

# Lecture 4

# Tunneling Through Fault Zones and Melanges

*BIMROCKS SHORT COURSE*

**Dr. Edmund Medley**

Consulting Geological Engineer, Belmont, California, USA

[emedley@bimrocks.com](mailto:emedley@bimrocks.com)

Geological Engineering Department, Hacettepe Univ, Ankara

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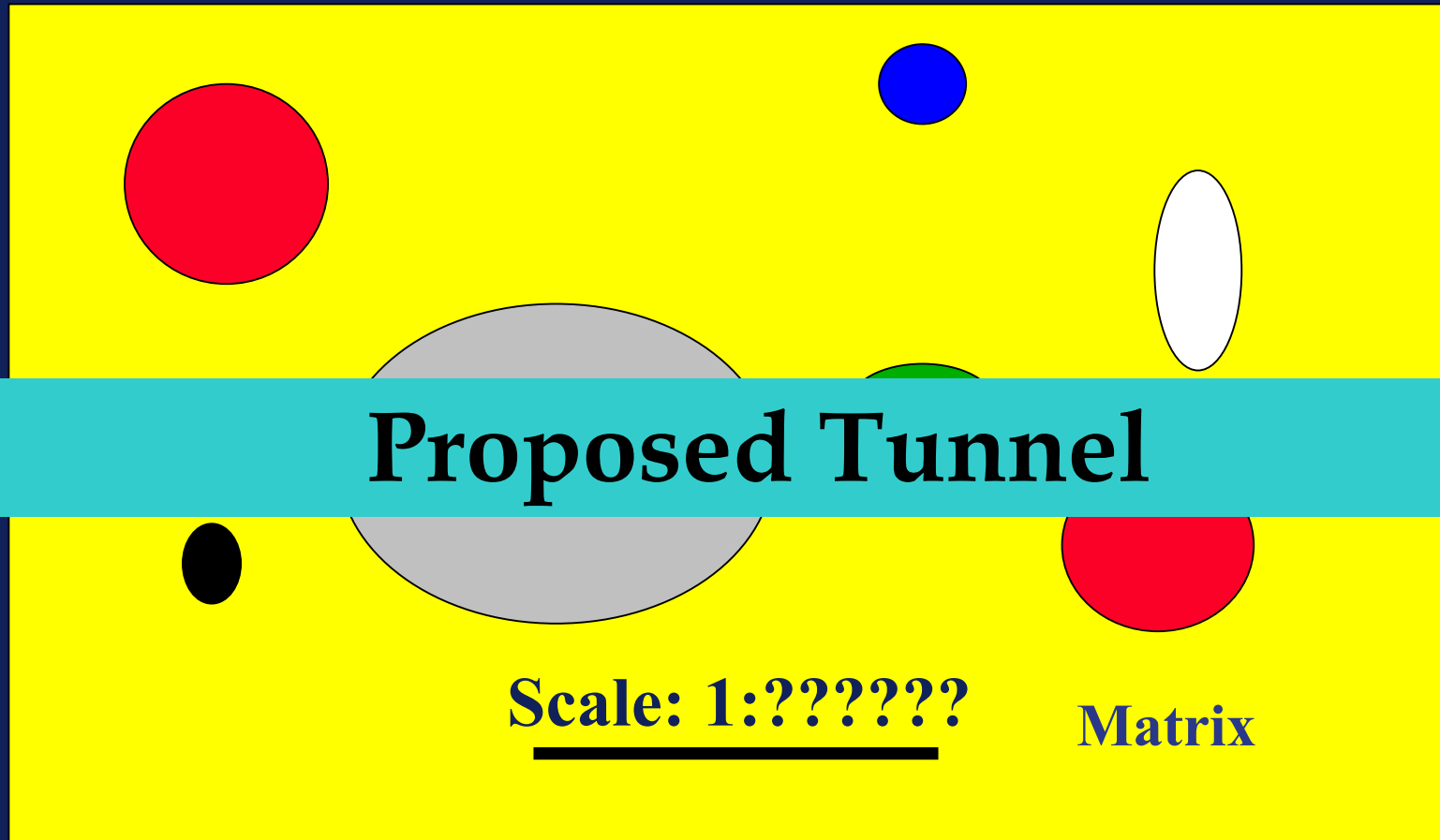
**Much of this lecture is possible thanks to the use of slides and photographs permitted by:**

**Gruppe Geotechnik Graz,  
Austria**



**Prof. Dick Goodman**

# BIG CONCLUSION 1: Remember this picture!!!



Actual Distribution of Blocks

**BIG CONCLUSION 2:**  
**Remember this picture as well!!!**



**Proposed Tunnel**

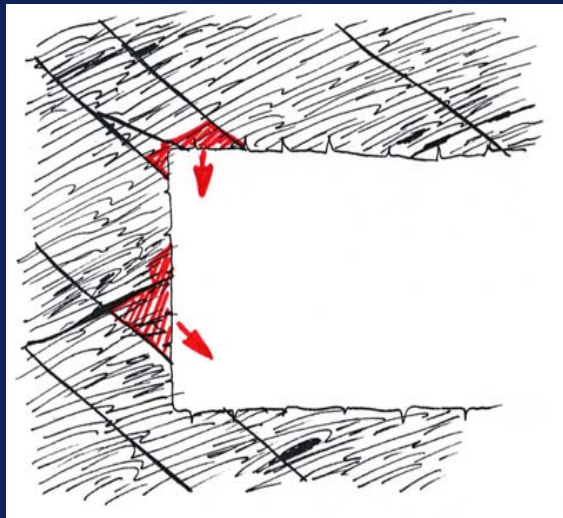
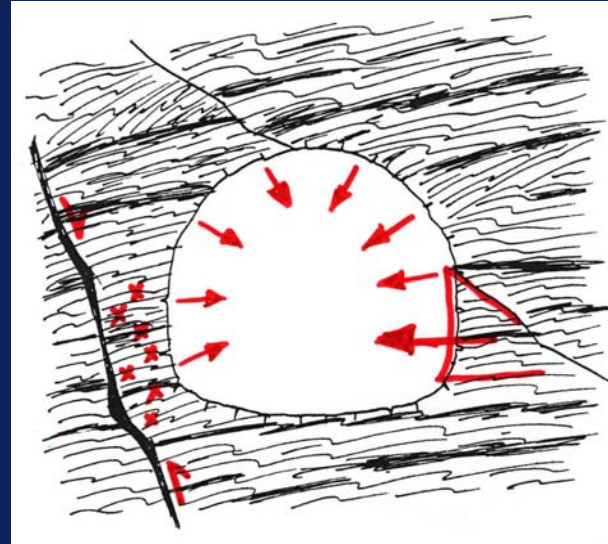
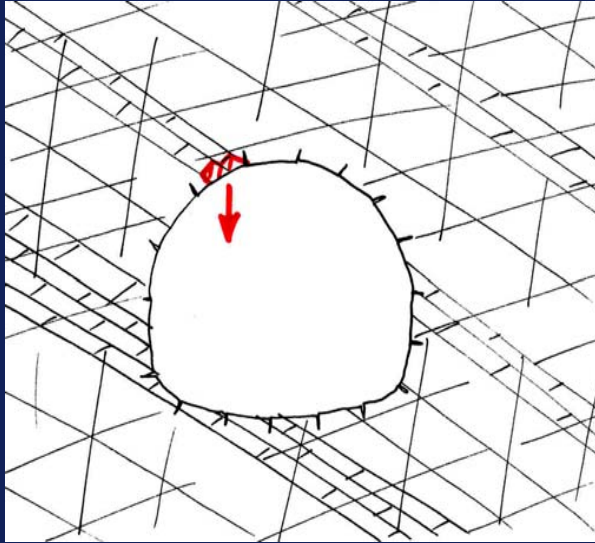
**Apparent Distribution of Blocks**

# Tunneling failures can occur in relatively coherent rock-masses



Photo: courtesy  
Prof. R. Goodman

# Some Rock Mass BEHAVIOUR TYPES



# Tunneling in fault rocks and melanges can result in failures



Collapsed Tunnel M2, Egnatia Motorway, Greece

# Tunnel Collapse in unexpected bimrock



Galgenberg Tunnel, Austria



# Example Case Study of Geotechnical Hazard Assessment

## Project Data

Upgrading of the river for energy production.

- Headrace tunnel (length 9km, diameter 9,0m)
- Power house

## Tasks

Geotechnical hazard assessment and optimization of design prior to construction





# Site mapping in faulted rocks



## *Geotechnical Hazard Assessment*



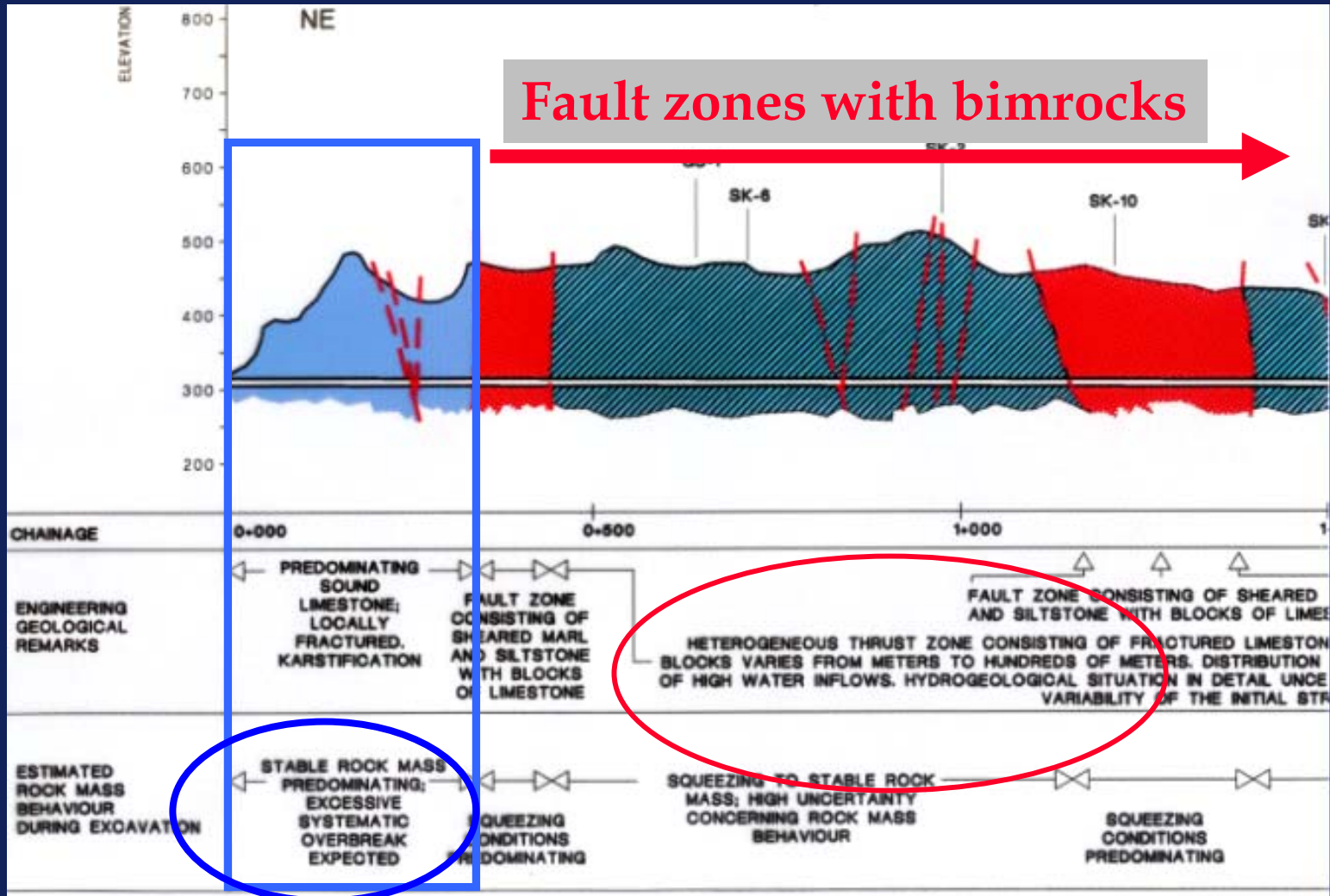
# Site mapping of geological structures



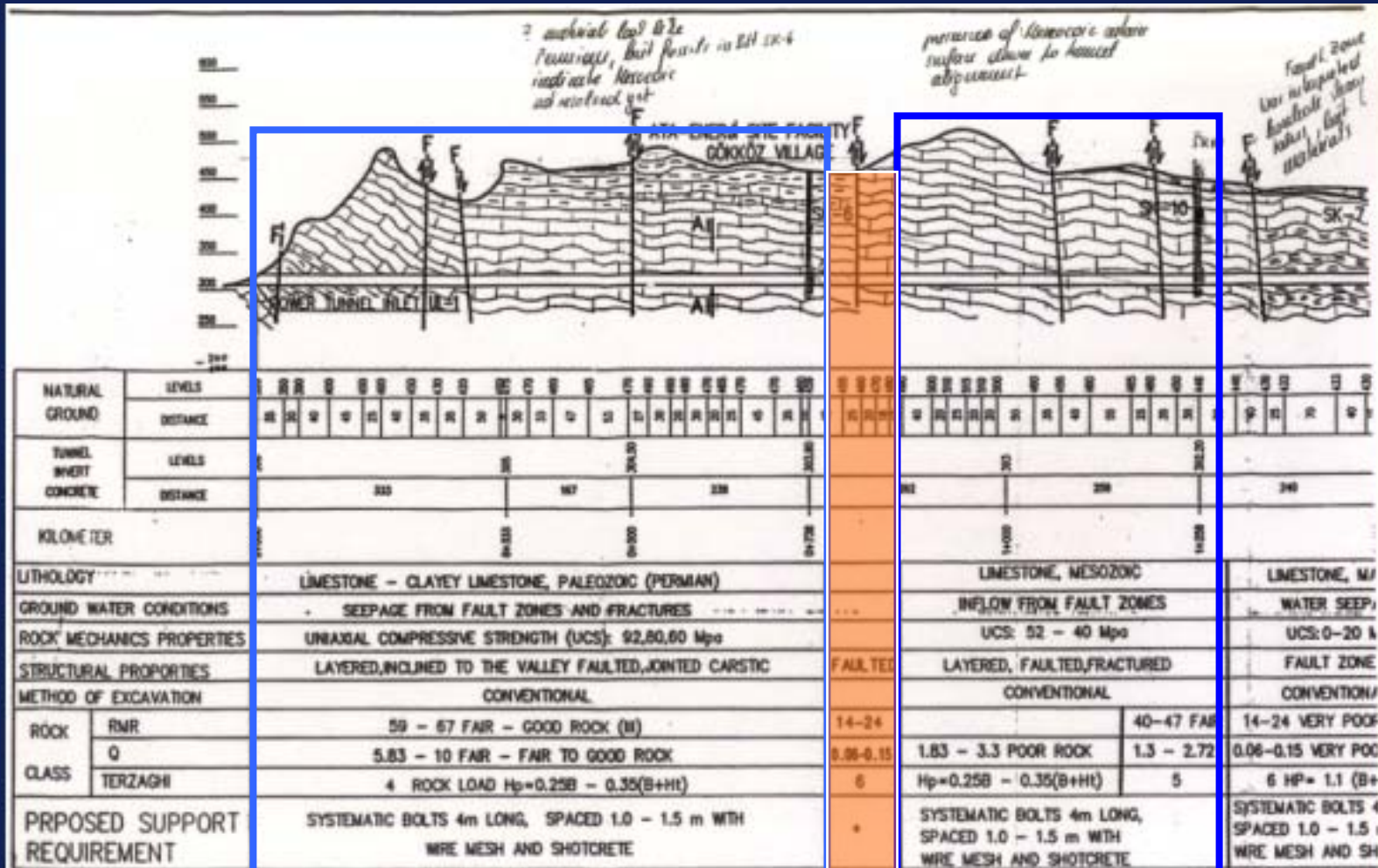
# Site mapping of bimrock...



# Revised Geotechnical Longitudinal Section



# Geotechnical Longitudinal Section for the Tender Design



“faulted”

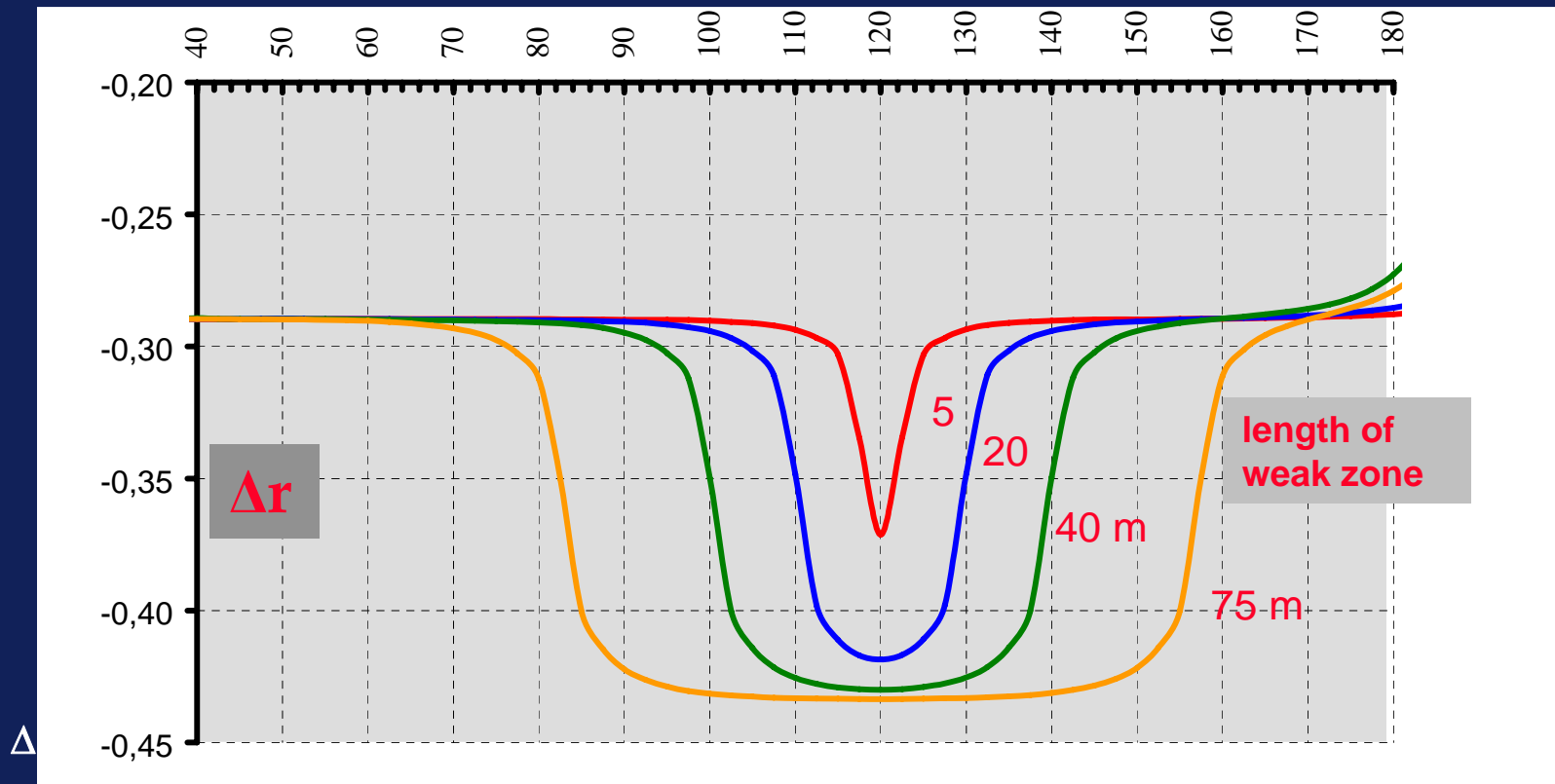
# BIMROCK EFFECTS in TUNNELS

- **Mixed face** conditions require different excavation methods on the same section
- Strong **variation** of rock mass quality
- **Stress redistribution** and deformations extremely influenced by arrangement of **blocks and matrix**
- **Prediction** of displacements and lining utilization **extremely difficult**
- **Danger of brittle failures in blocks**
- Difficulty of determination of proper support

# BIMROCK EFFECTS

## PROBLEMS of DISPLACEMENTS IN MATRIX IN RELATION TO BLOCK DISTANCE

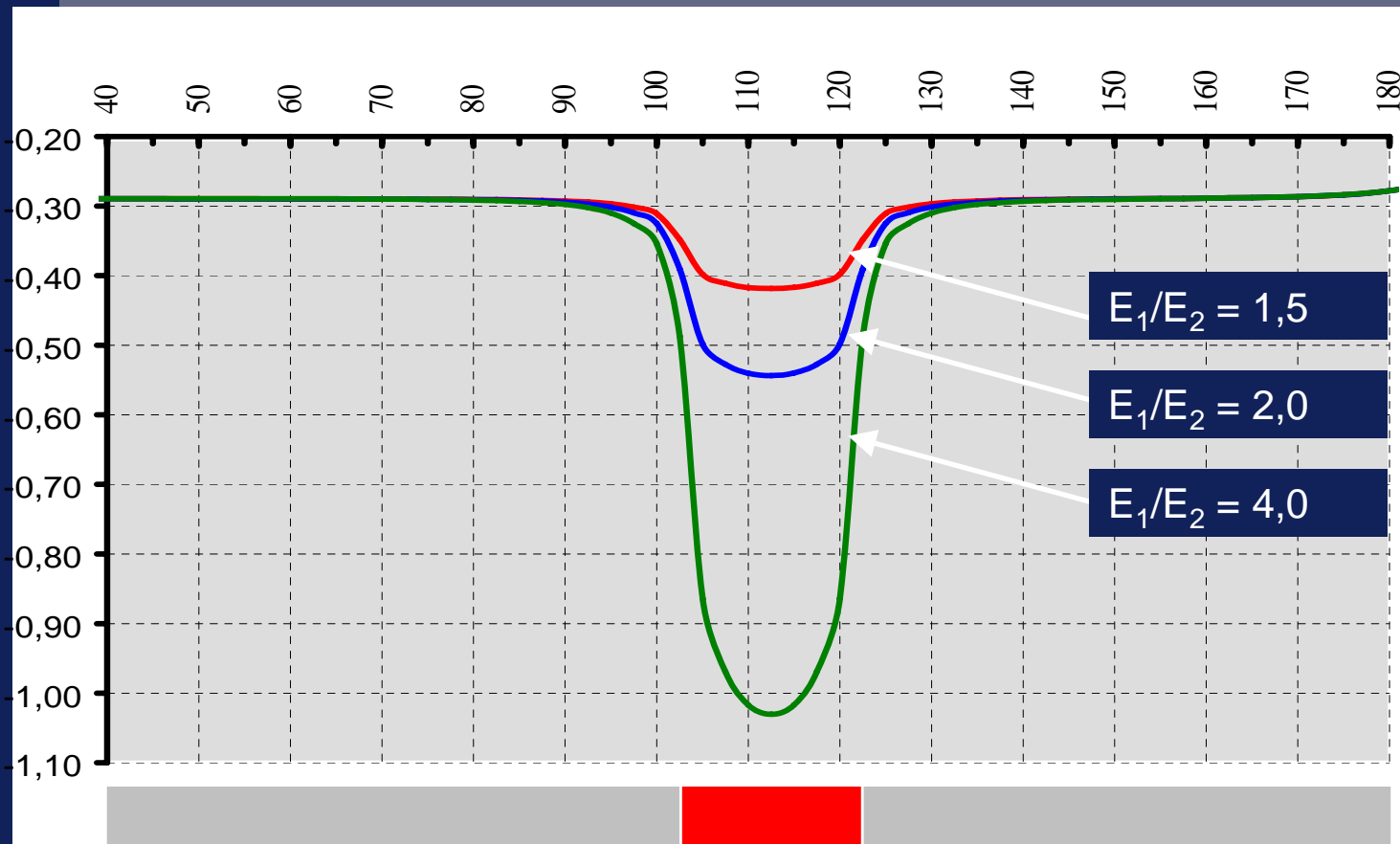
- Displacements depend on the length of the weak zone between **two stiff blocks**



# BIMROCK EFFECTS

## DISPLACEMENTS

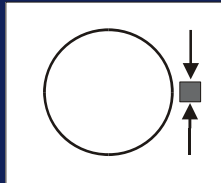
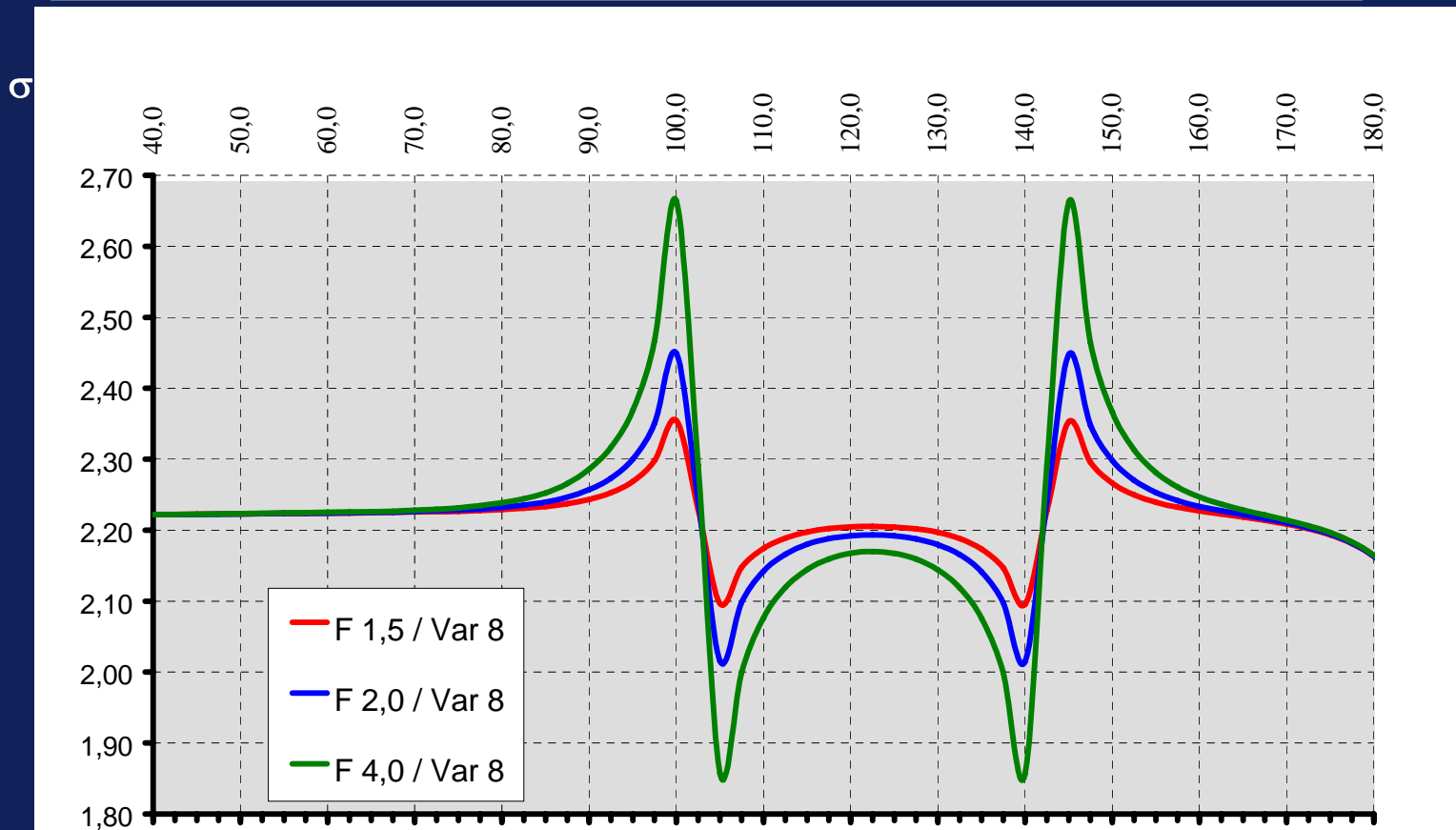
- Final displacements influenced by zone length and stiffness contrast between blocks and matrix



# BIMROCK EFFECTS

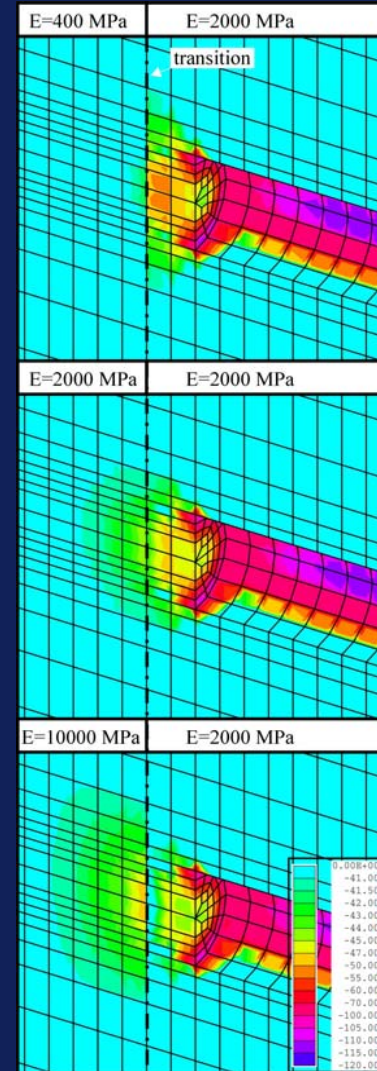
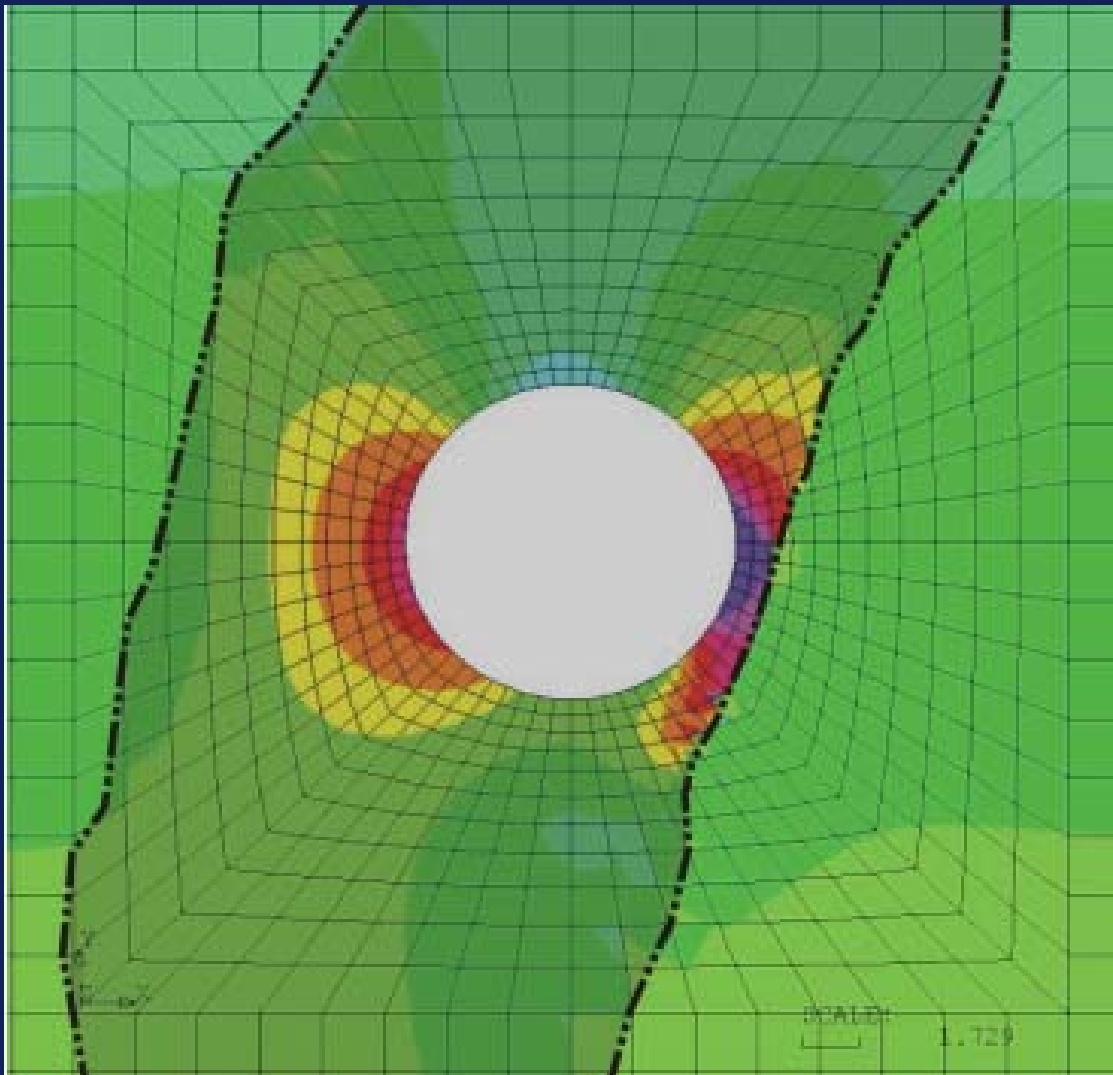
## STRESS DISTRIBUTION

➤ Stress concentration in blocks depend on stiffness contrast and distance between blocks

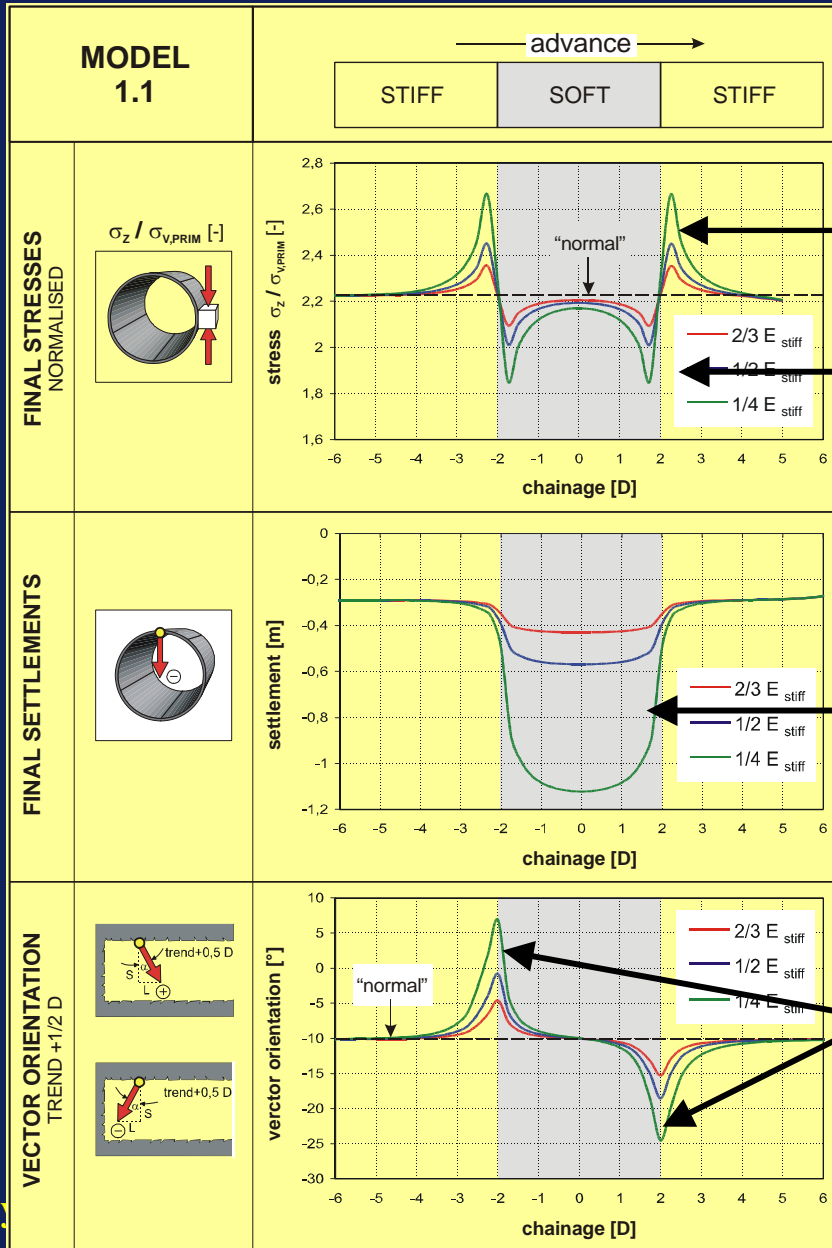


# BIMROCK EFFECTS

## STRESS CONCENTRATIONS



# BIMROCK EFFECTS



STIFF-SOFT-STIFF

Relative stress increase in stiff material

Relative stress decrease in soft material

Trough shaped displacement

Change of displacement vector orientation near transition



# BIMROCK EFFECTS

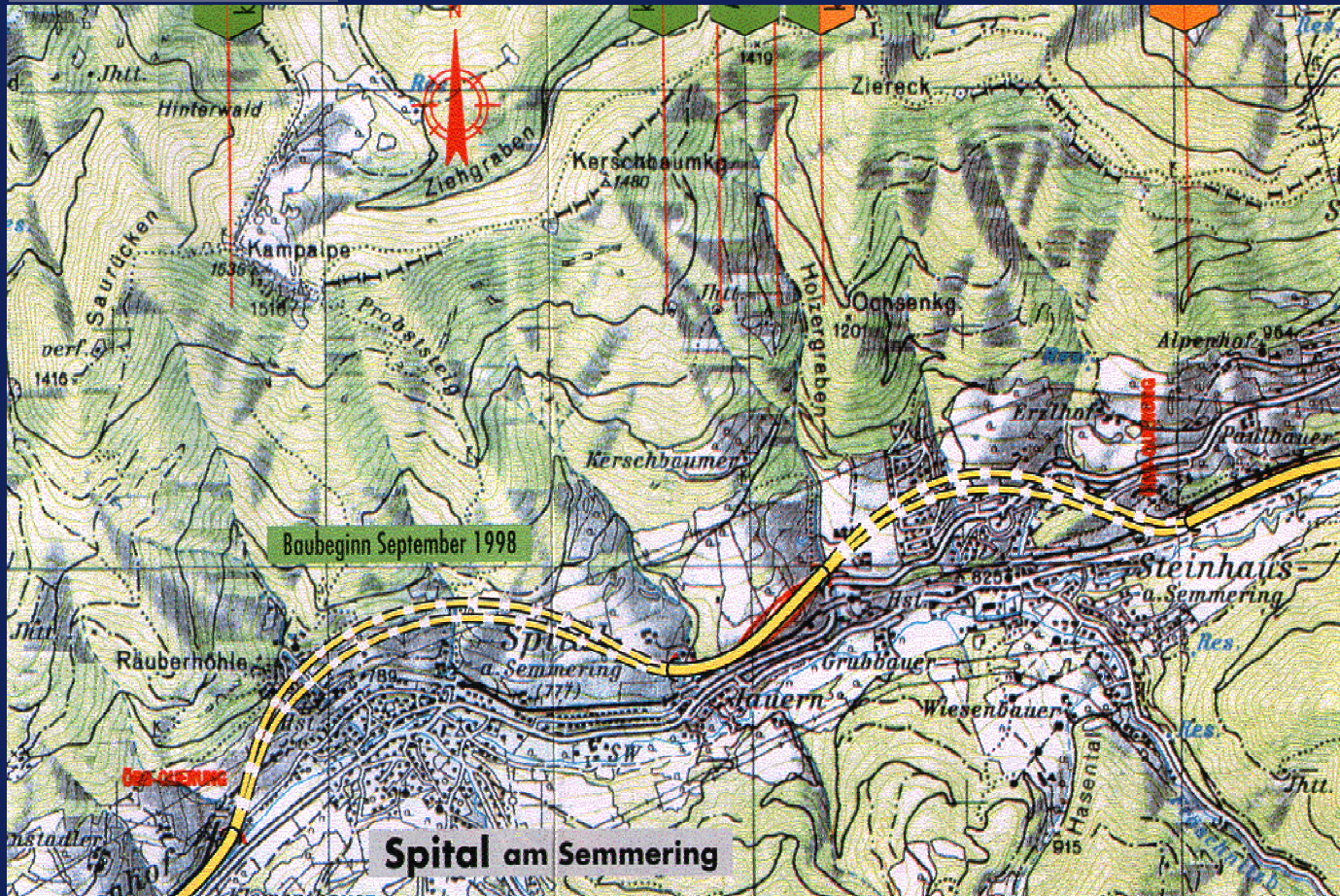
## BLOCK REINFORCEMENT

- **Stress concentrations** can cause **brittle failure** in stiff blocks
- Resulting stress redistribution leads to **additional displacements in the matrix material**
- **Knowledge of the spatial distribution of blocks and matrix essential to properly estimate stress situation**
- Short term prediction and prediction of displacements extremely important
- **Support / reinforcement of blocks necessary** to avoid brittle failure and long term stress redistribution, **frequently mistaken for creeping**

# BIMROCK EFFECTS

## CASE STUDIES

### Location Map



Tunnel Spital, Austria

# BIMROCK EFFECTS: Case Study

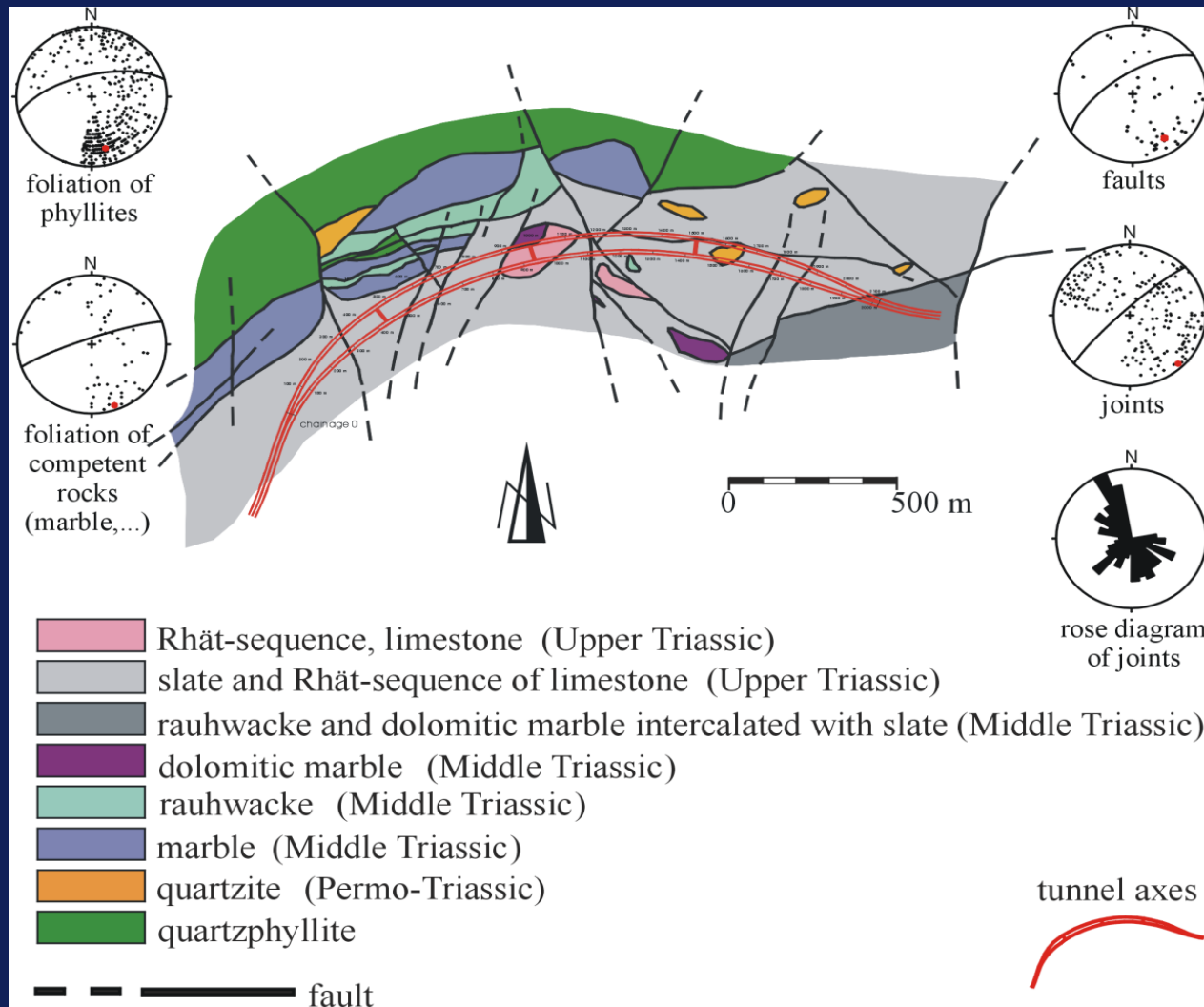
Project data : Tunnel Spital, Austria

- **Twin 2,2 km long freeway tunnels in the Semmering region, eastern Austria**
- **Alignment along a major fault zone**
- **Excavation area 70 – 90 m<sup>2</sup>**
- **Underpass of a railway line and built up area**
- **average overburden 30 m, maximum 80 m**



# BIMROCK EFFECTS CASE STUDY

## Tunnel Spital, Austria Geological overview



# BIMROCK EFFECTS CASE STUDY

Geological sections at tunnel faces at various tunnel locations



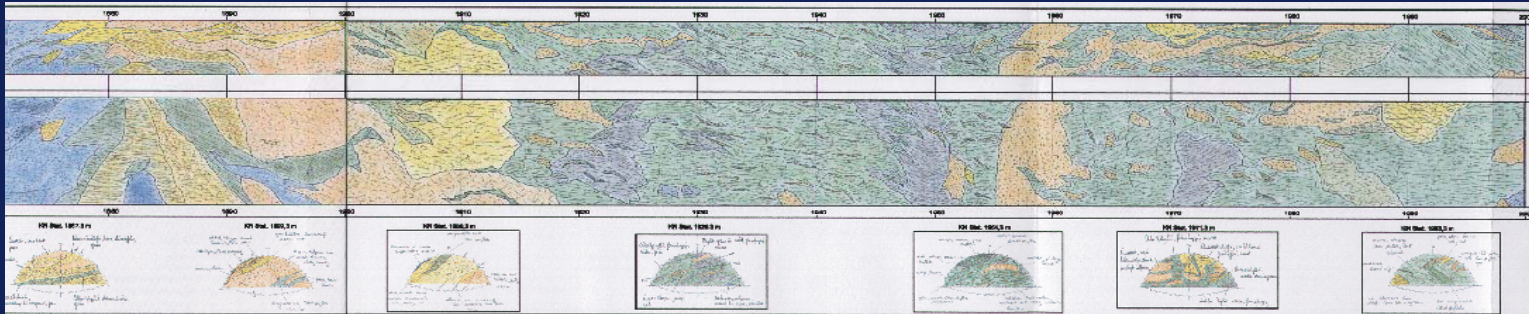
Tunnel Spital, Austria



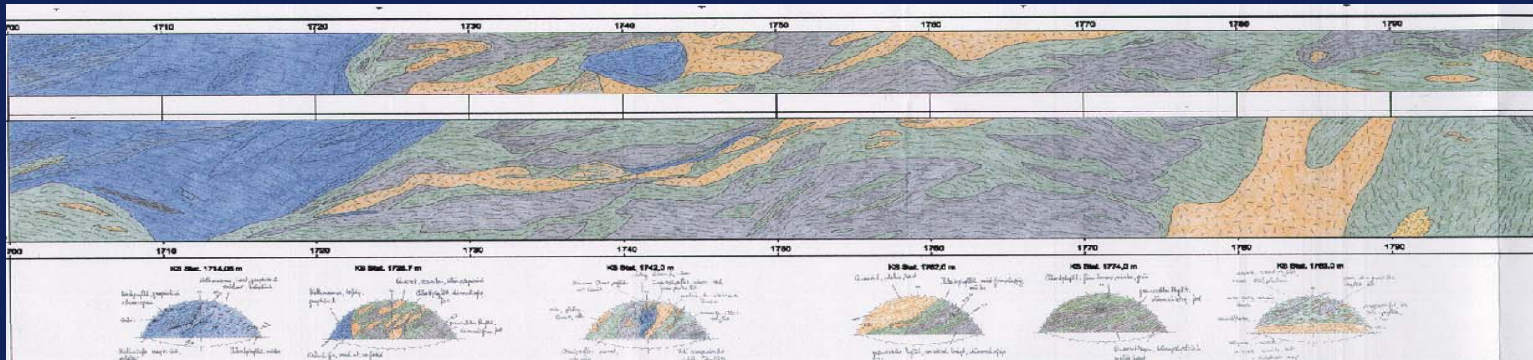
# BIMROCK EFFECTS CASEY STUDY

## Geological overview

Construction



Nord tube: 1870-2000m

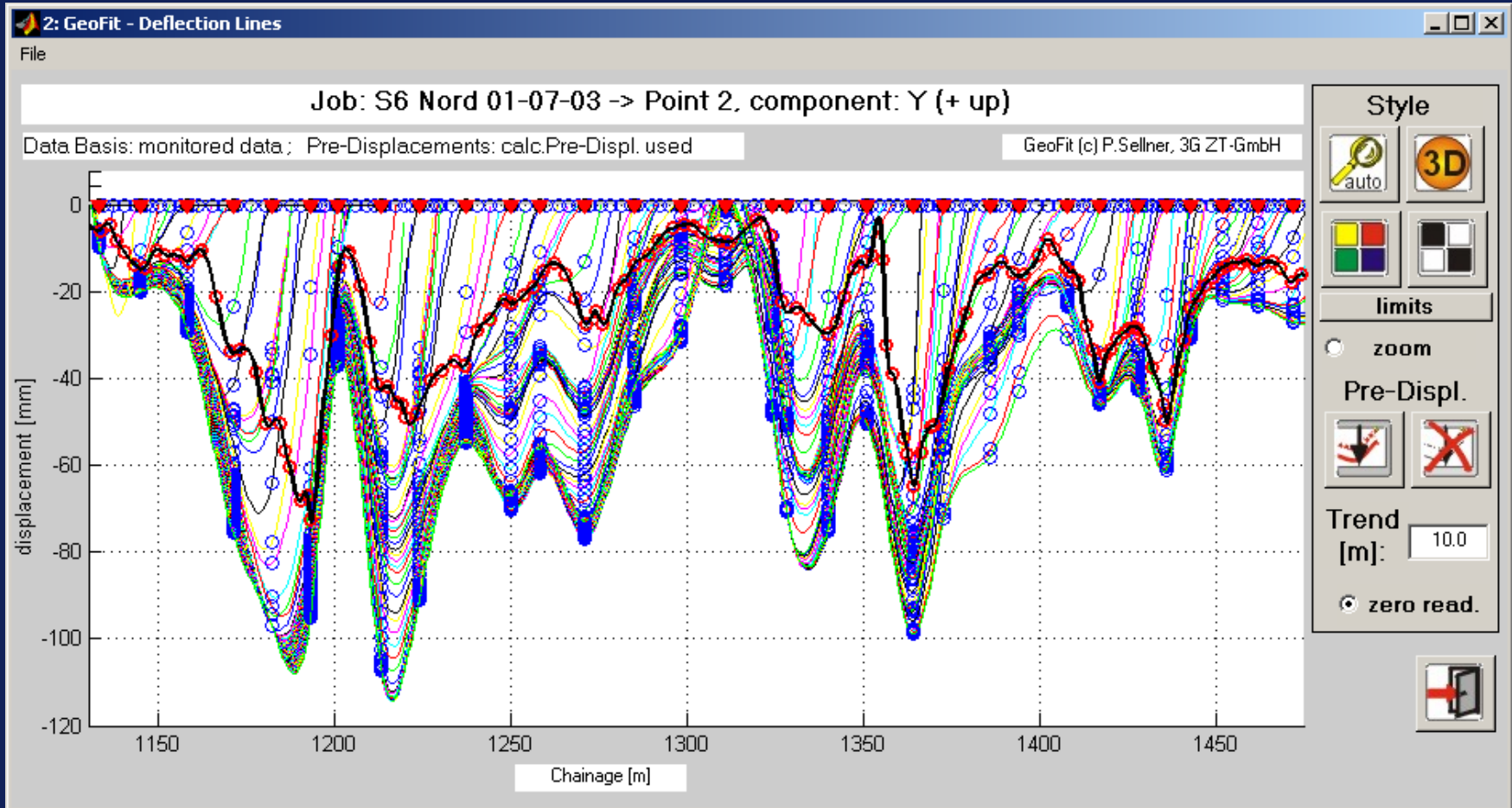


South tube: 1700-1800m



# BIMROCK EFFECTS Case study

## Heterogeneity - Displacements

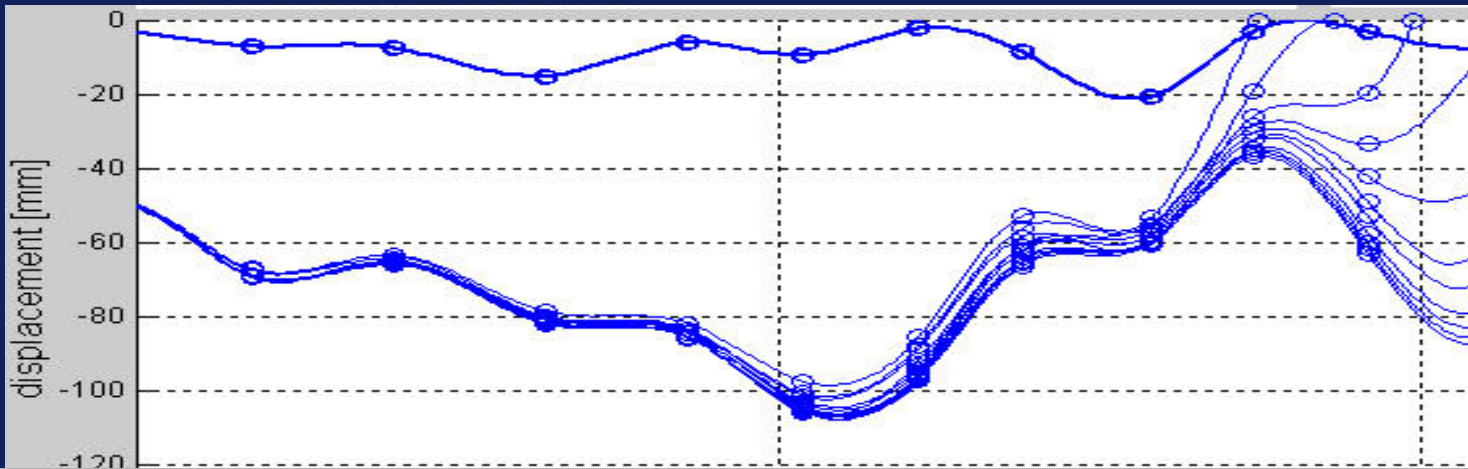
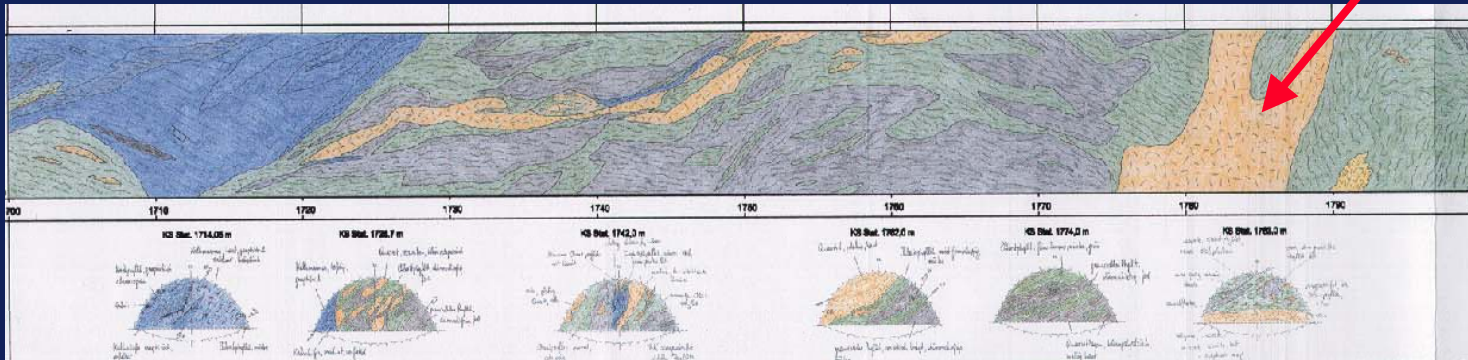


Tunnel Spital, Austria

# BIMROCK EFFECTS CASE STUDY

## Block effect on displacement settlement crown / top heading

Block



Tunnel Spital, Austria



## BIMROCK EFFECTS: COLLAPSE at GALGENBERG TUNNEL, AUSTRIA

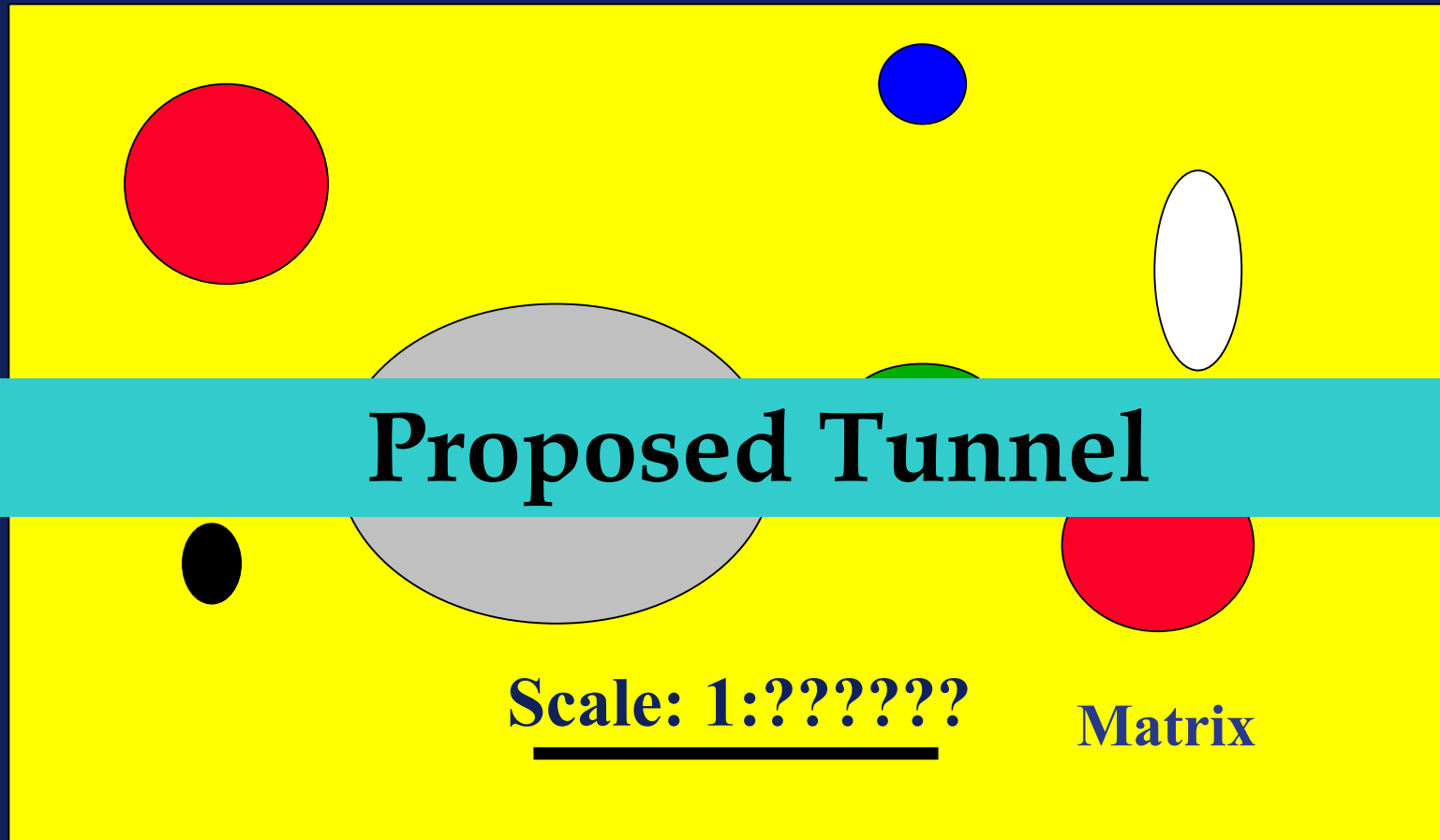
A fatal collapse July 1994 at station 1330 m.  
Eight meters of heavily supported tunnel section collapsed at the face.  
A miner, and equipment was buried  
Redesign and maintenance work lasted for two months.



**Collapse** caused by **brittle failure** of stiff rock  
**outside** of excavation



# BIG CONCLUSION 1: Remember this picture!!!



Actual Distribution of Blocks

**BIG CONCLUSION 2:**  
**Remember this picture as well!!!**



**Proposed Tunnel**

**Apparent Distribution of Blocks**



# Exponent™



ex·po·nent  
(ik-spo'nent) *n.*

1. *One who expounds or interprets.*