

AFTES – Conférence 11 Juin 2009

Mécanique des roches et tunneliers

Experience Gained in Mechanical and Conventional Excavations in the Gotthard Base Tunnel, Switzerland

Presented by:

M.Sc. Rolf Stadelmann

Amberg Engineering Ltd., Regensdorf, Switzerland



Engineering Joint Venture Gotthard Base Tunnel South



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

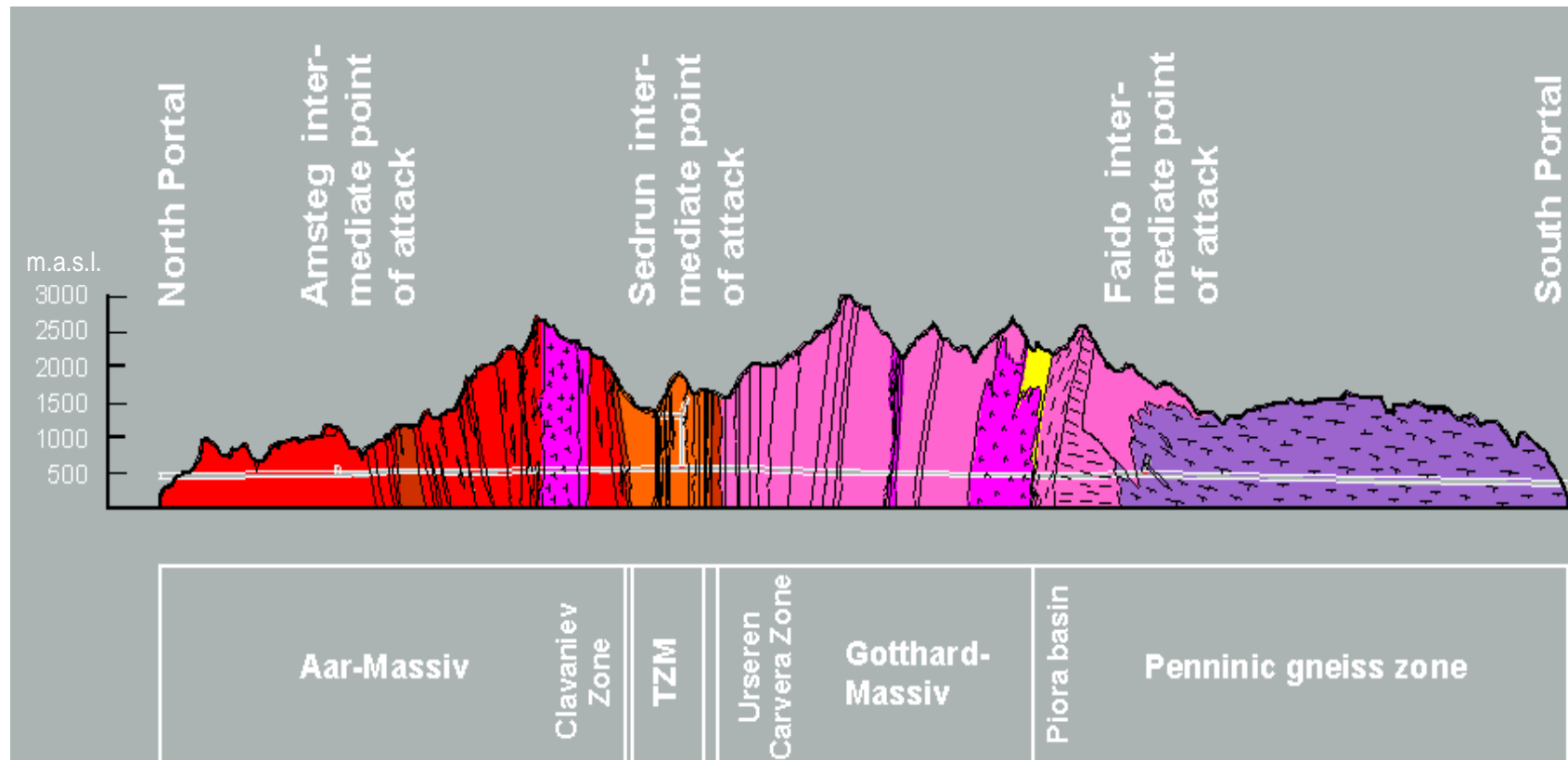
3.3 TBM Heading Piora Basin

4. Problems encountered during TBM heading

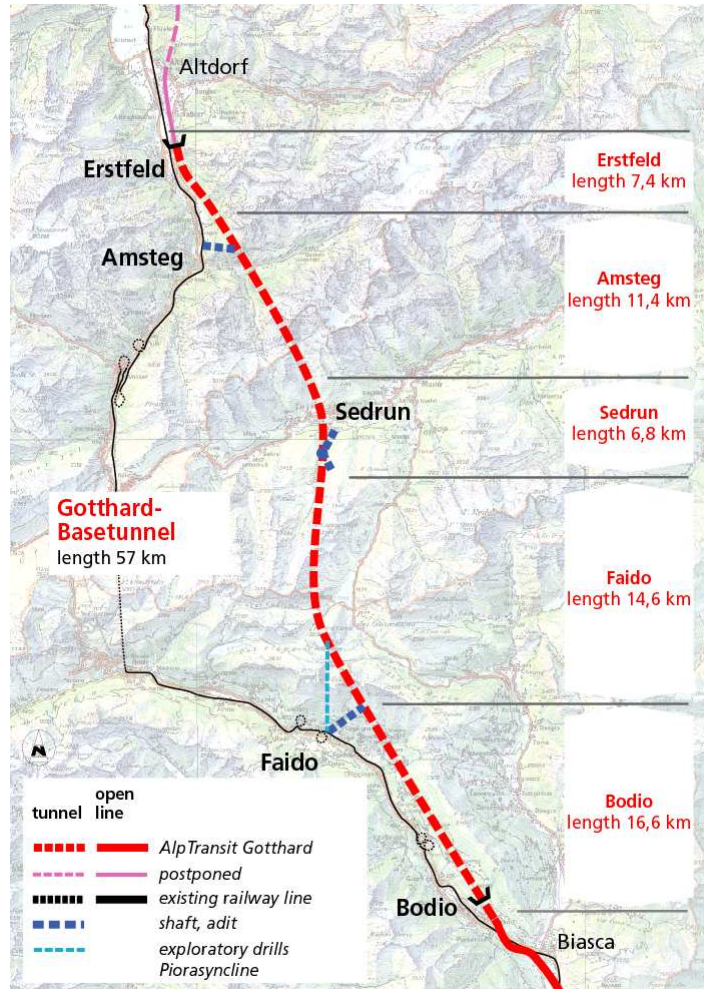
5. Interaction between two tubes



Gotthard Base Tunnel (GBT), Geological Longitudinal Profile



GBT, Alignment and Tunnel Lots



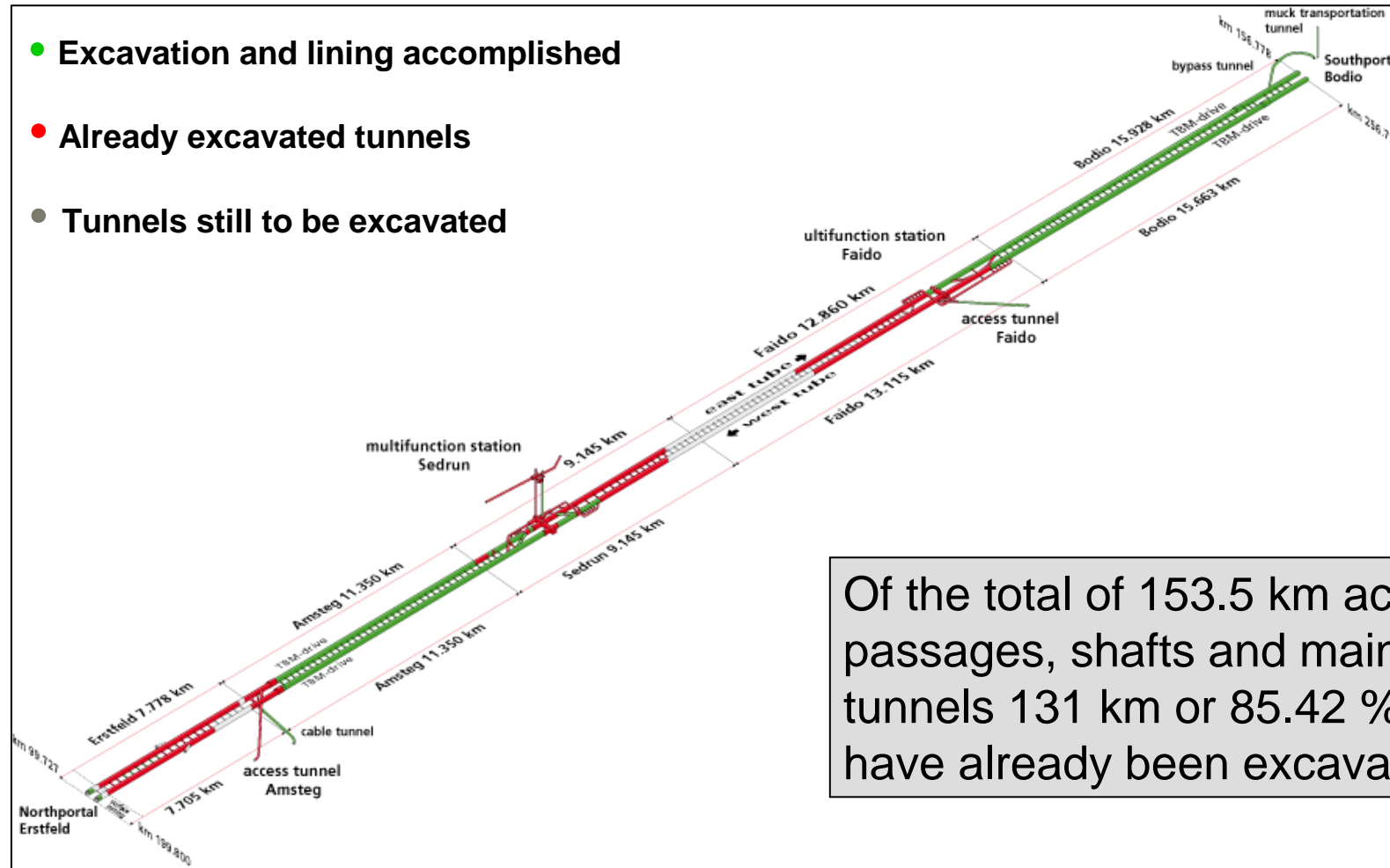
- Total length: 57 km
- Three intermediate points of attack
- Five construction sections



Engineering Joint Venture Gotthard Base Tunnel South

GBT, State of Excavations May 1st 2009

- Excavation and lining accomplished
- Already excavated tunnels
- Tunnels still to be excavated



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

3.3 TBM Heading Piora Basin

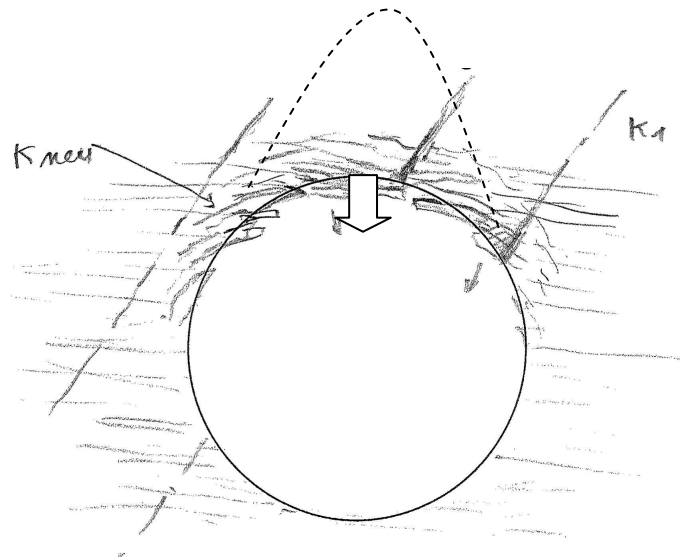
4. Problems encountered during TBM heading

5. Interaction between two tubes

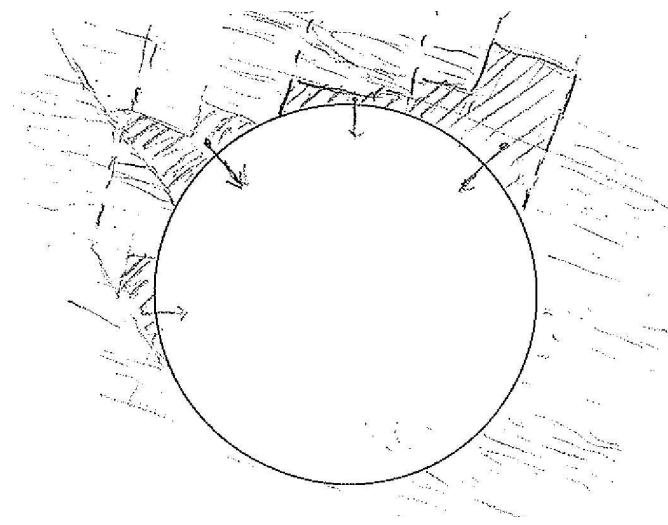


Hazard scenarios

Loosening of the ground

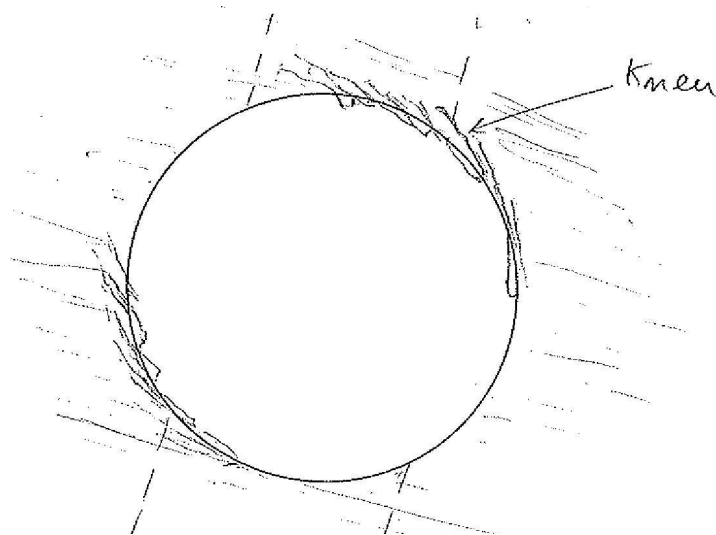


Detaching of wedges

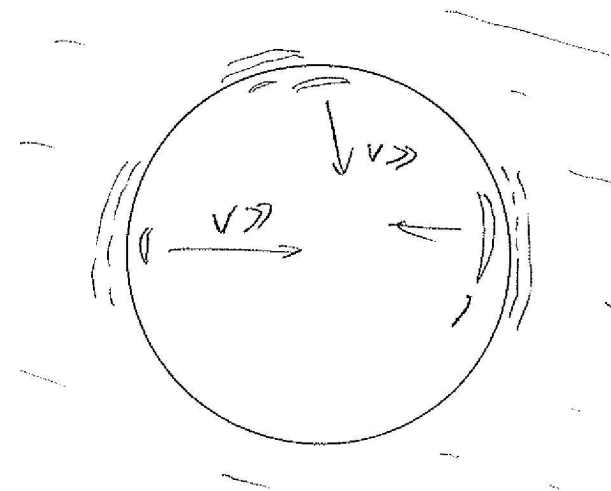


Hazard scenarios

Brittle failure, rock burst related phenomena



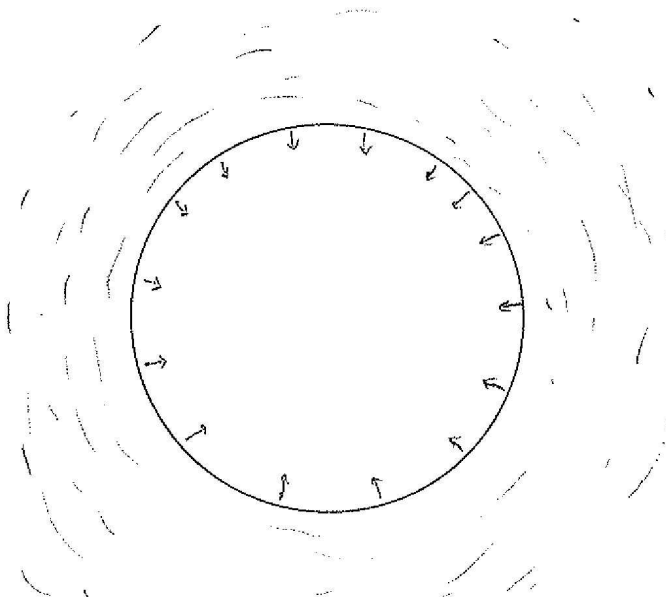
Rock burst



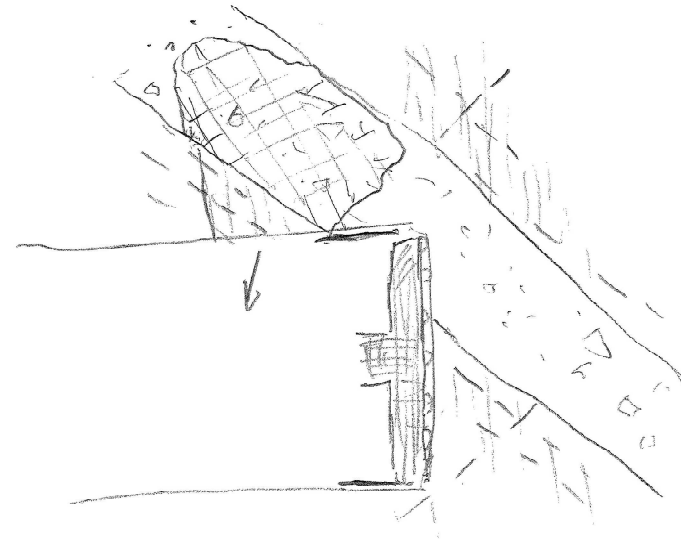
Engineering Joint Venture Gotthard Base Tunnel South

Hazard scenarios

Plastic deformation



Fault zones



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

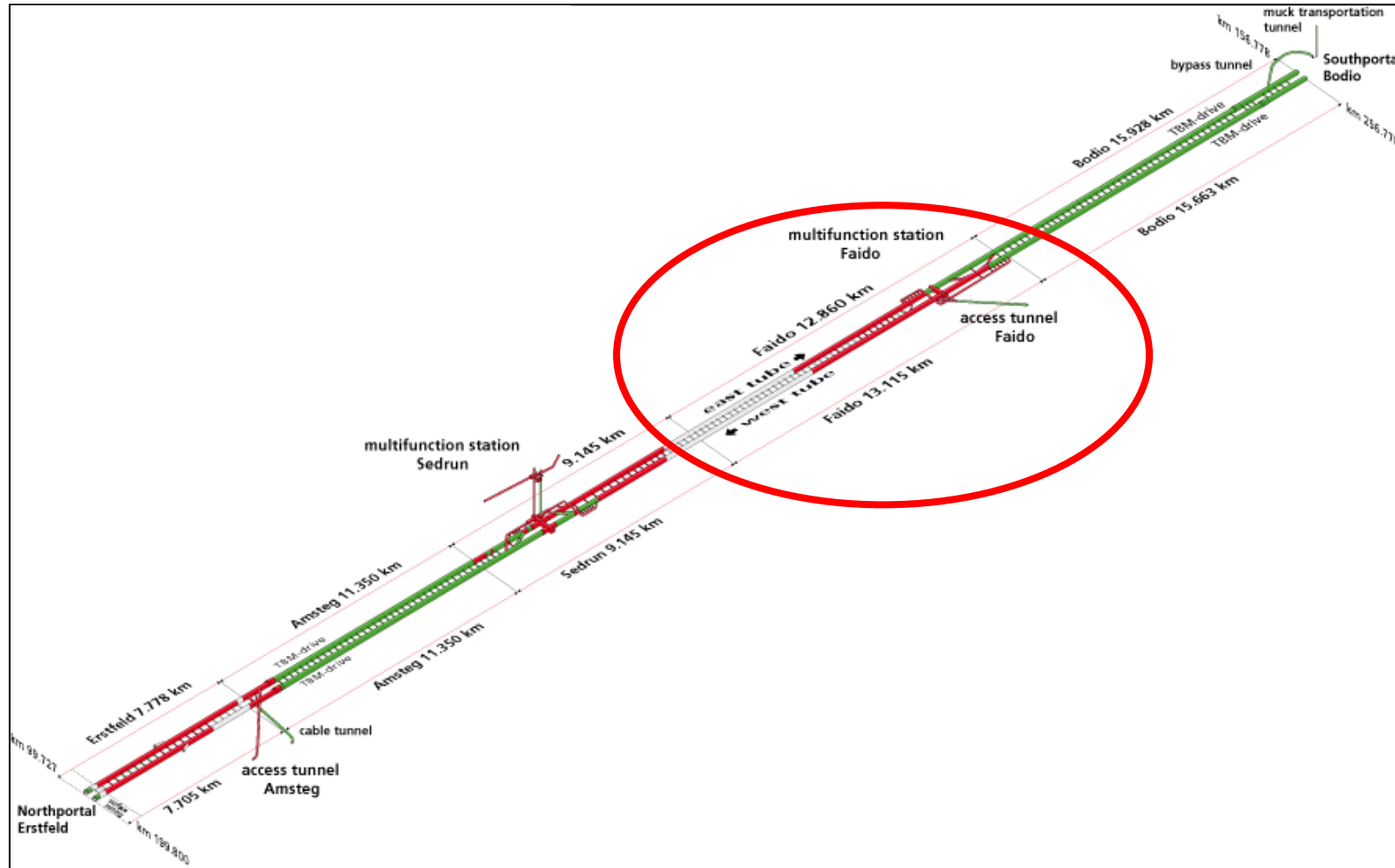
3.3 TBM Heading Piora Basin

4. Problems encountered during TBM heading

5. Interaction between two tubes



Construction Section Faido



AFTES Conférence "Mécanique des Roches et Tunneliers", Paris le 11 Juin 2009



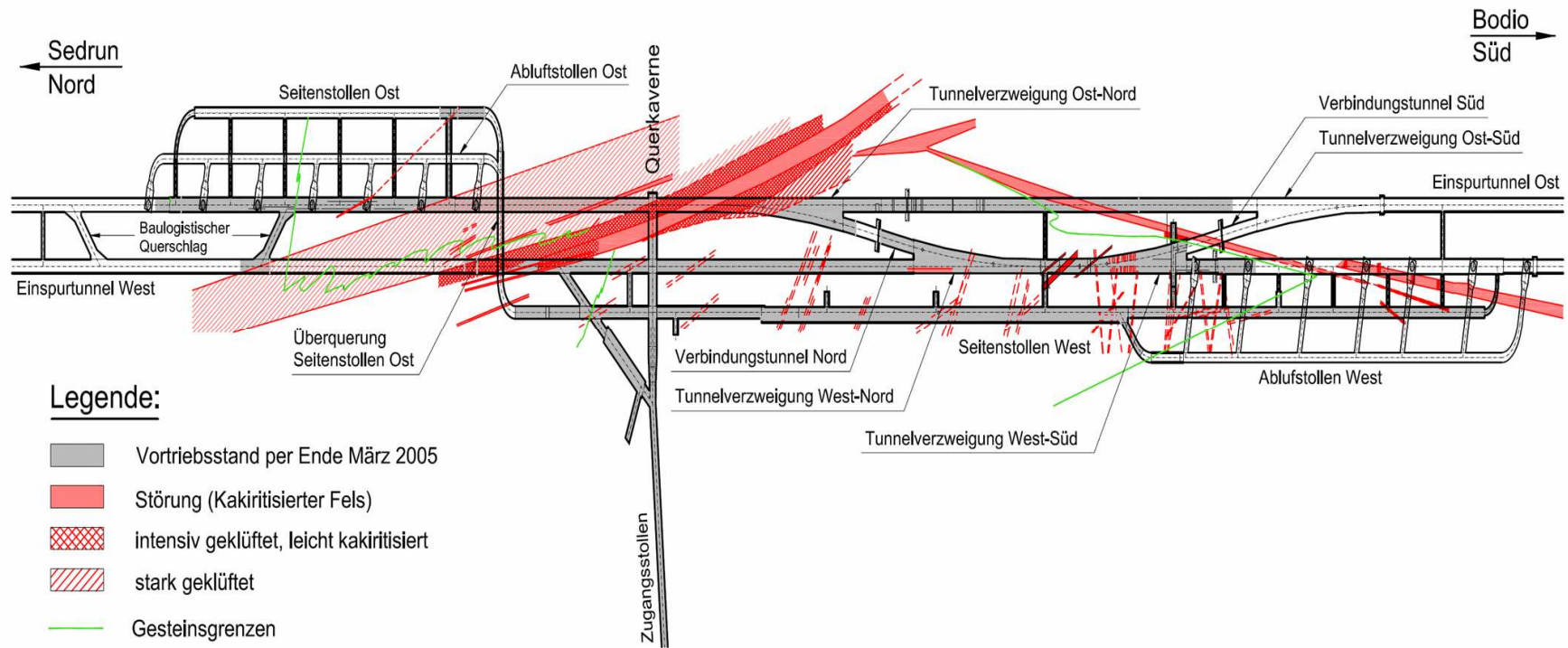
Multifunctional Station (MFS) Faido, Cross Cavern, Unexpected Downfall April 2002



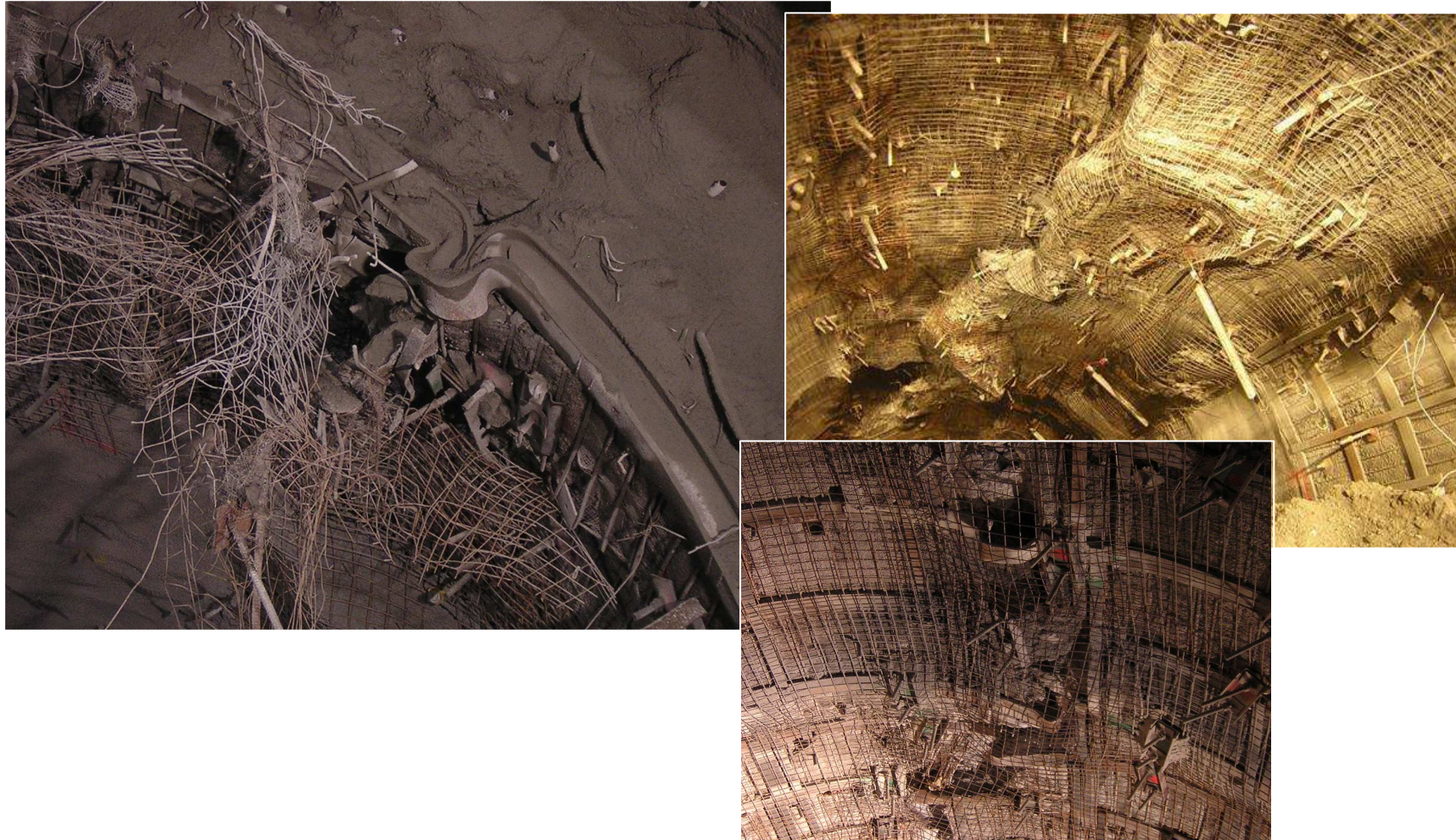
Engineering Joint Venture Gotthard Base Tunnel South



MFS Faido, Encountered Geology



Deformation of Steel Support



Deformation of Invert, Destroyed Steel Support

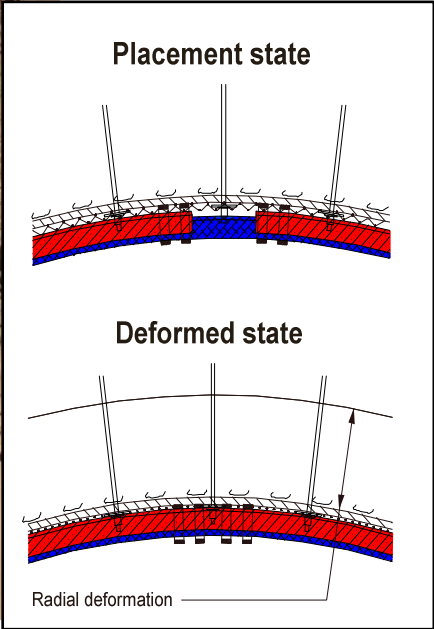


Engineering Joint Venture Gotthard Base Tunnel South

Flexible Lining Concept

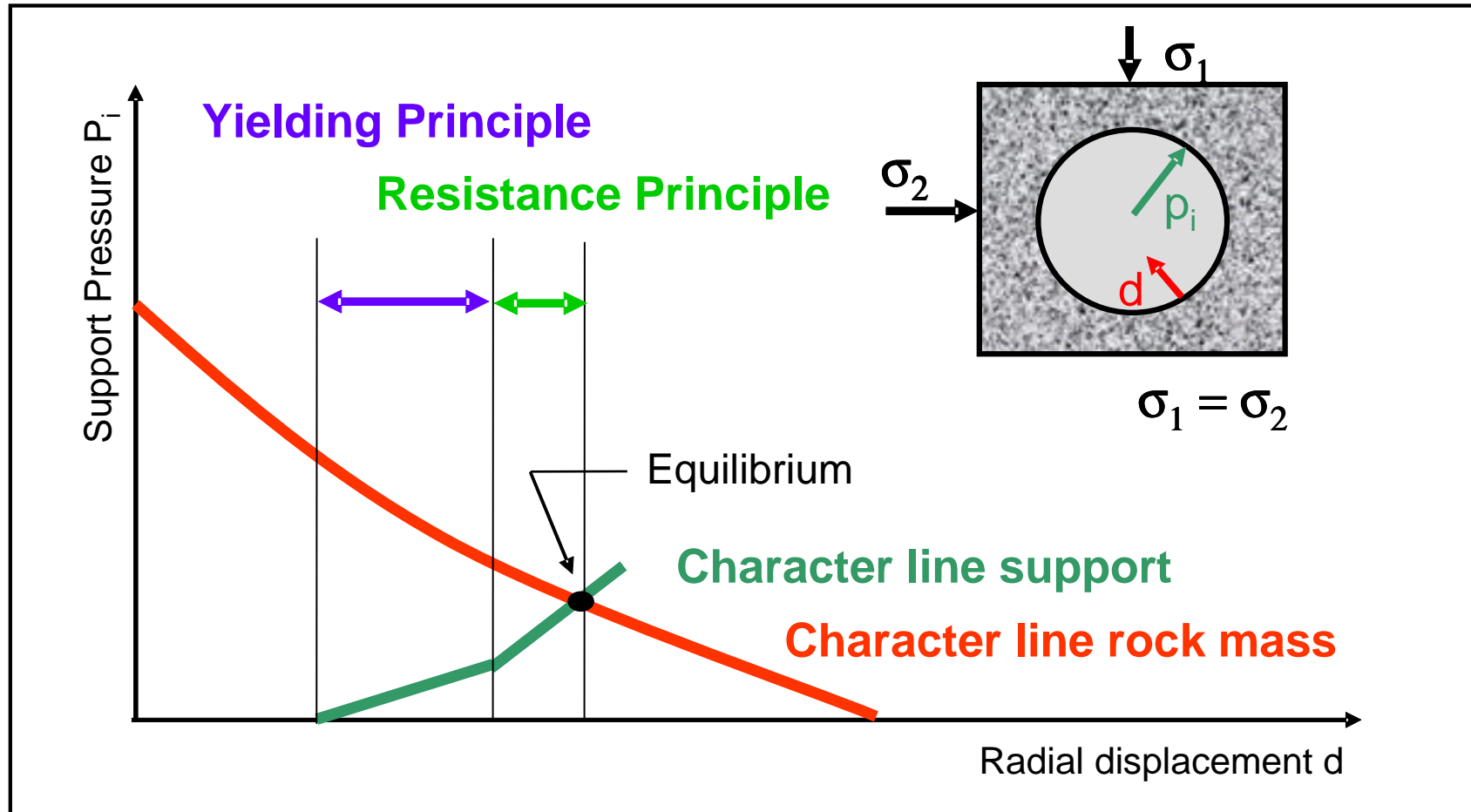


- Flexible steel arches
- Horizontal slits

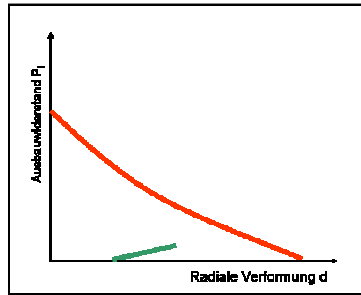


Engineering Joint Venture Gotthard Base Tunnel South

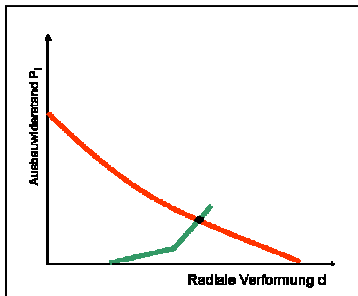
Characteristic Line Method



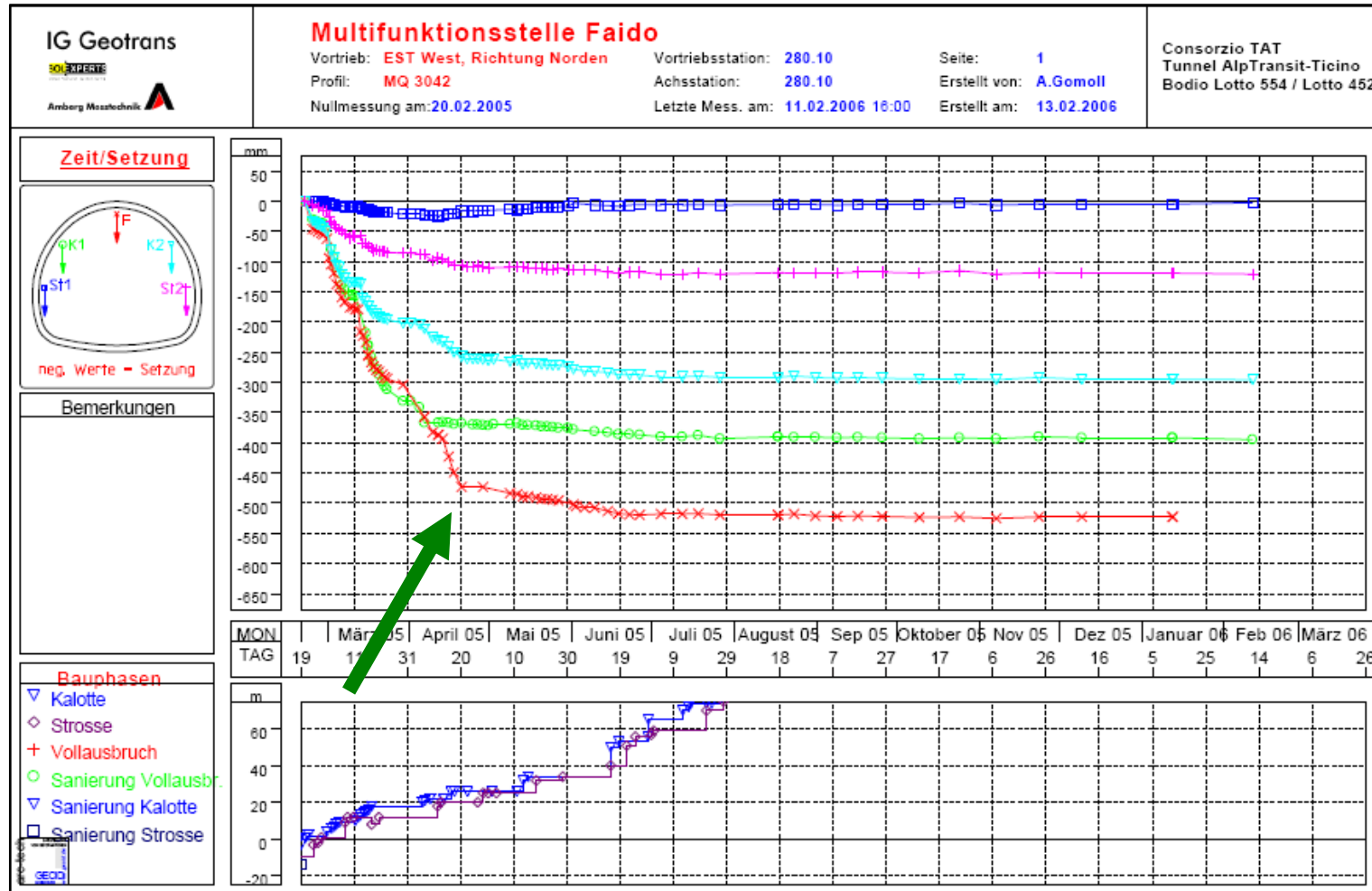
Example: applied method for Drill & Blast



Example: applied method for Drill & Blast



Time dependent deformation behaviour



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

3.3 TBM Heading Piora Basin

4. Problems encountered during TBM heading

5. Interaction between two tubes



TBM Heading in the Single-Track Tubes, TBM Data

Length

- TBM: 26 m
- Back-up installations: 450 m

TBM Cutter Head

- Diameter: 9.43 m
- Shifted: max. 9.53 m
- Weight: 240 t

Discs

- Number: 66
- Diameter: 43 cm



Section Faido, Start of the TBM in Northern Direction



- TBM East Tube:
July 2007
- TBM West Tube:
October 2007



Engineering Joint Venture Gotthard Base Tunnel South

Tunnel Faido: Geology, Support Elements

Start East TBM: July 2007

Start West TBM: October 2007

Encountered geology:

- subhorizontal layers of Lucomagno Gneiss

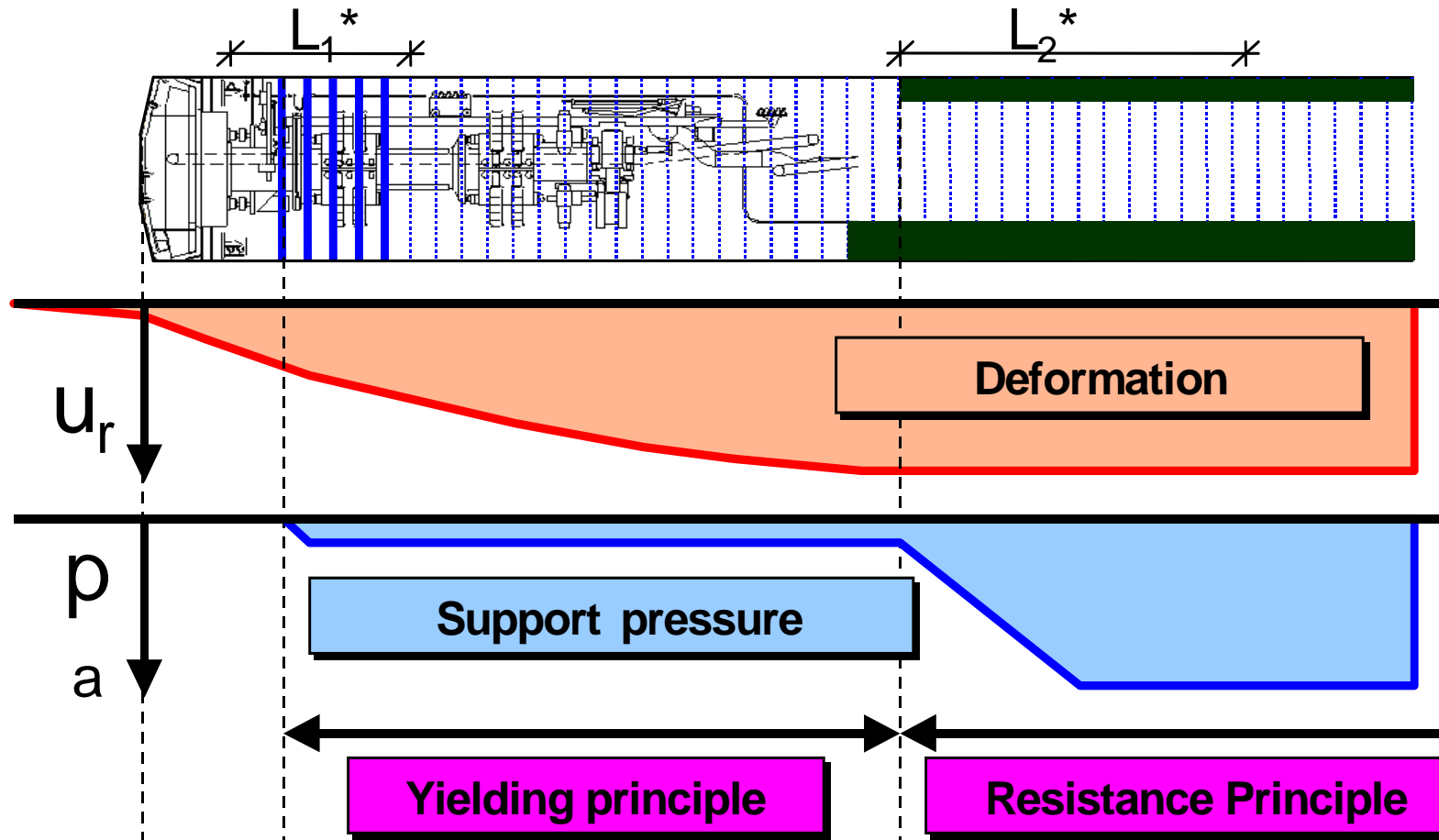
A yielding support system

- Shotcrete with slits
- Yielding steel arches
- Rock bolts

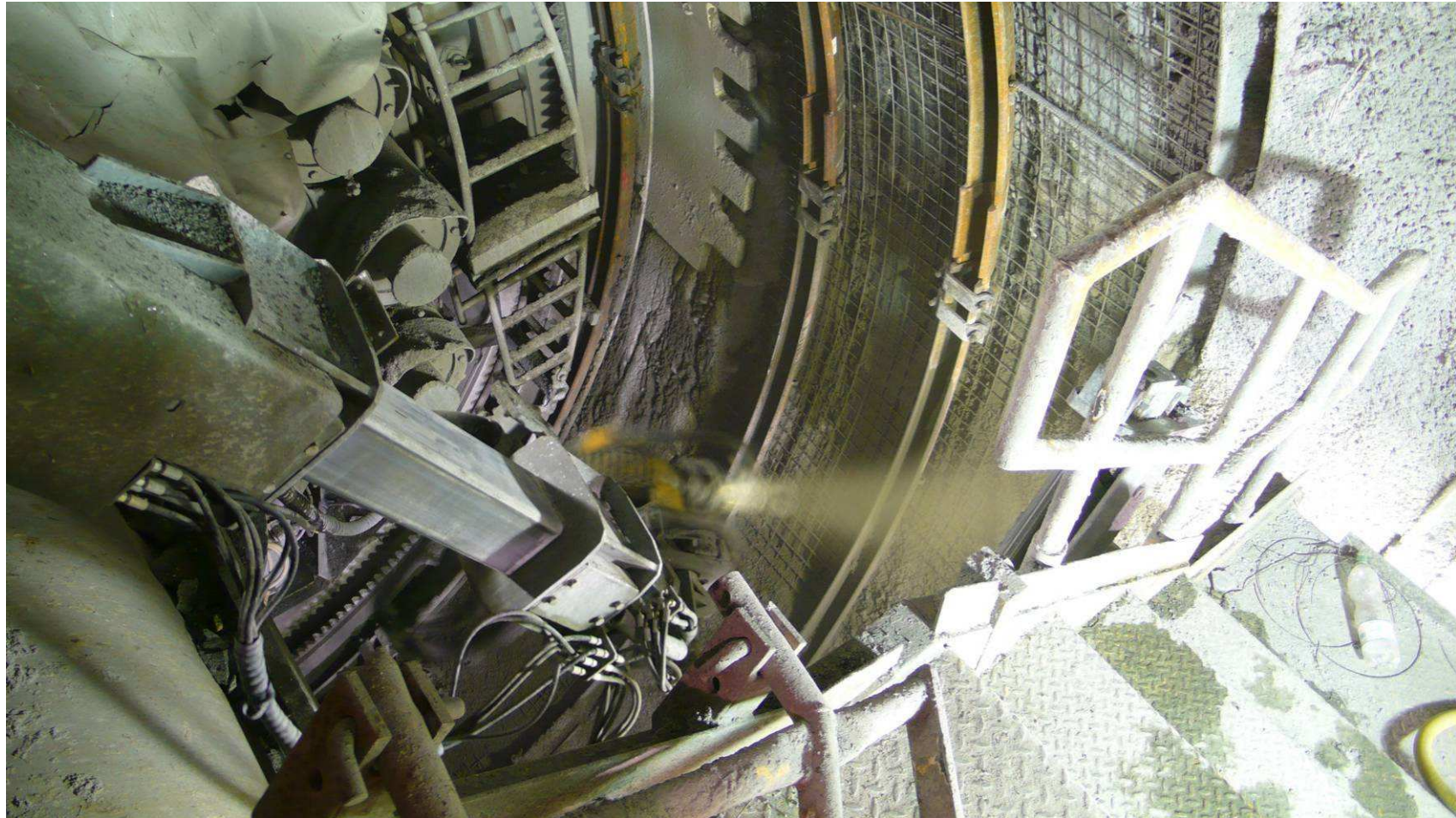
is installed



Rock Support Concept



Yielding Steel Arches



Engineering Joint Venture Gotthard Base Tunnel South



Tunnel Faido, Rock Support Concept

- Rock support measures behind cutter head required
- Second possibility only 65 m behind the face

East tube

- 8-16 rock bolts
- Steel arches @ 1m
- 15 cm shotcrete
- Low advance rate of approx 6.5 m/day



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

3.3 TBM Heading Piora Basin

4. Problems encountered during TBM heading

5. Interaction between two tubes



Piora Basin

- **Piora Basin:** Triassic deposit of Dolomite in the Gotthard Massif, inserted between Lucomagno Gneiss and Medelser Granite
- Extension approx. 150m
- Overburden approx. 1'800m
- Extensive investigations to explore geological conditions
- Four exploratory drillings showed solid Dolomite-Anhydrite-formations and no water pressure
- Additional measures: preventer protected core drillings up to 250 m



Piora Basin



Engineering Joint Venture Gotthard Base Tunnel South



Piora Basin, Preventer



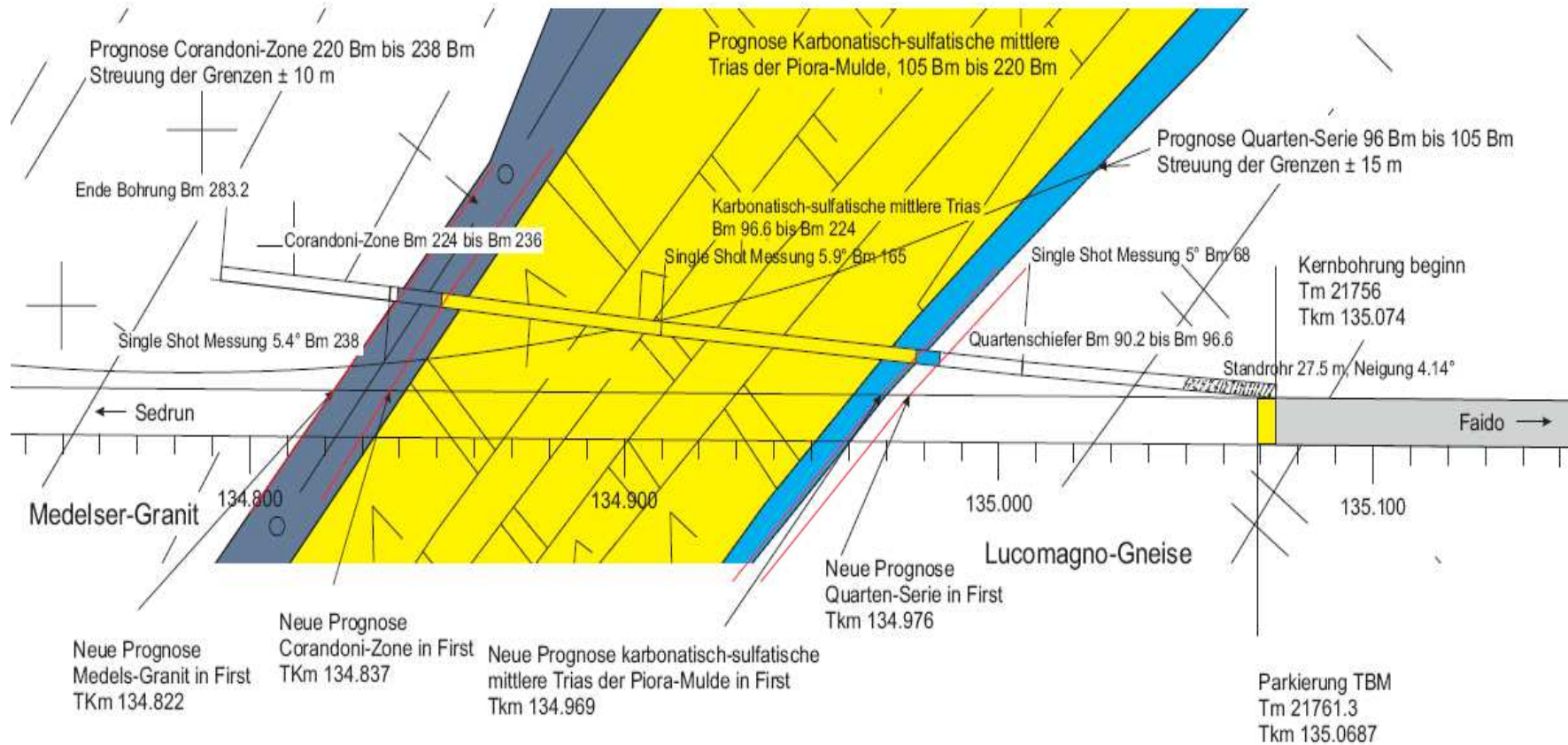
Preventer:

- Shear Preventer
- Pipe Ram
- Roto Pac



Engineering Joint Venture Gotthard Base Tunnel South

Piora Basin



Exploration - decision tree

Gotthard-Basistunnel
Los 452/554, Tunnel Faido

Vorauserkundung TBM-Vortrieb
Konzept

Ausführung

Bericht: R175/06.010 J
Amberg Engineering AG, Regensdorf, 22. Mai 2008

Seite 21 von 28
Regensdorf, 22. Mai 2008

6 ABLAUF VORAUSERKUNDUNG TBM FAIDO

Abbildung 2: Ablaufschema für die Vorauserkundung

© DBTS - Amberg Engineering AG

Exploration - decision tree

Systematic exploration

- Measure of temperature
- Tunnel Seismic prediction
- Percussion drilling
- Protected with preventer

Depending on the results excavation

Additional exploration

- Borlog scanning
- additional percussion drilling
- Core drilling
- Protected with preventer

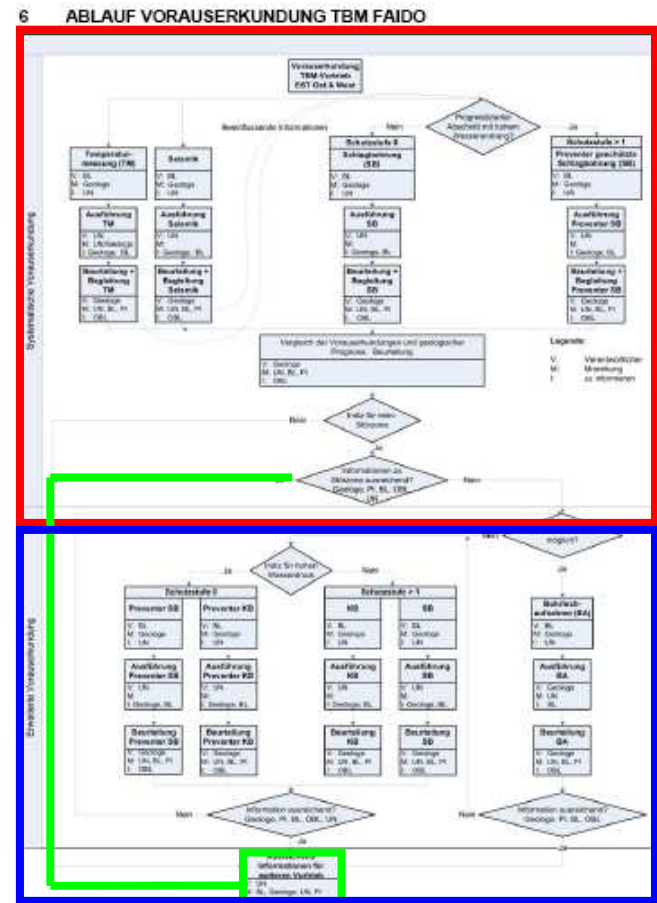
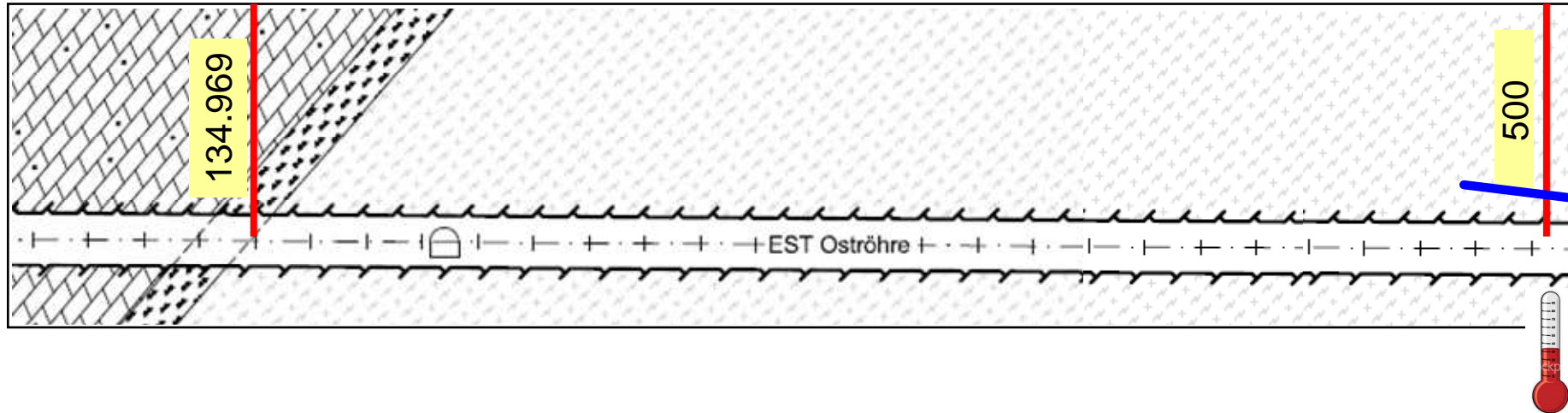


Abbildung 2: Ablaufschema für die Vorauserkundung

Exploration – approach of Piora Basin

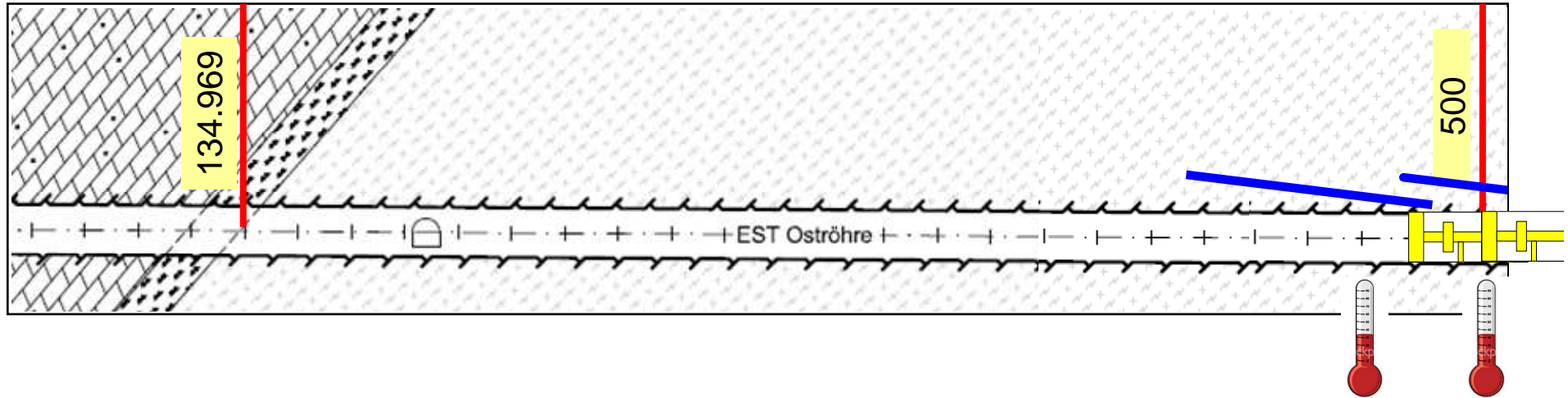


500 m / 450 m / 400 m / 350 m to Piora

- Intensify measurements of temperature



Exploration – approach of Piora Basin

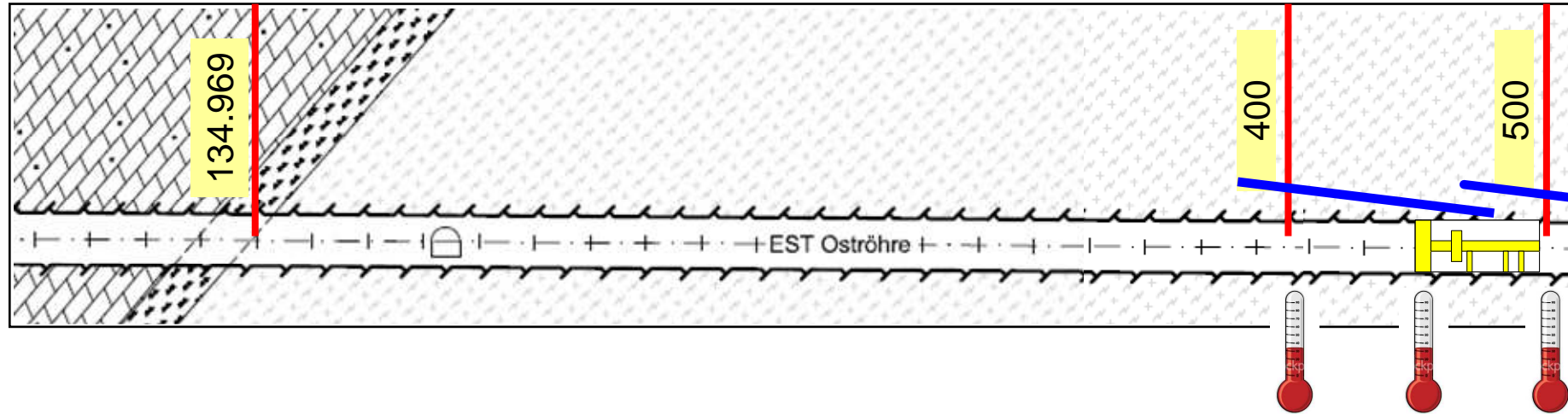


500 m / 450 m / 400 m / 350 m to Piora

- Intensify measurements of temperature



Exploration – approach of Piora Basin

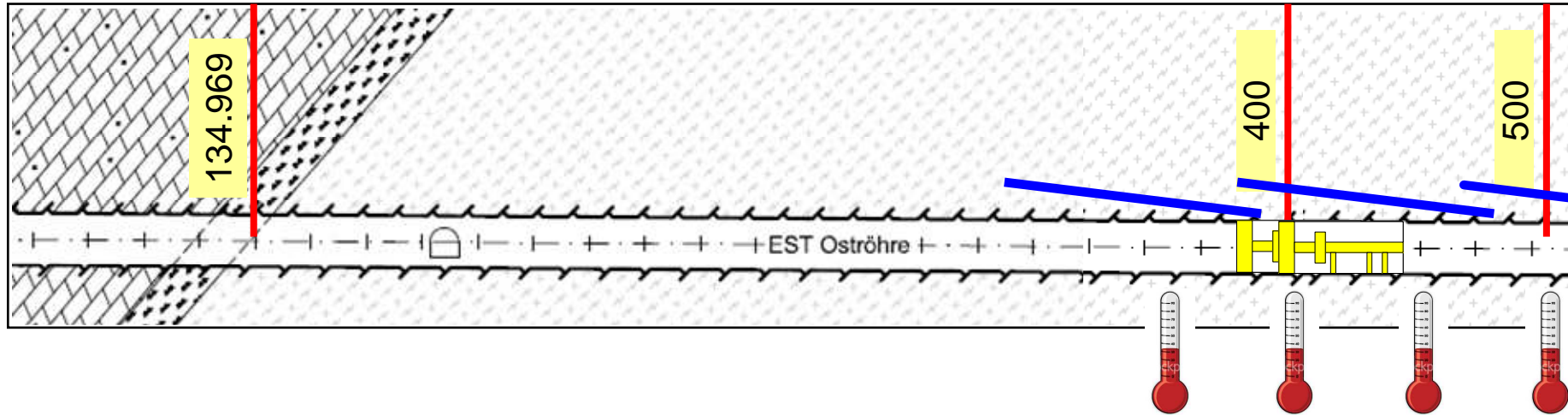


500 m / 450 m / 400 m / 350 m to Piora

- Intensify measurements of temperature



Exploration – approach of Piora Basin

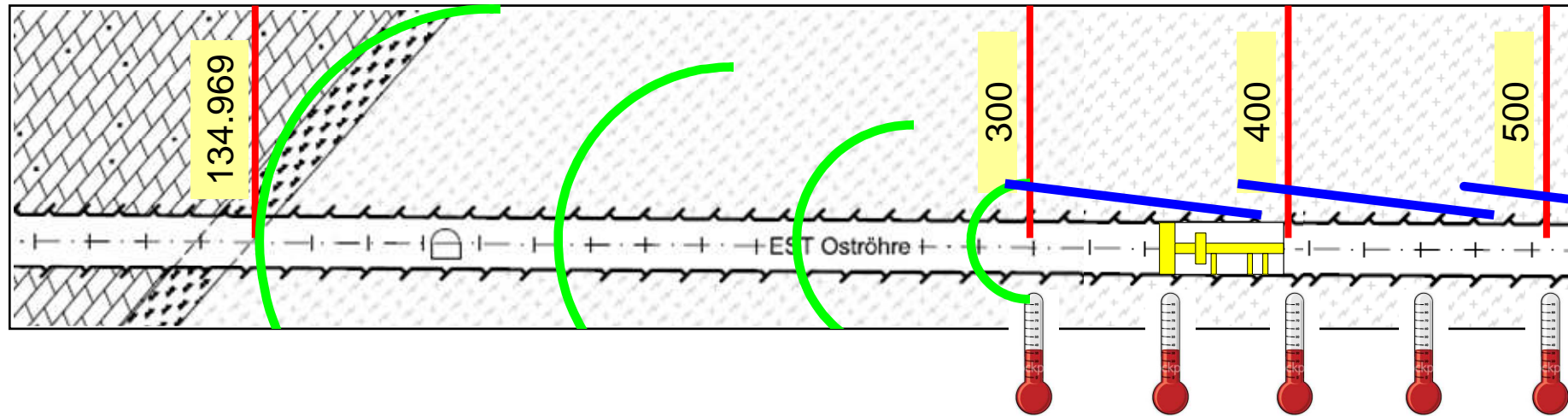


500 m / 450 m / 400 m / 350 m to Piora

- Intensify measurements of temperature



Exploration – approach of Piora Basin



500 m / 450 m / 400 m / 350 m to Piora

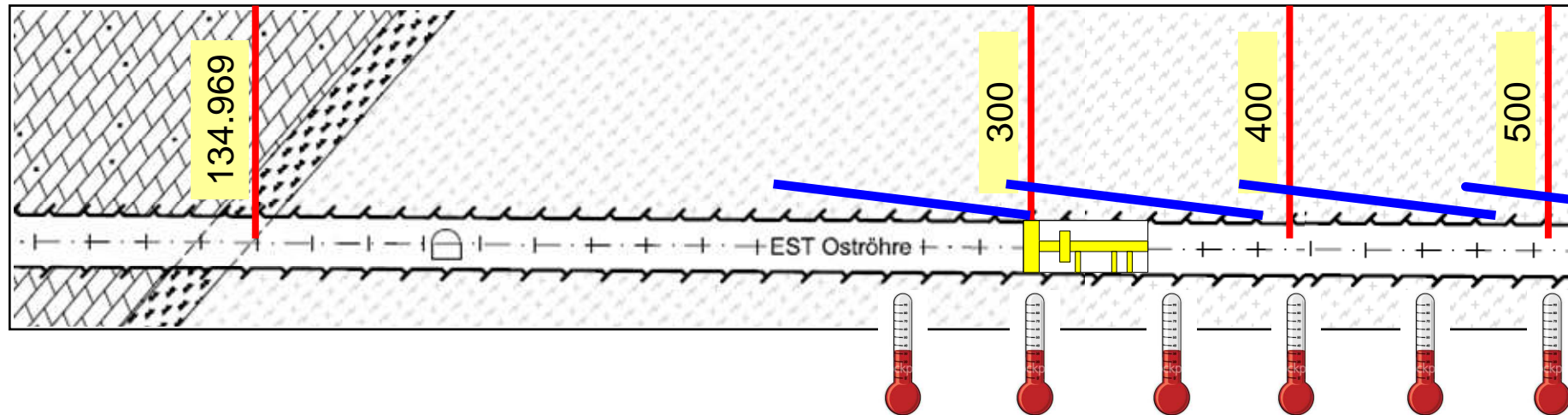
- Intensify measurements of temperature

300 m to Piora

- Additional measurement of temperature
- Tunnel seismic prediction



Exploration – approach of Piora Basin

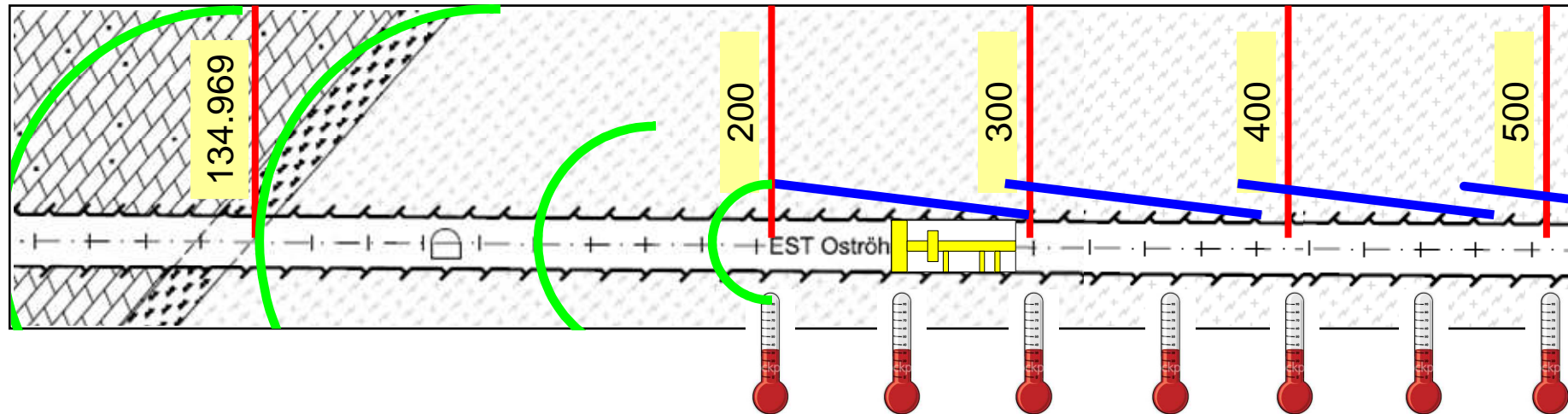


250 m / 200 m / 150 m / 100 m to Piora

- Additional measurement of temperature
- At 200 m: - tunnel seismic prediction
- At 150 m: - overlapping percussion drilling: 50 m
- At 100 m: - drillings with Preventer
- tunnel seismic prediction



Exploration – approach of Piora Basin

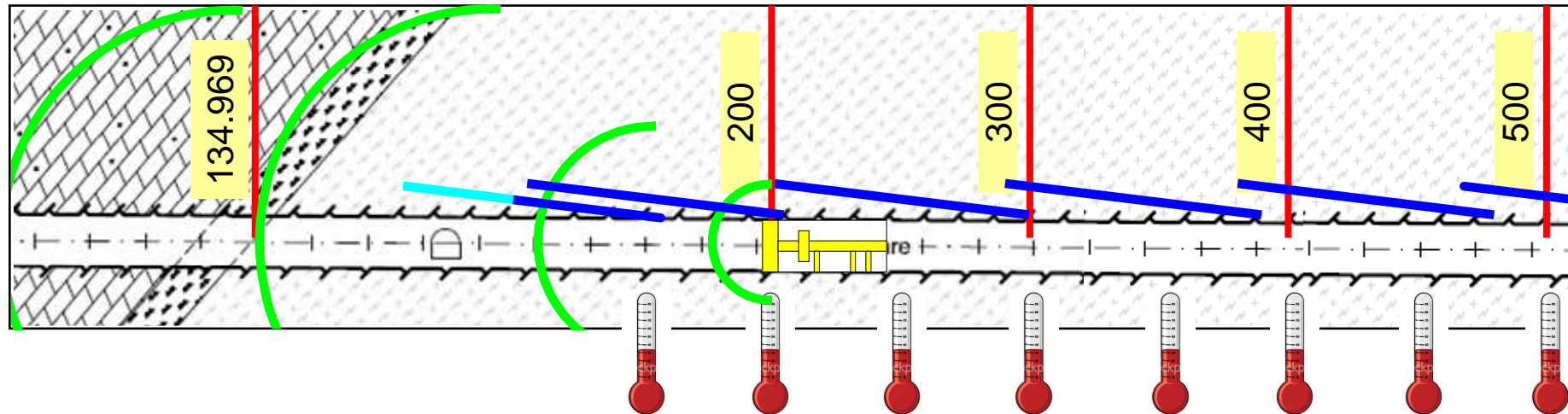


250 m / 200 m / 150 m / 100 m to Piora

- Additional measurement of temperature
- At 200 m: - tunnel seismic prediction
- At 150 m: - overlapping percussion drilling: 50 m
- At 100 m: - drillings with Preventer
- tunnel seismic prediction



Exploration – approach of Piora Basin

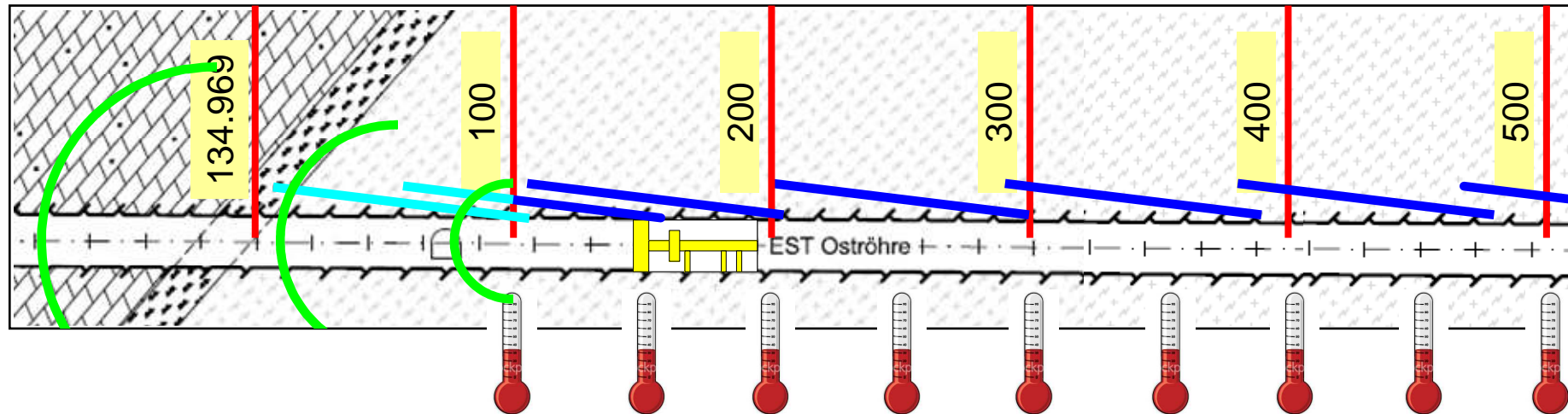


250 m / 200 m / 150 m / 100 m to Piora

- Additional measurement of temperature
- At 200 m: - tunnel seismic prediction
- At 150 m: - overlapping percussion drilling: 50 m
- At 100 m: - drillings with Preventer
- tunnel seismic prediction



Exploration – approach of Piora Basin

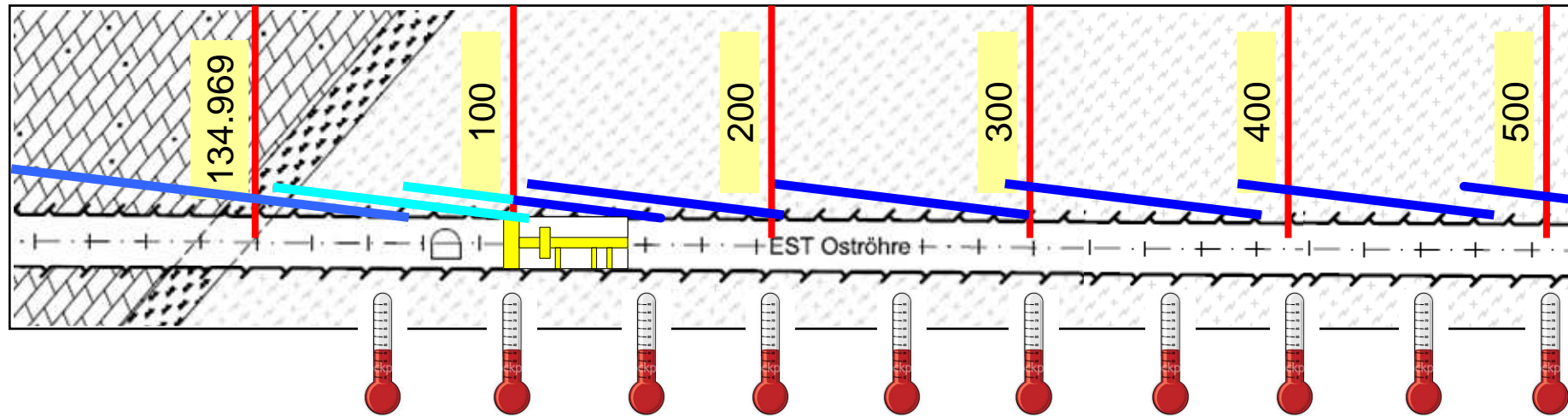


250 m / 200 m / 150 m / 100 m to Piora

- Additional measurement of temperature
- At 200 m: - tunnel seismic prediction
- At 150 m: - overlapping percussion drilling: 50 m
- At 100 m: - drillings with Preventer
- tunnel seismic prediction



Exploration – approach of Piora Basin



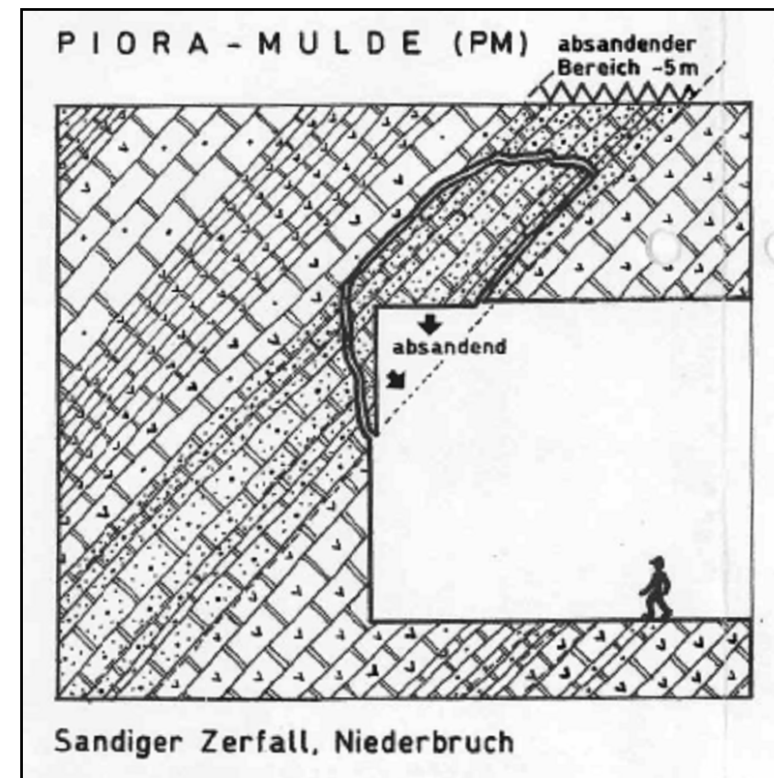
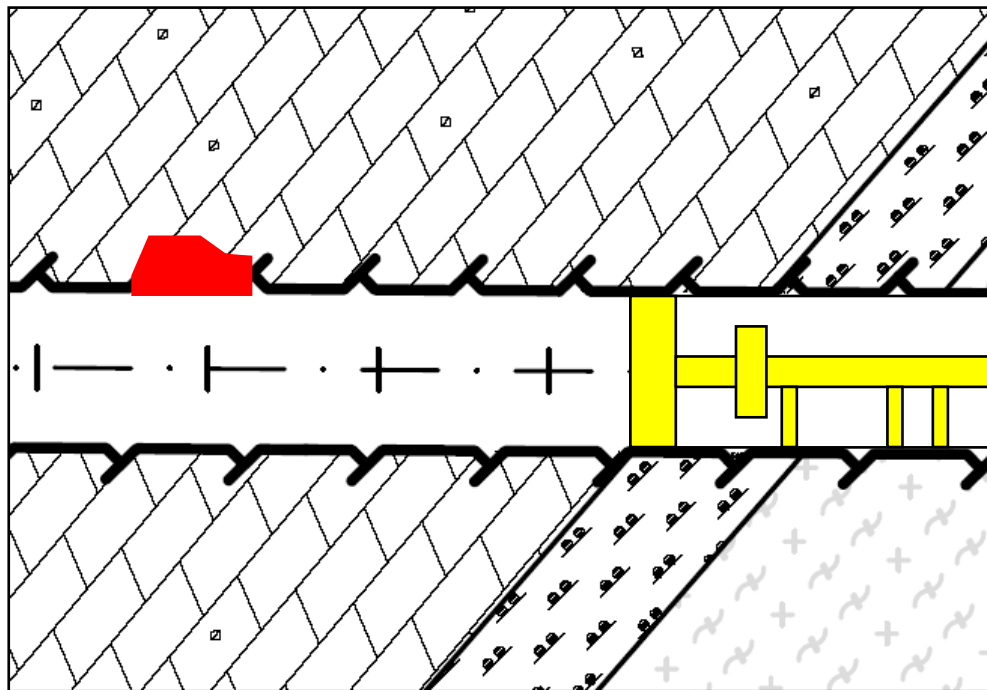
50 m to Piora (Tkm 135.019)

- Additional measurements of temperature
- Intended stop
- Core drilling through Piora



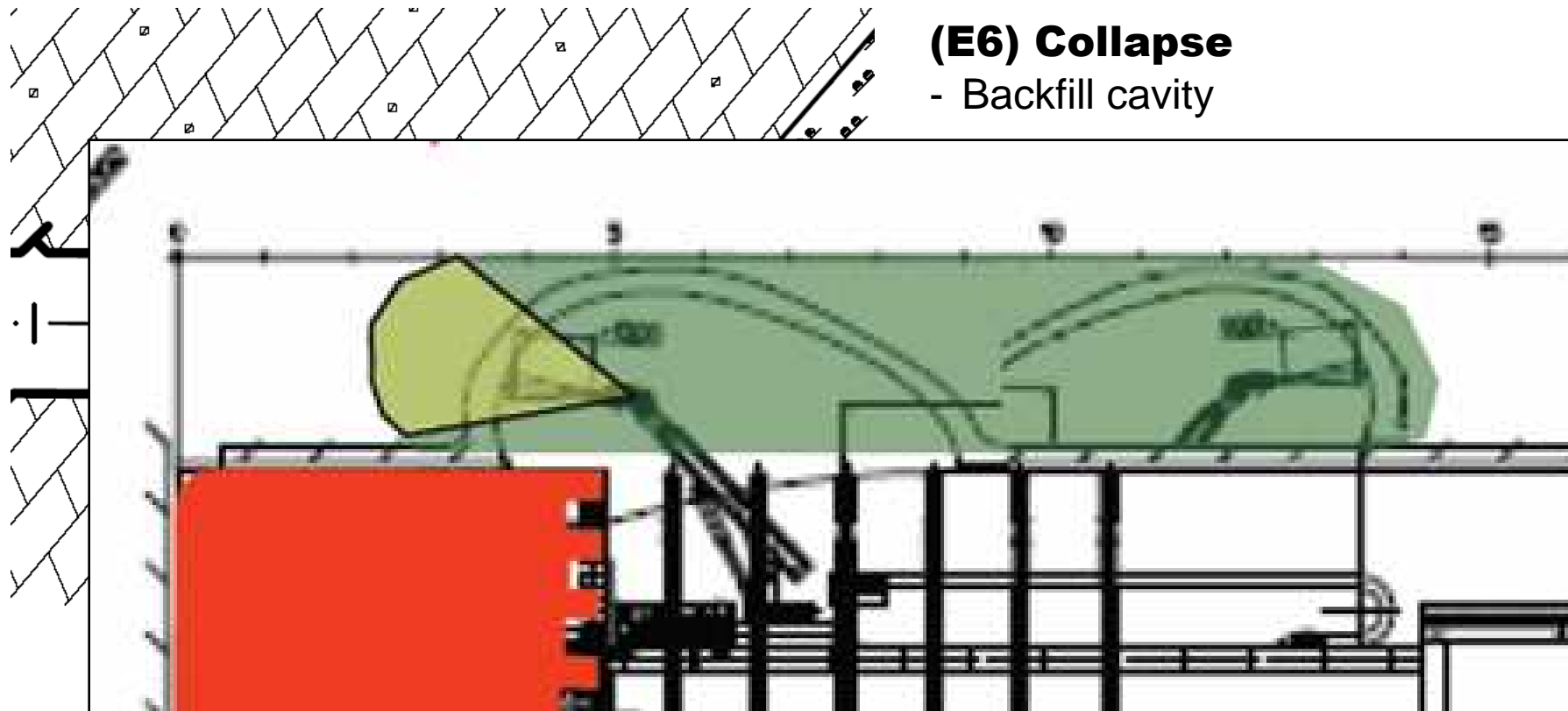
Piora – possible hazards

Local decomposition into sand



Piora – possible hazards

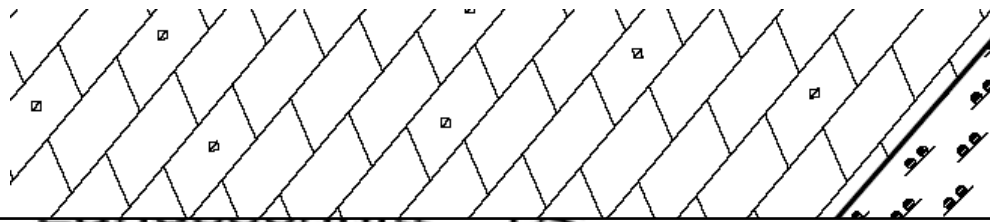
Action plan



Engineering Joint Venture Gotthard Base Tunnel South

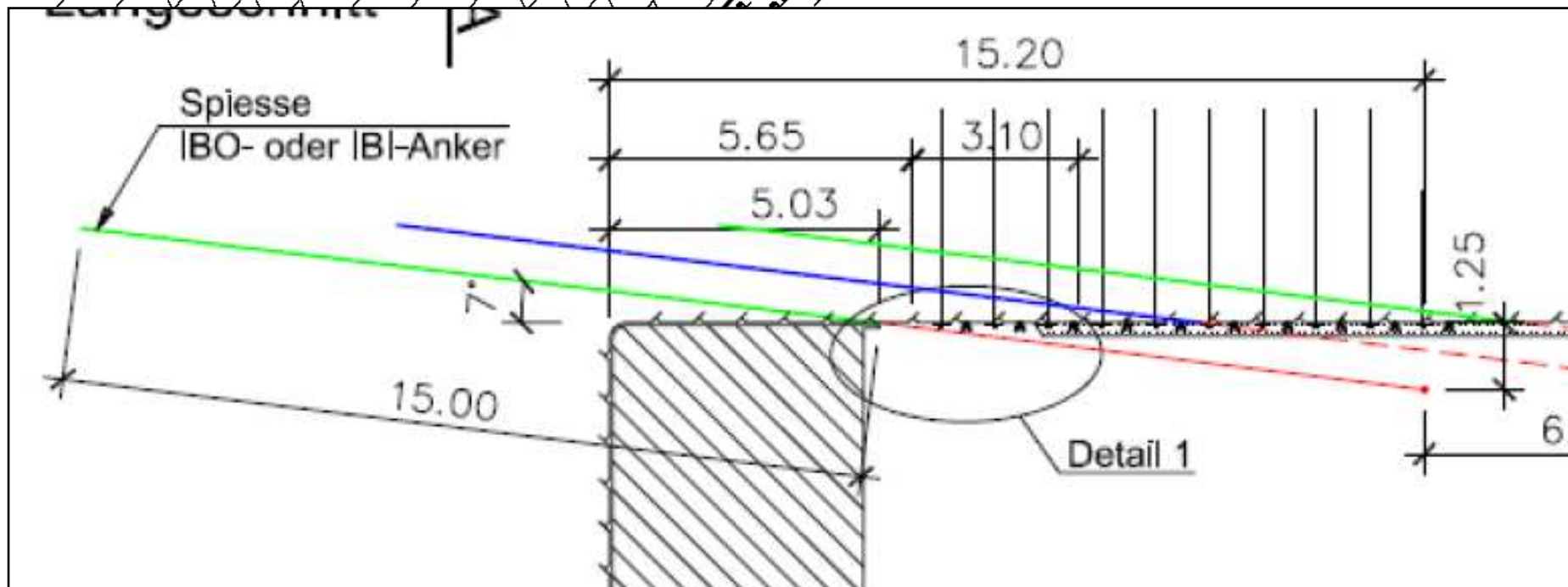
Piora – possible hazards

Action plan



(E6) Collapse

- Backfill cavity
- forepoling (M3)



Piora – possible hazards

Action plan

ANHANG M2 INJEKTIONEN

1. Einleitung

Injektionen werden im TBM-Vortrieb des Gotthard Basistunnels (GBT) als Massnahmen für besondere Zwecke bei ausserordentlichen Gebirgsverhältnissen eingesetzt.

1.1 Ziel und Zweck

Anhang M1 Bohrungen

Was die Bohrausrüstungen auf der TBM Faido können

Als Grundlage für die Planung von Massnahmen für die Überwindung von schwierigen und ausserordentlichen Gebirgsverhältnissen wird in diesem Anhang etwas vereinfacht aufgezeigt, welche Art von Bohrungen die im Bereich L1* direkt hinter dem Bohrkopf zum Einsatz gelangenden Bohrgeräte ausführen können und wo ihre Einschränkungen liegen.

Grundlagen und weiterführende Informationen

1. Technischer Bericht und Dokumentation preventergeschützte Kern- und Schlagbohrungen im Zeitraum 01.05.2007 – 24.05.2007 [F579]
2. Technischer Bericht und Dokumentation Versuchs-Injektionsbohrungen TBM West, Faido im Zeitraum 007.09.2007 -10.09.2007 [F636]
3. Technischer Bericht und Dokumentation Versuchs-Injektionskernbohrungen TBM Ost, Faido im Zeitraum 02.01.2008 – 06.01.2008

Prüfstatus

Die Informationen in diesem Dokument wurden von TAT kontrolliert und in Ordnung befunden.

Inhaltsverzeichnis

- | | |
|---------------------------------------|---------|
| 1. Kapitel: Sondierbohrgerät im First | Seite 2 |
| 2. Kapitel: Horizontalbohrlafetten | Seite 4 |

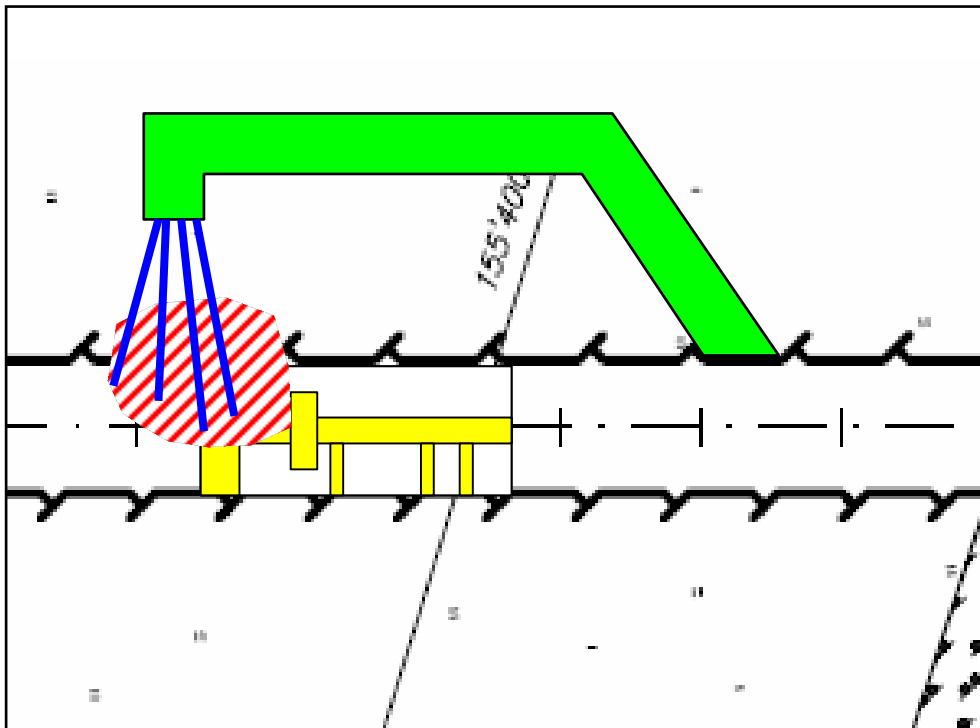
(E6) Collapse

- Backfill cavity
- forepoling (M3)
- Grouting (M1, M2)
- Grouting gallery (U1, U2)



Piora – possible hazards

Action plan

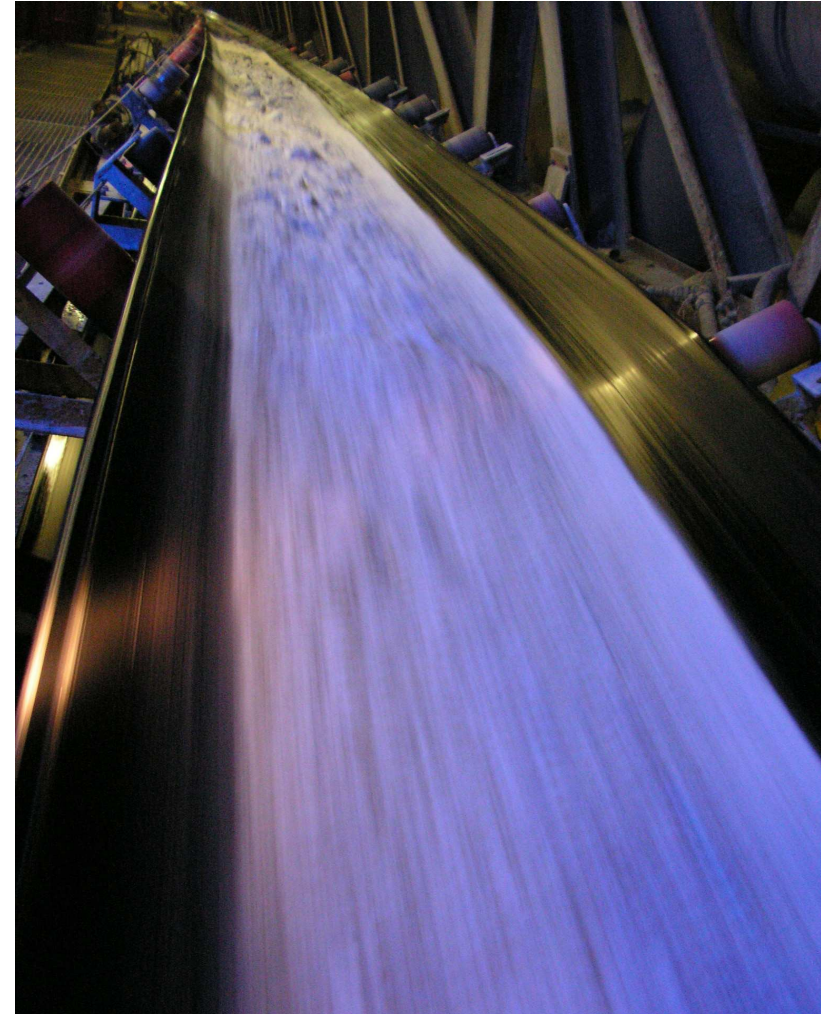


(E6) Collapse

- Backfill cavity
- forepoling (M3)
- Grouting (M1, M2)
- Grouting gallery (U1, U2)



Piora Basin, Excavation



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

3.3 TBM Heading Piora Basin

4. Problems encountered during TBM heading

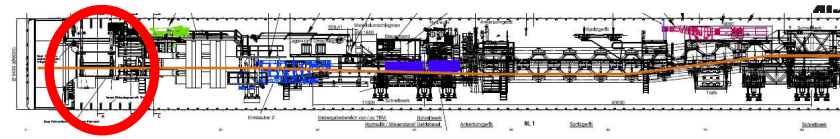
5. Interaction between two tubes



Damages at Crown and Invert



Problems TBM Heading



Shotcrete cracks (support includes 6m SN M33, TH 36, 40 cm SC2)



Engin

Problems TBM Heading

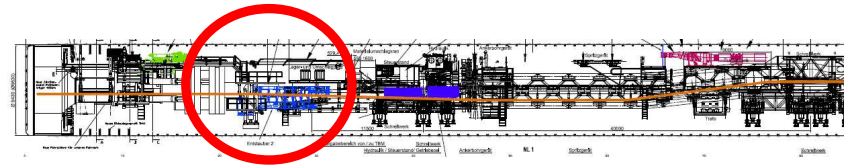
Shotcrete cracking invert

Deformed steel arches



Engineering Joint Venture Gotthard Base Tunnel South

Problems TBM Heading Section L1 to operators stand

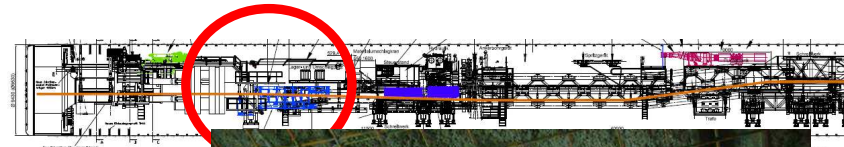


Bereich Tm 18435 – 18450, Tkm 238'375 – 238'360



Engineering Joint Venture Gotthard Base Tunnel South

Problems TBM Heading Section L1 to operators stand

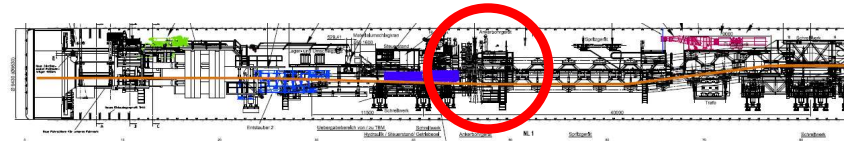


Bereich Tm 18'435 - 18'450, Tkm 238'375 - 238'360



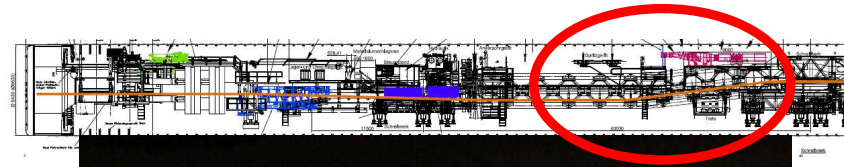
Problems TBM Heading

Section L2: Drilling rig



Problems TBM Heading

Section L2: Shotcrete robot

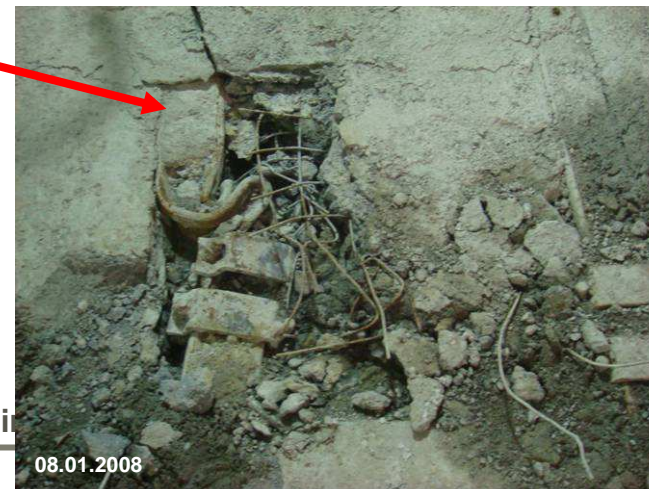
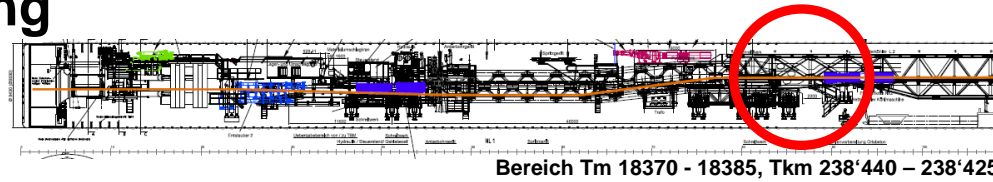


Problems TBM Heading

Intact rock bolts SN M33 L=4m

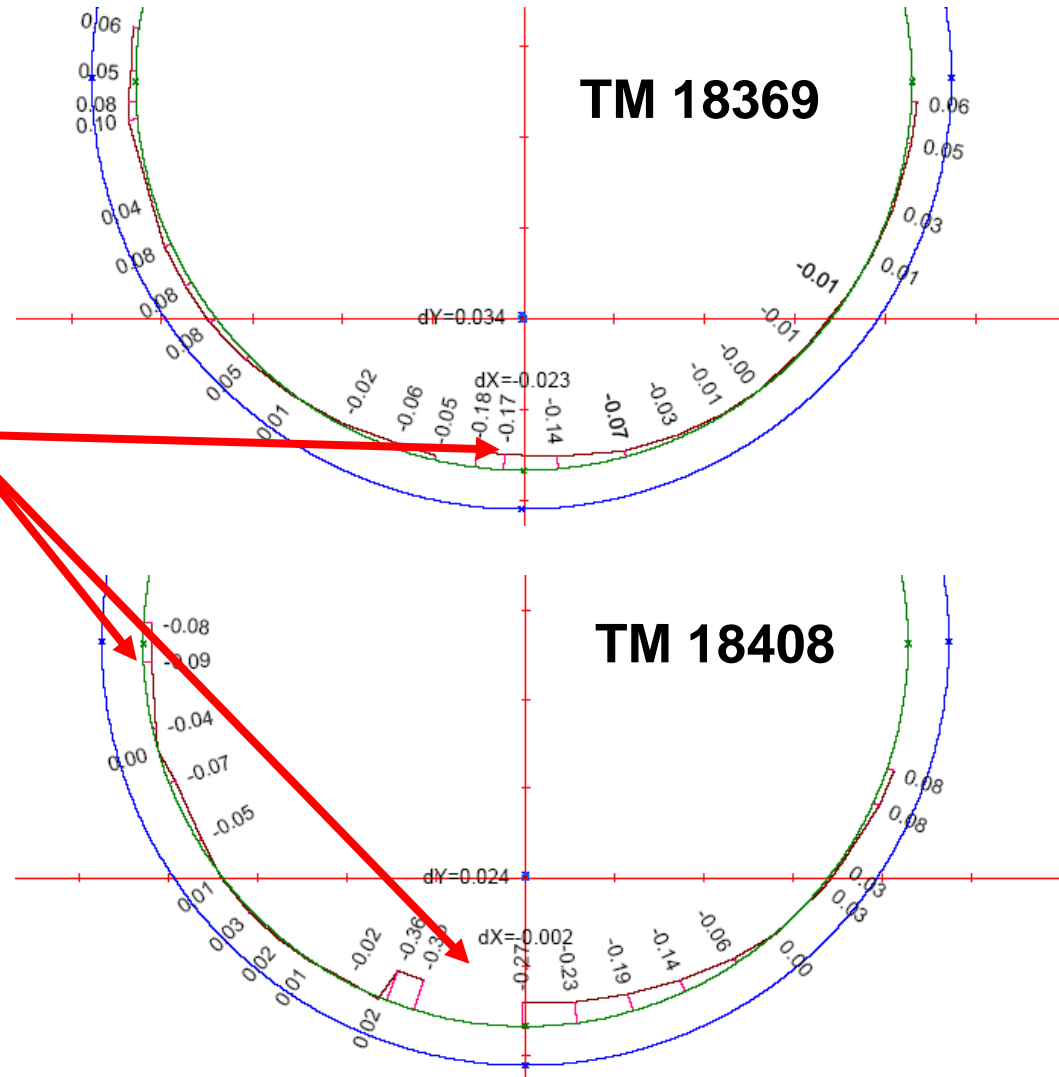


Problems TBM Heading Damages Invert

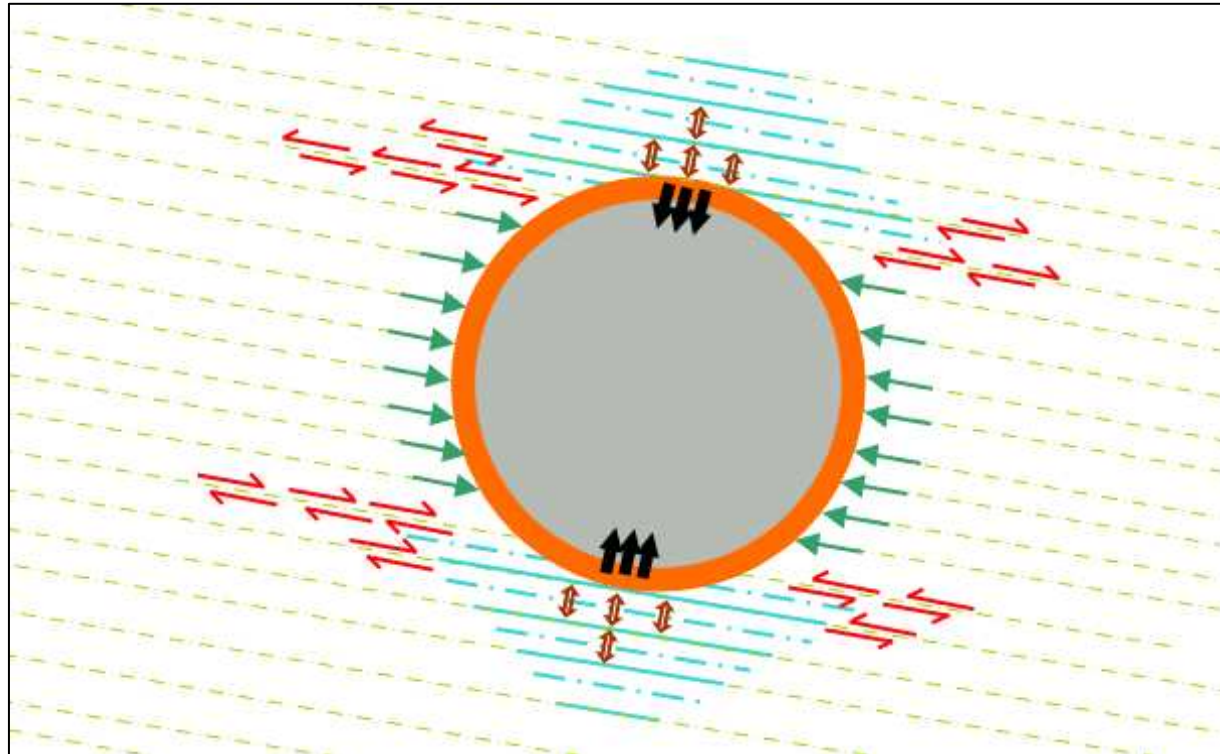


Problems TBM Heading at the invert

Problem with the clearance profile up to 70 cm



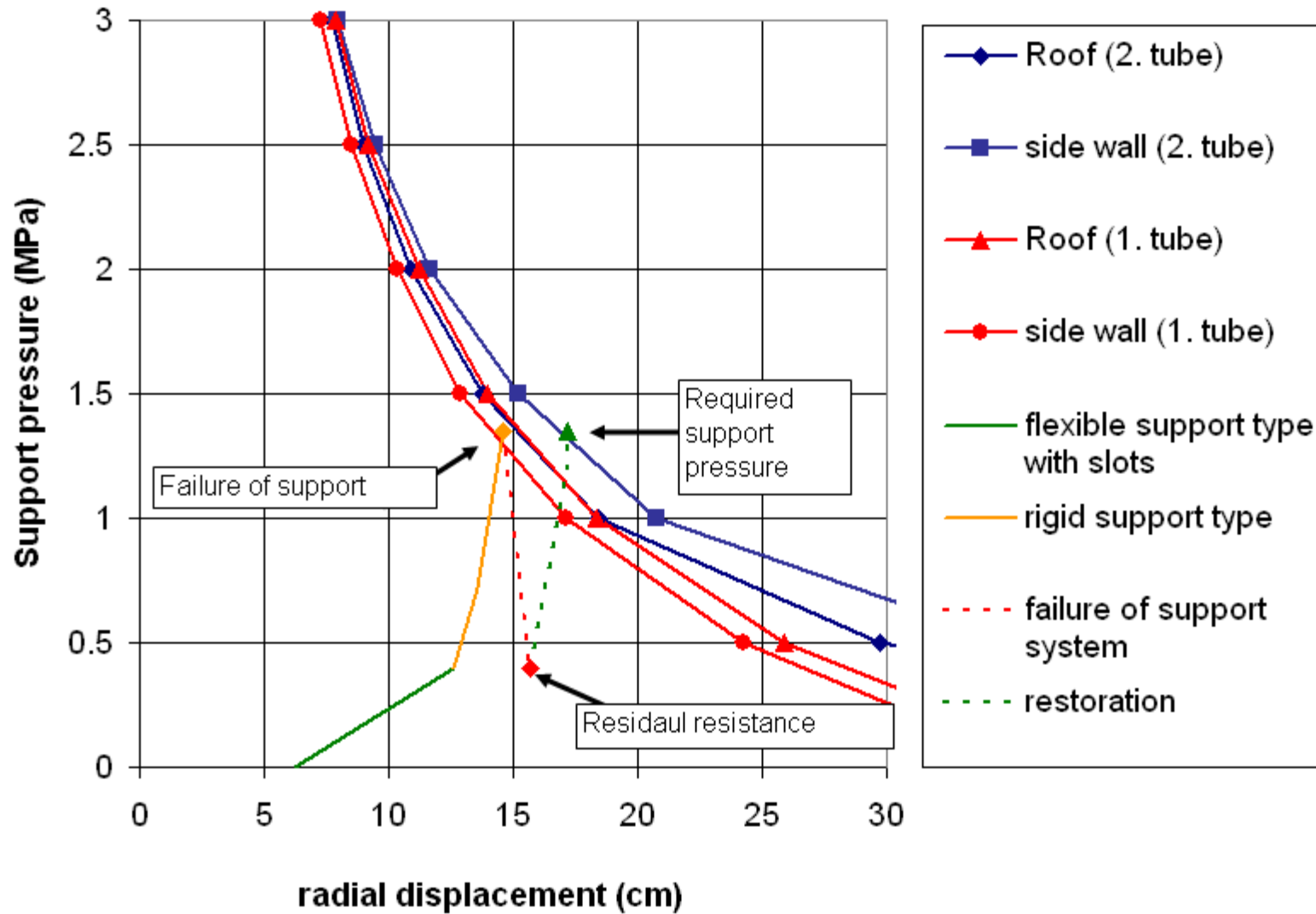
Failure Mechanisms, Load of Rock Support



- Loosening
- Buckling
- Brittle failure (shear off)
- Lateral Pressure



Pi



Content

1. Gotthard Base Tunnel, Introduction

2. Hazard scenarios

3. Construction Section Faido

3.1 Multifunctional Station (MFS) Faido

3.2 TBM Heading in the Single-Track Tunnels

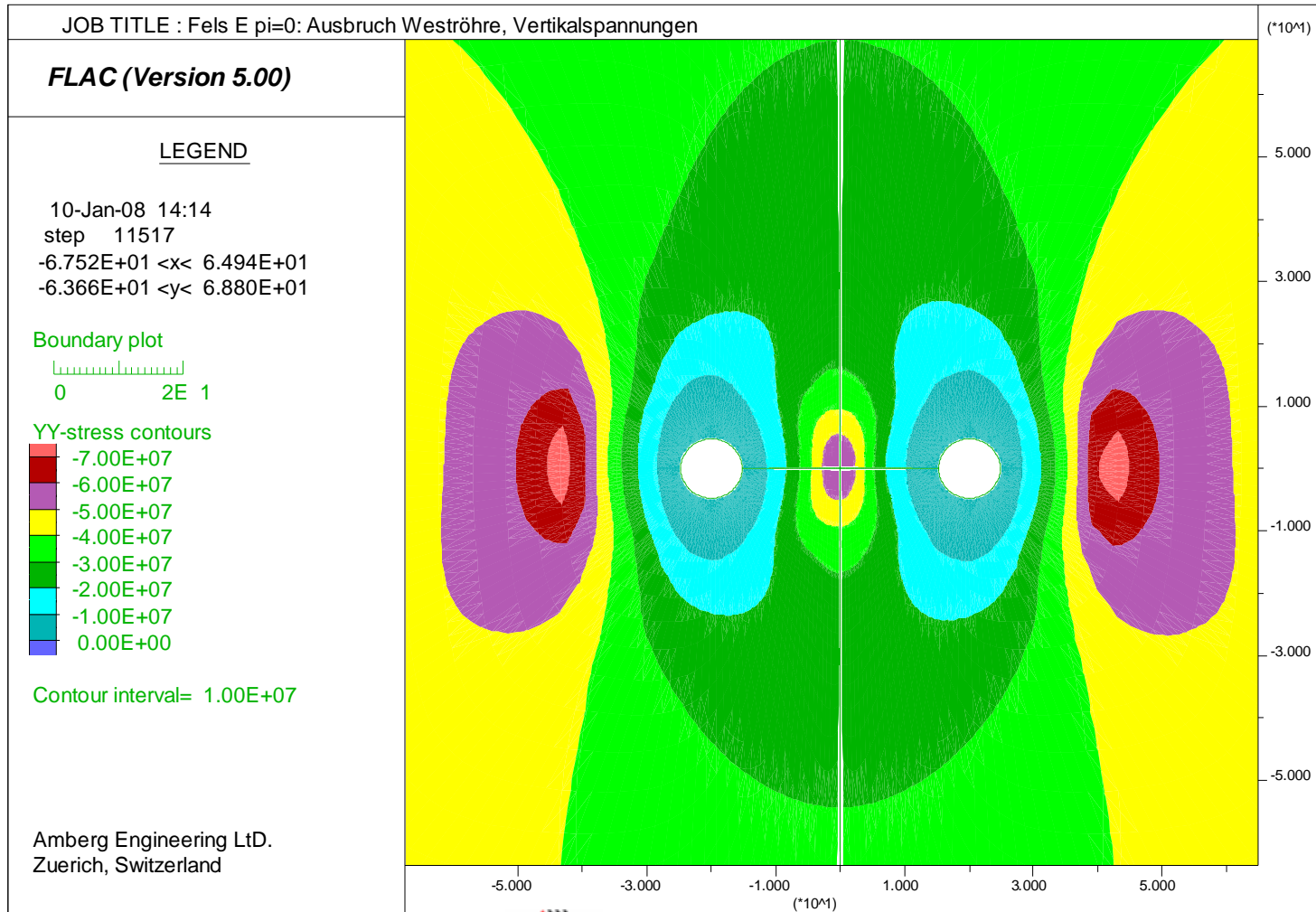
3.3 TBM Heading Piora Basin

4. Problems encountered during TBM heading

5. Interaction between two tubes



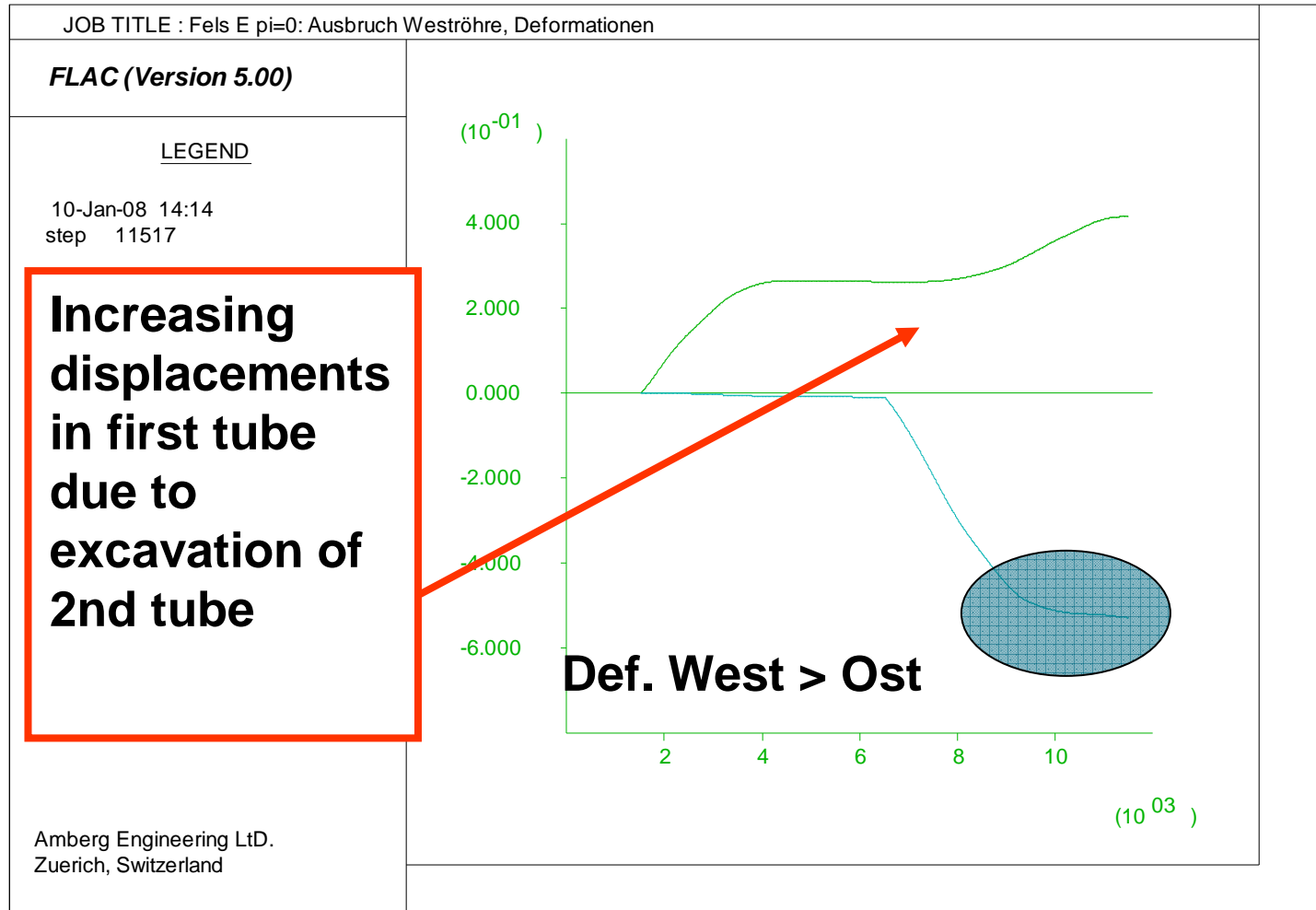
Heading interaction



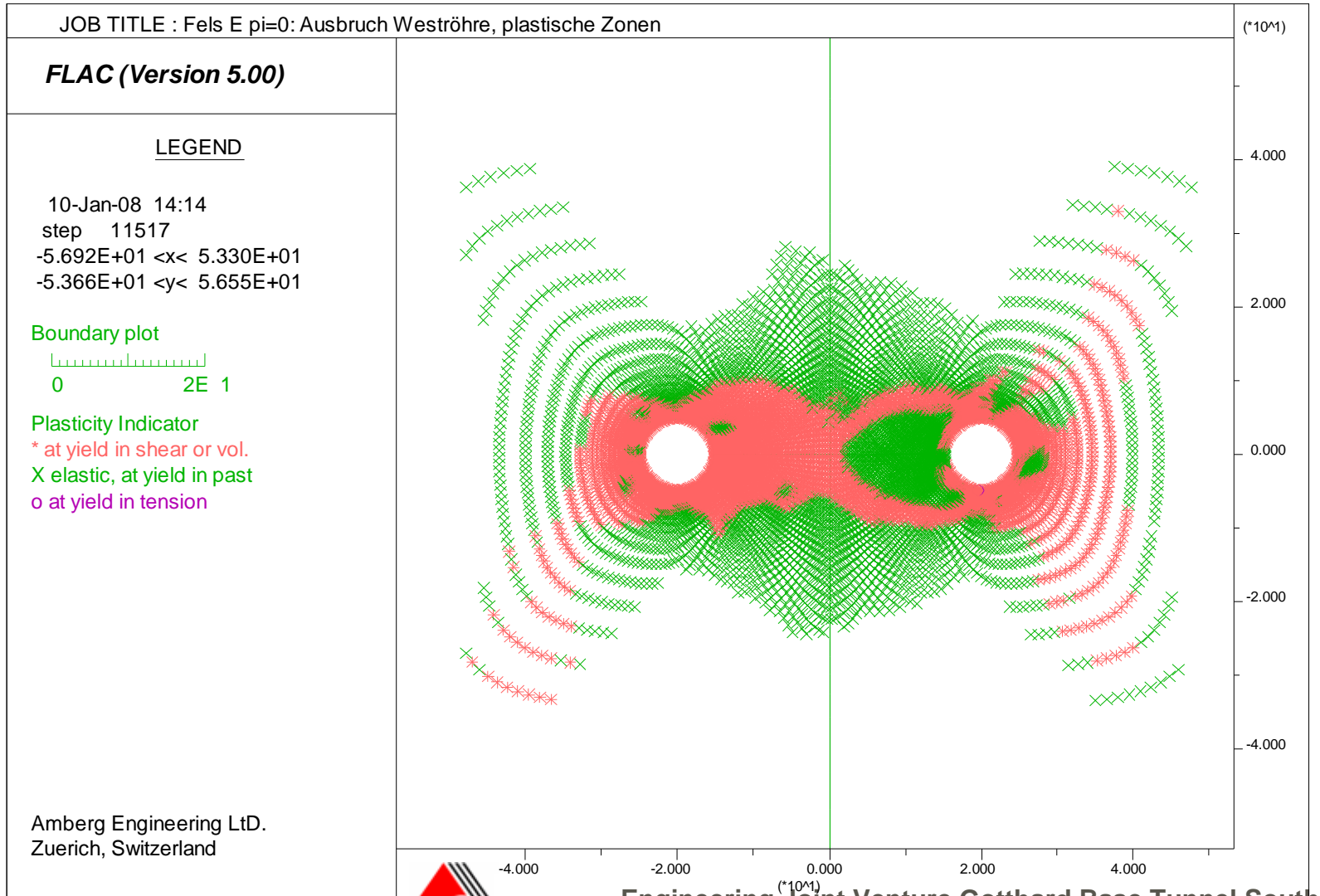
Engineering Joint Venture Gotthard Base Tunnel South



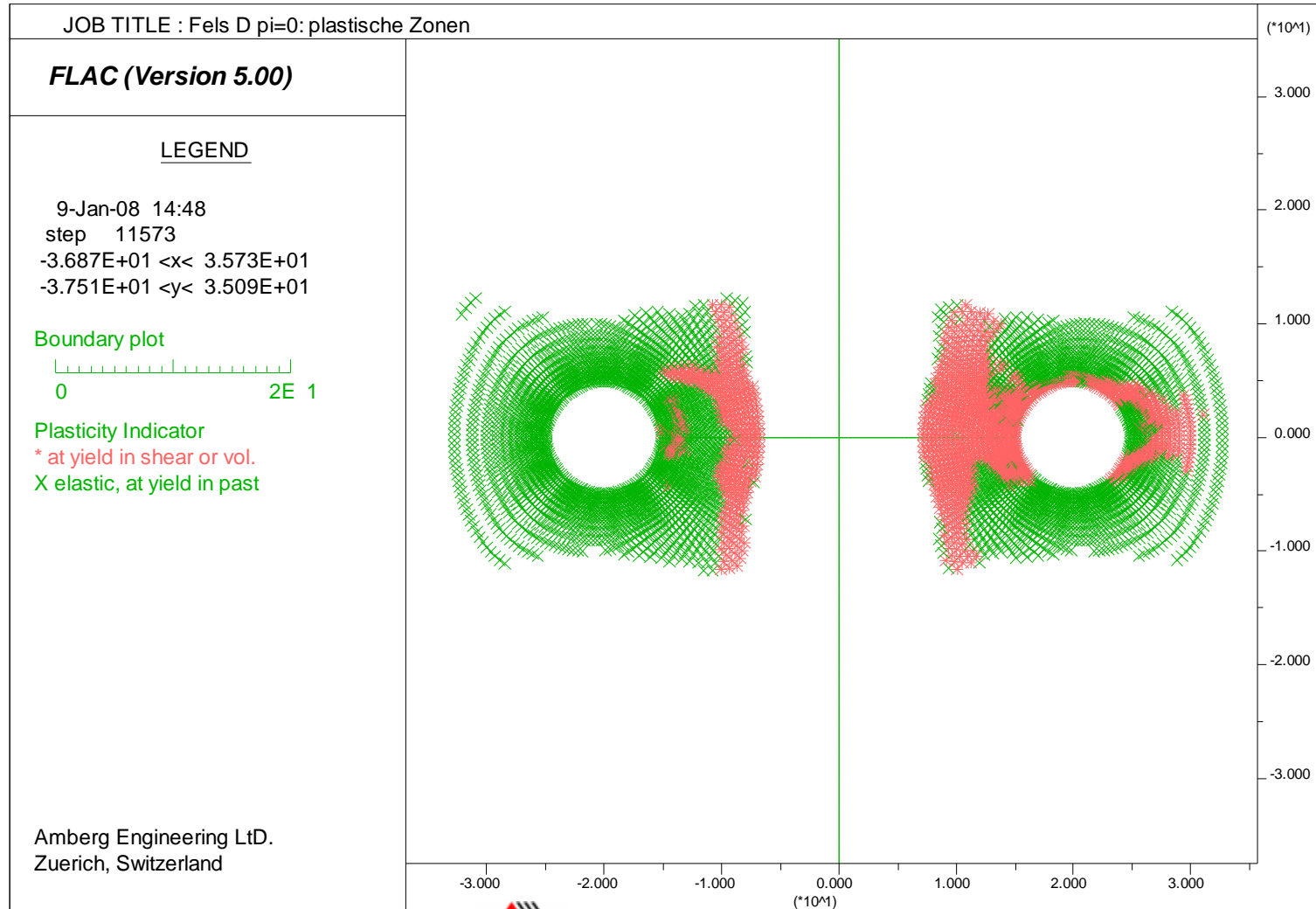
Heading interaction



Heading interaction



Heading interaction



Engineering Joint Venture Gotthard Base Tunnel South

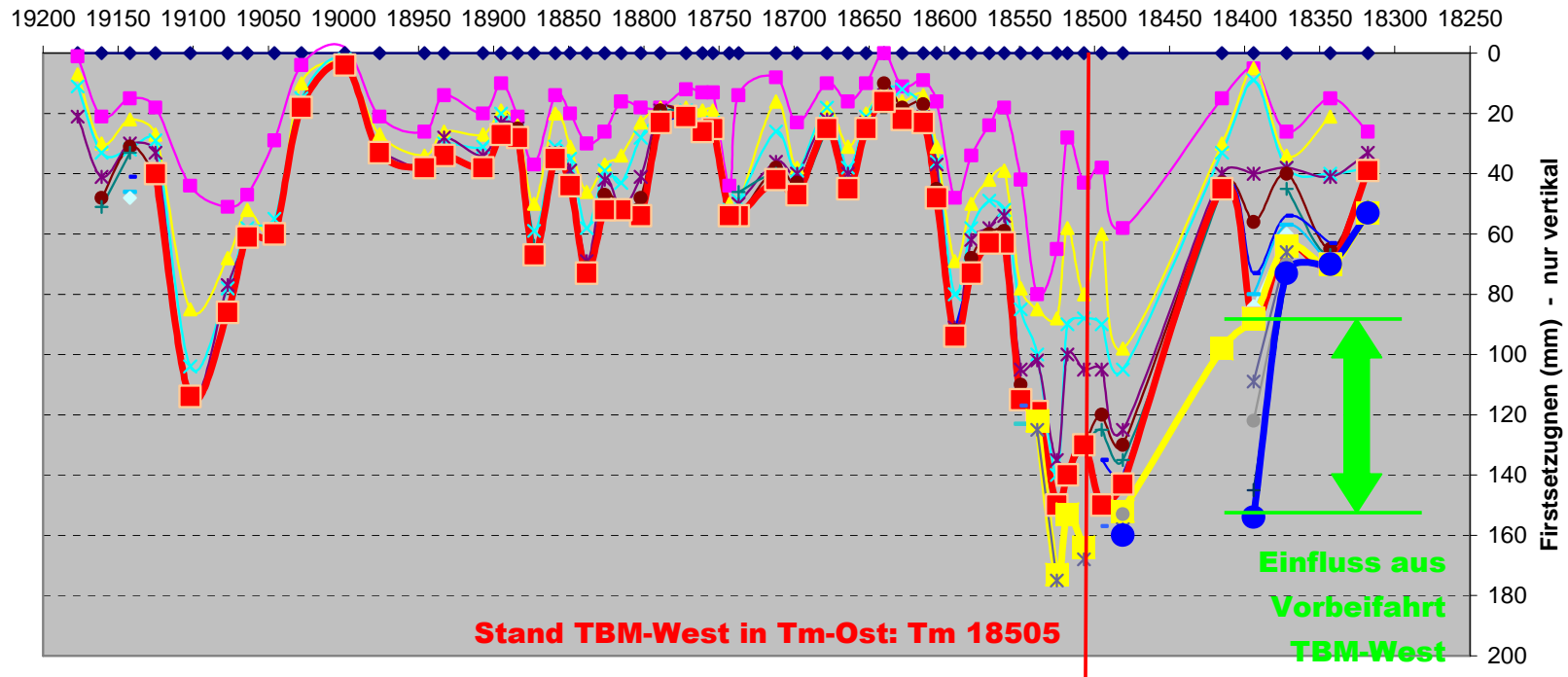


Heading interaction

Convergence Measurements

(Firstisochronen)

TBM-Ost Tunnelmeter



◆ Nullmessung	■ Folgemessung 1	▲ Folgemessung 2	✕ Folgemessung 3	✱ Folgemessung 4	● Folgemessung 5
✚ Folgemessung 6	■ Folgemessung 7	■ Folgemessung 8	✚ Folgemessung 9	■ Folgemessung 10	▲ Folgemessung 11
✚ Folgemessung 12	✱ Folgemessung 13	● Folgemessung 14	■ Maximum am Steuerstand	■ NL Folgemessung 1	■ NL Folgemessung 2
◆ NL Folgemessung 3	■ NL Folgemessung 4	▲ NL Folgemessung 5	■ NL gesamt	✱ West Folgemessung 1	● West Folgemessung 2
✚ West Folgemessung 3	■ West Folgemessung 4	● West gesamt			



Engineering Joint Venture Gotthard Base Tunnel South

**Merci beaucoup pour
votre attention!**



LOMBARDI SA
INGEGNERI CONSULENTI

Engineering Joint Venture Gotthard Base Tunnel South

