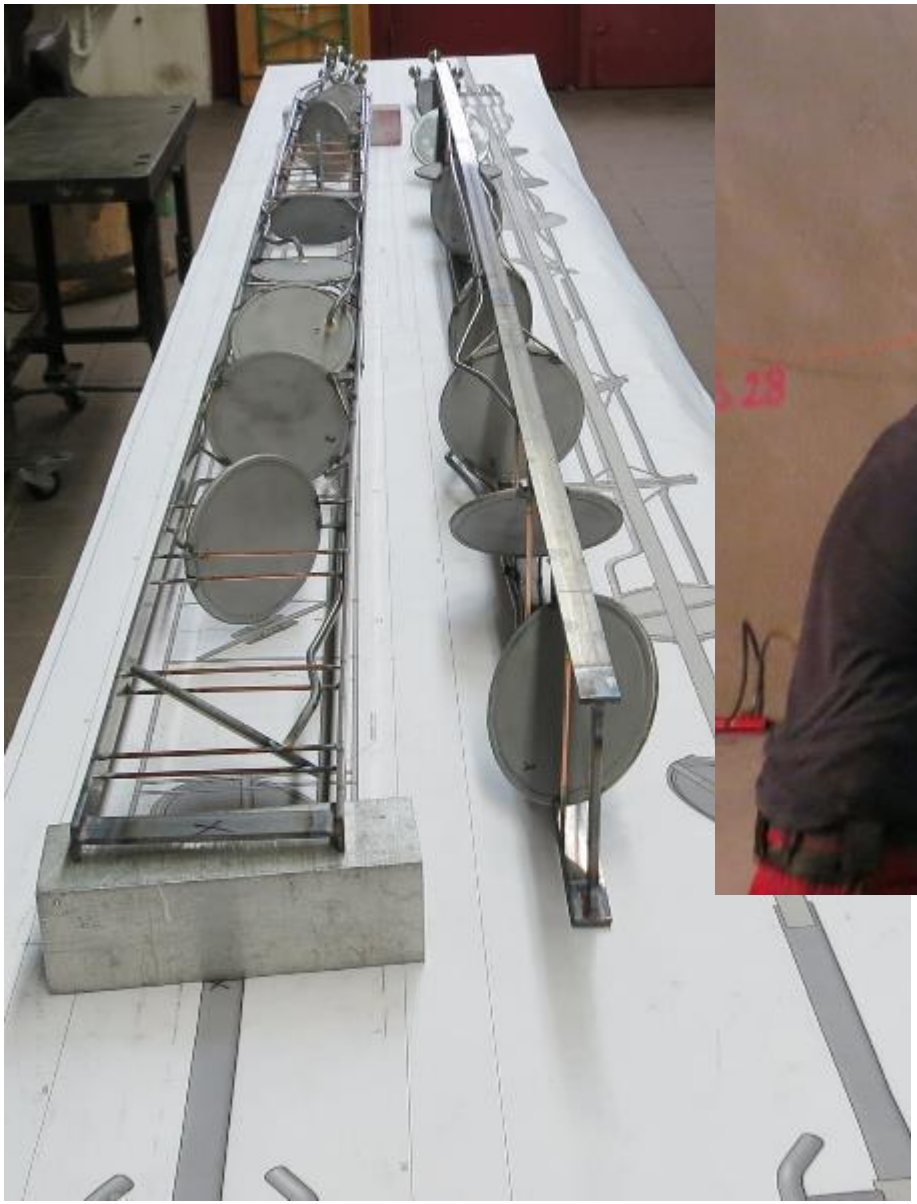
(1;0;1)	(1;-1;0)	(1;0;0)	(0;1;1)	(0;0;1)	(0;1;-1)	(0;1;0)	(1;1;0)	(1;0;-1)
(-1;0;-1)	(-1;1;0)	(-1;0;0)	(0;-1-1)	(0;0;-1)	(0;-1;1)	(0;-1;0)	(-1;-1;0)	(-1;0;1)

Mont Terri – Experiment

Plan of the monitoring setup with 4 Stress Monitoring Stations

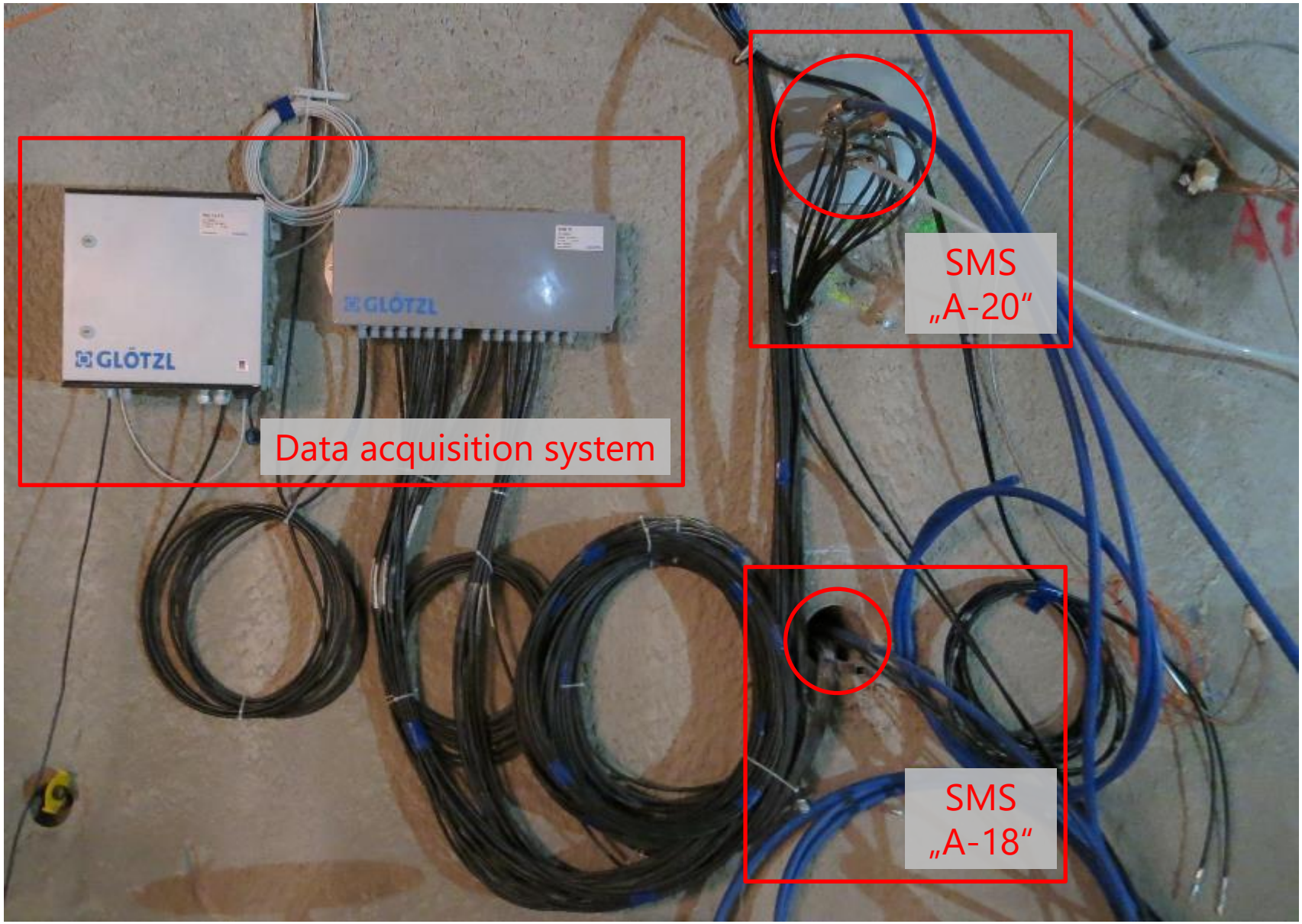


SMS – Installation

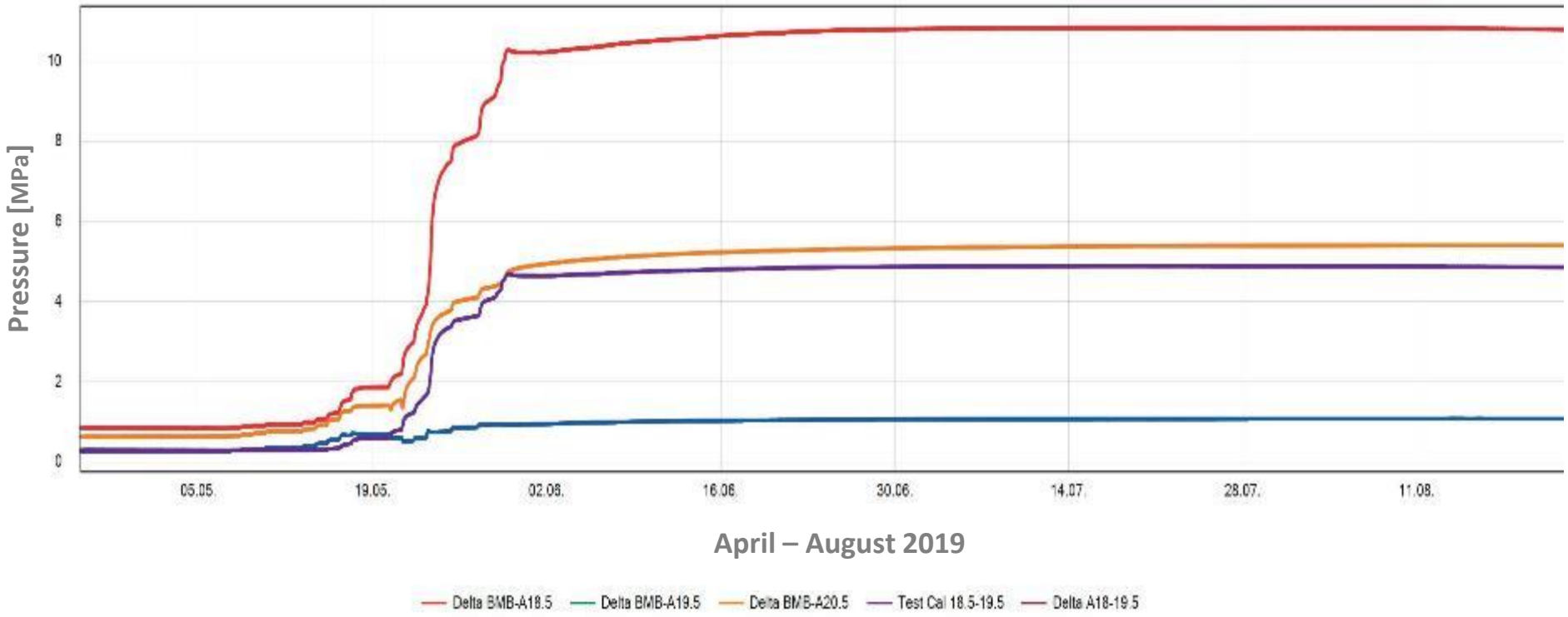


SMS – Installation

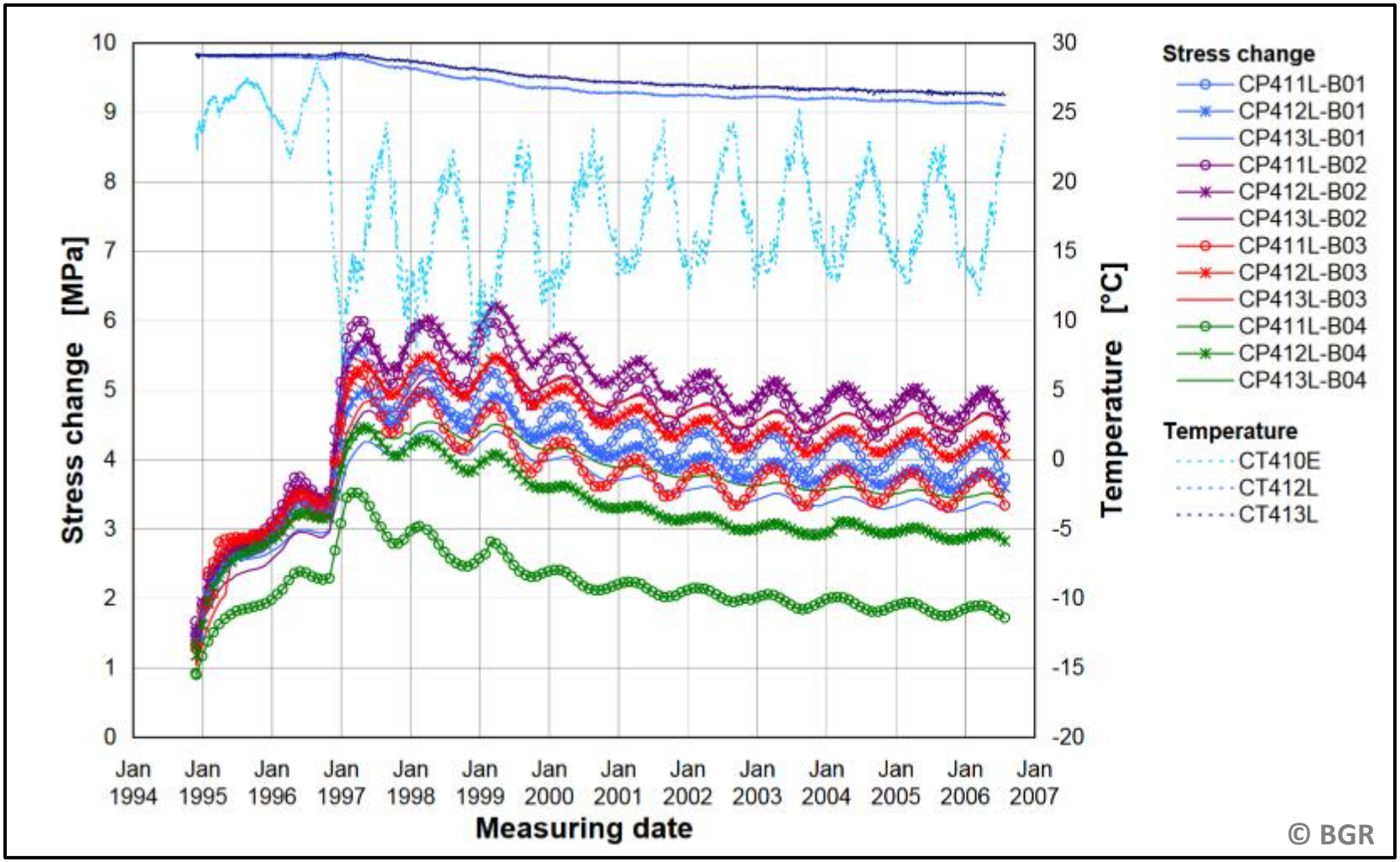
SMS – Installation



SMS – Data


Pressure [MPa]
10
8
6
4
2
0
05.05.
19.05.
02.06.
16.06.
30.06.
14.07.
28.07.
11.08.
April – August 2019
Delta BMB-A18.5
Delta BMB-A19.5
Delta BMB-A20.5
Test Cal 18.5-19.5
Delta A18-19.5

Long-term Test with Cyclic Temperature Loading



Strengths / Weaknesses

- Easy to install
- Sensitive instrument
- Long-term monitoring

- Soft/hard inclusion effect
- Secondary injection
- Absolute value n/a

GLÖTZL

schneider@gloetzl.com