



Challenges to Tunnel Design

A Case History of the Bolu Tunnel

Johann Brandl

Major Tunnelling Projects along the Turkish Motorway Network



- Istanbul – Ankara Motorway: Izmit Tunnels (1987-1990), Bolu Tunnel (1990-2006)
- Tarsus Adana Gaziantep Motorway – Section 3: Tasoluk-, Ayran-, Kizlac- and Aslani Tunnels (1990 – 1998)
- Izmir-Aydin Motorway: Selatin Tunnel, Karsiyaka Tunnels (1988 – 2000)

Alignment of Bolu Mountain Crossing

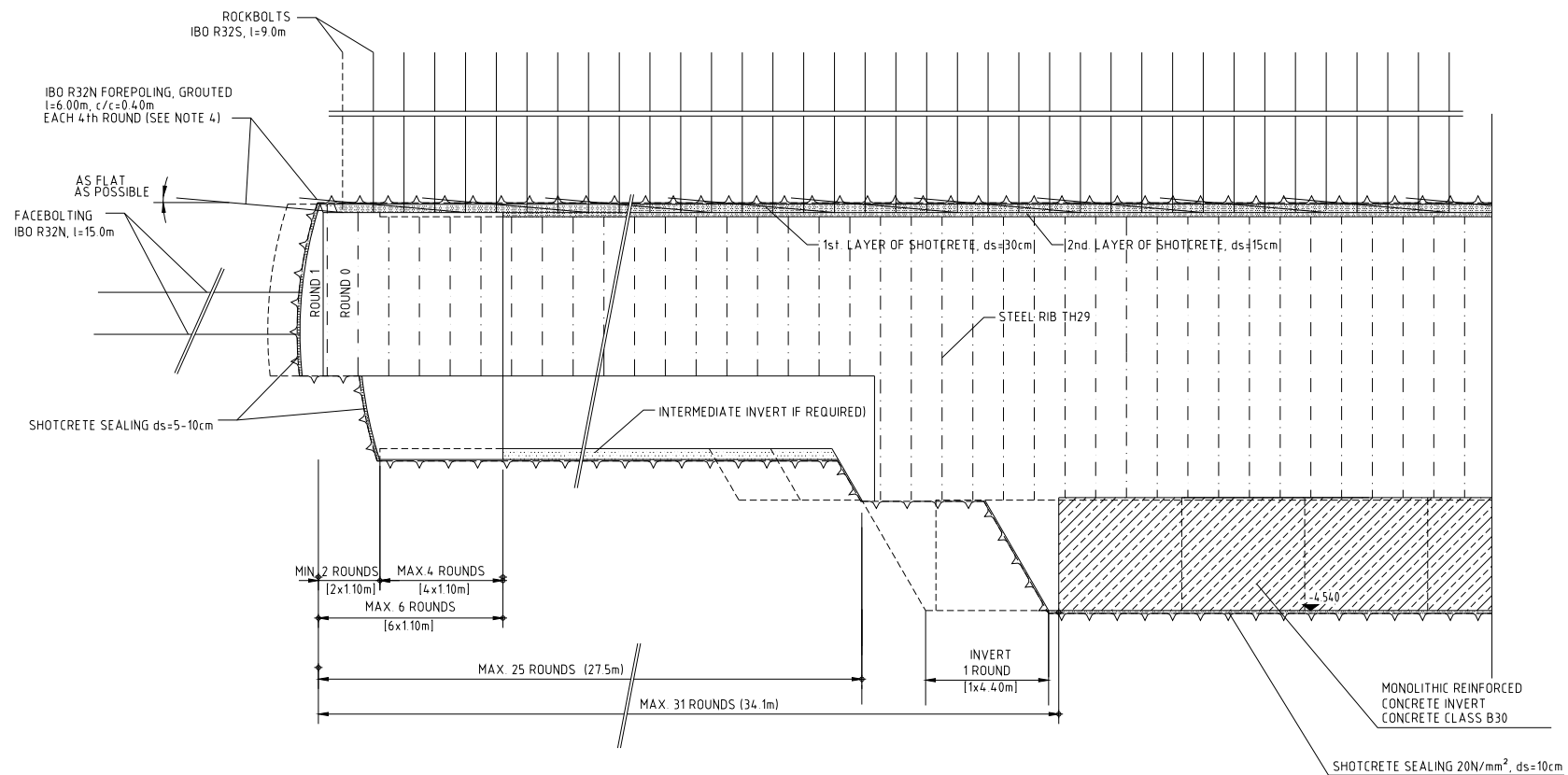


Elmalik Portal View

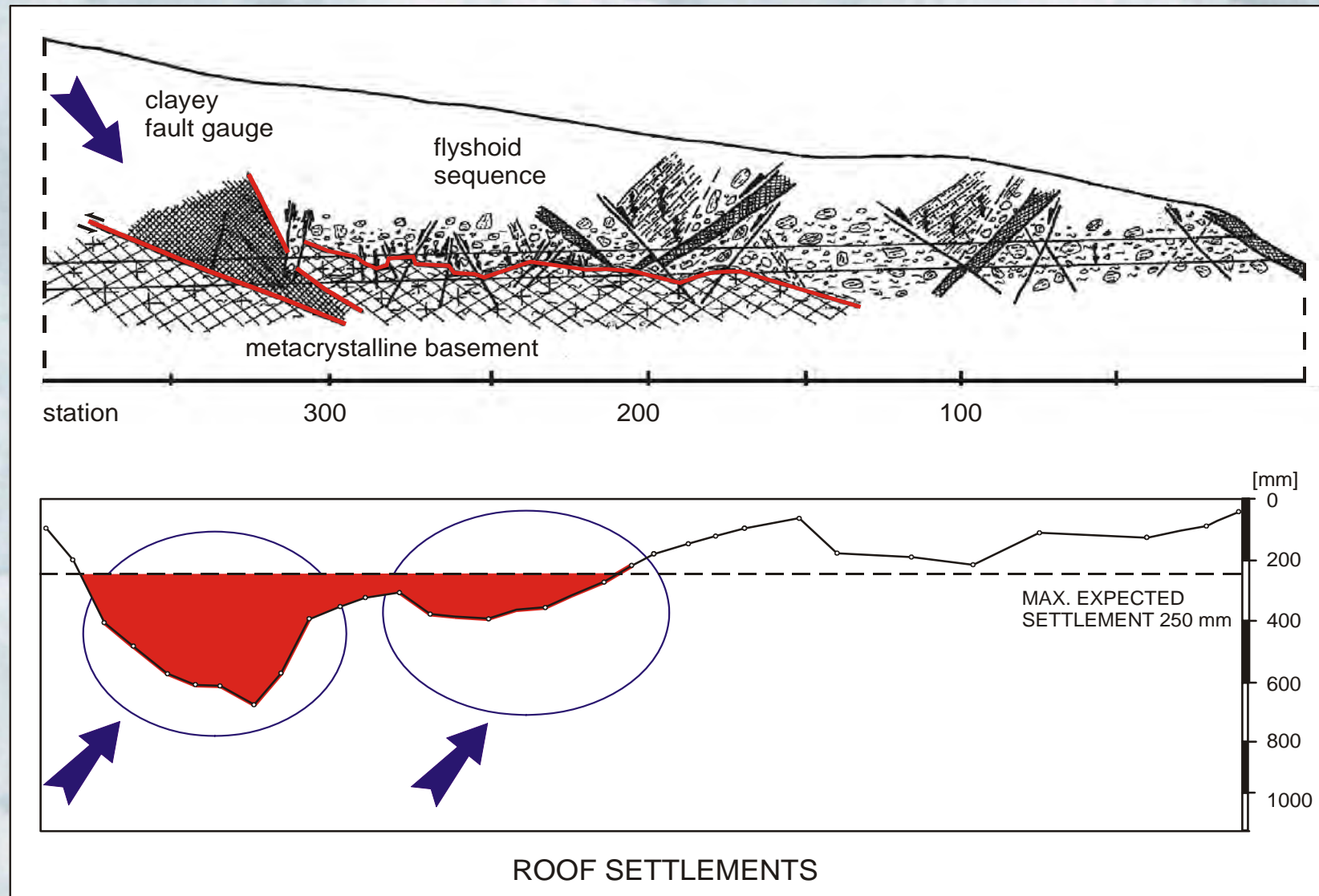


5

Typical Excavation Sequence for NATM



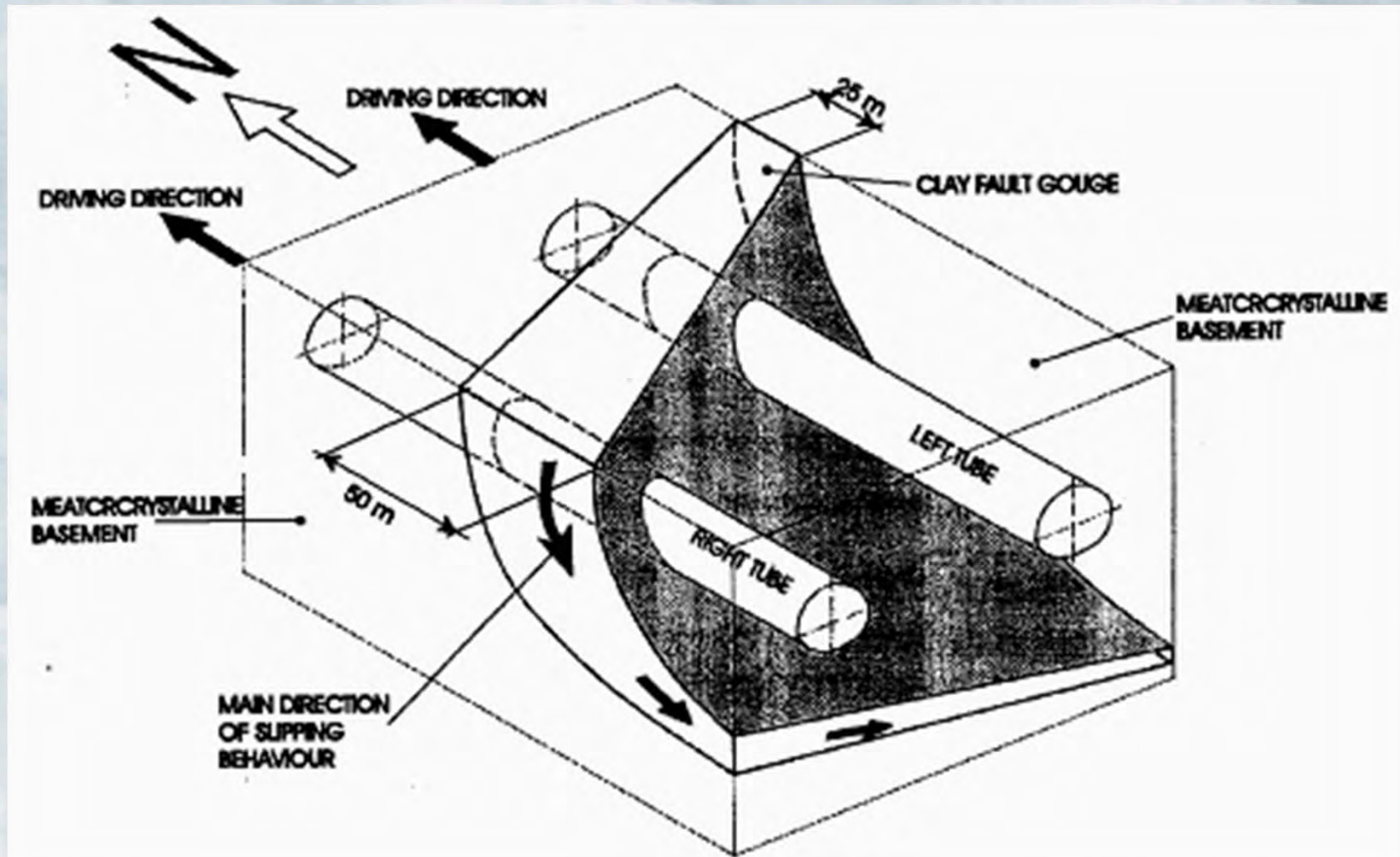
Geological Condition Elmalik (1997)



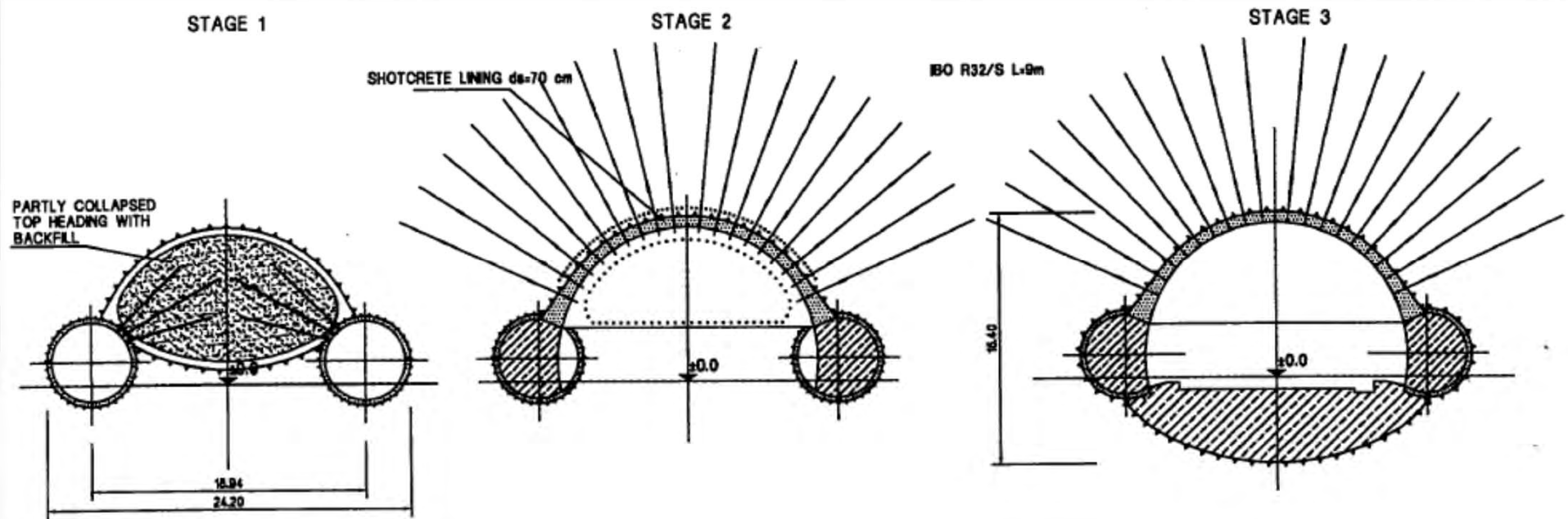
Settlements and Reexcavation at Elmalik Portal



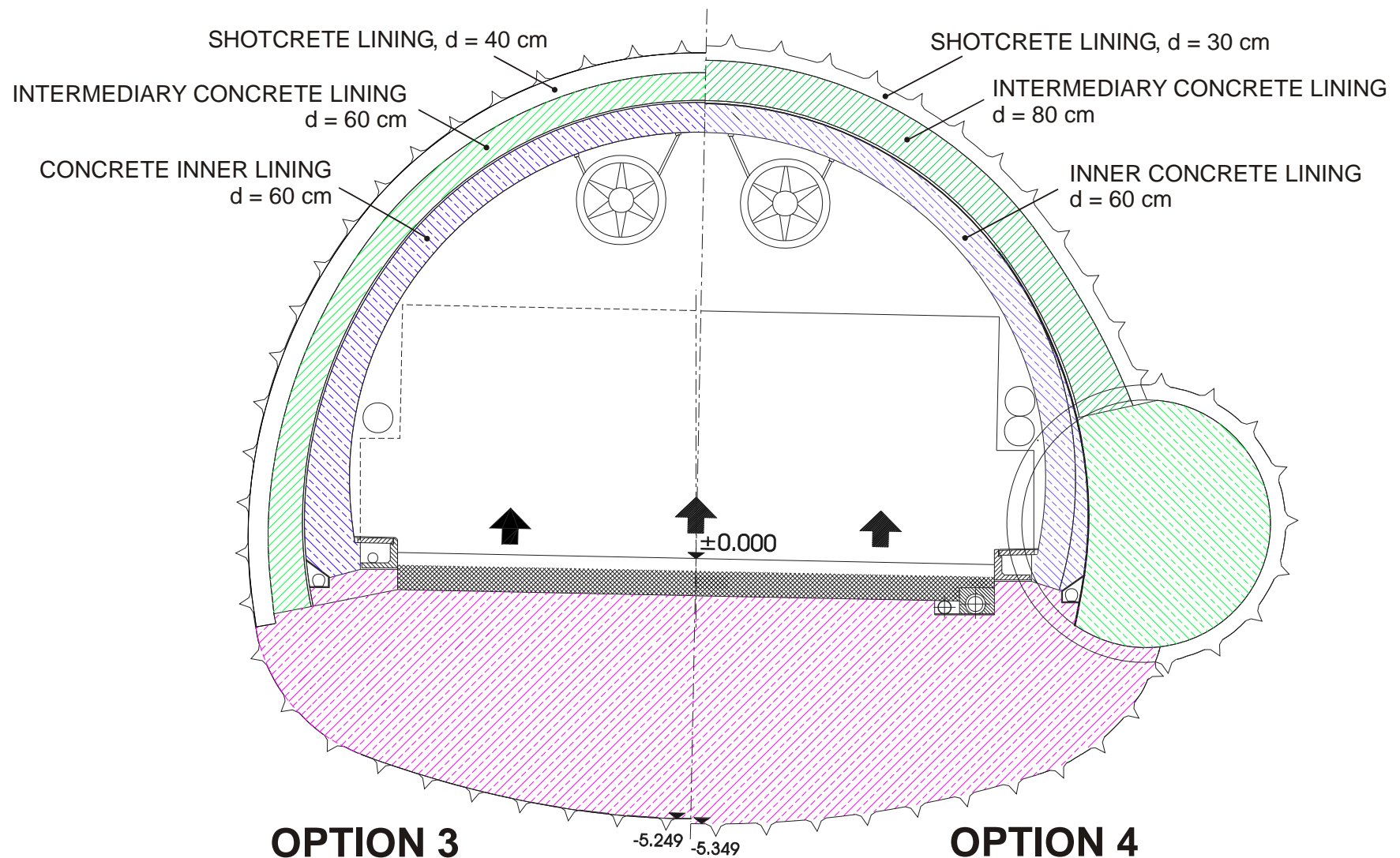
Slip Mechanism of Fault



Principle of Reexcavation



Support Classes Option 3 and Option 4



Earthquakes in 1999

August 1999

– Kocaeli Quake

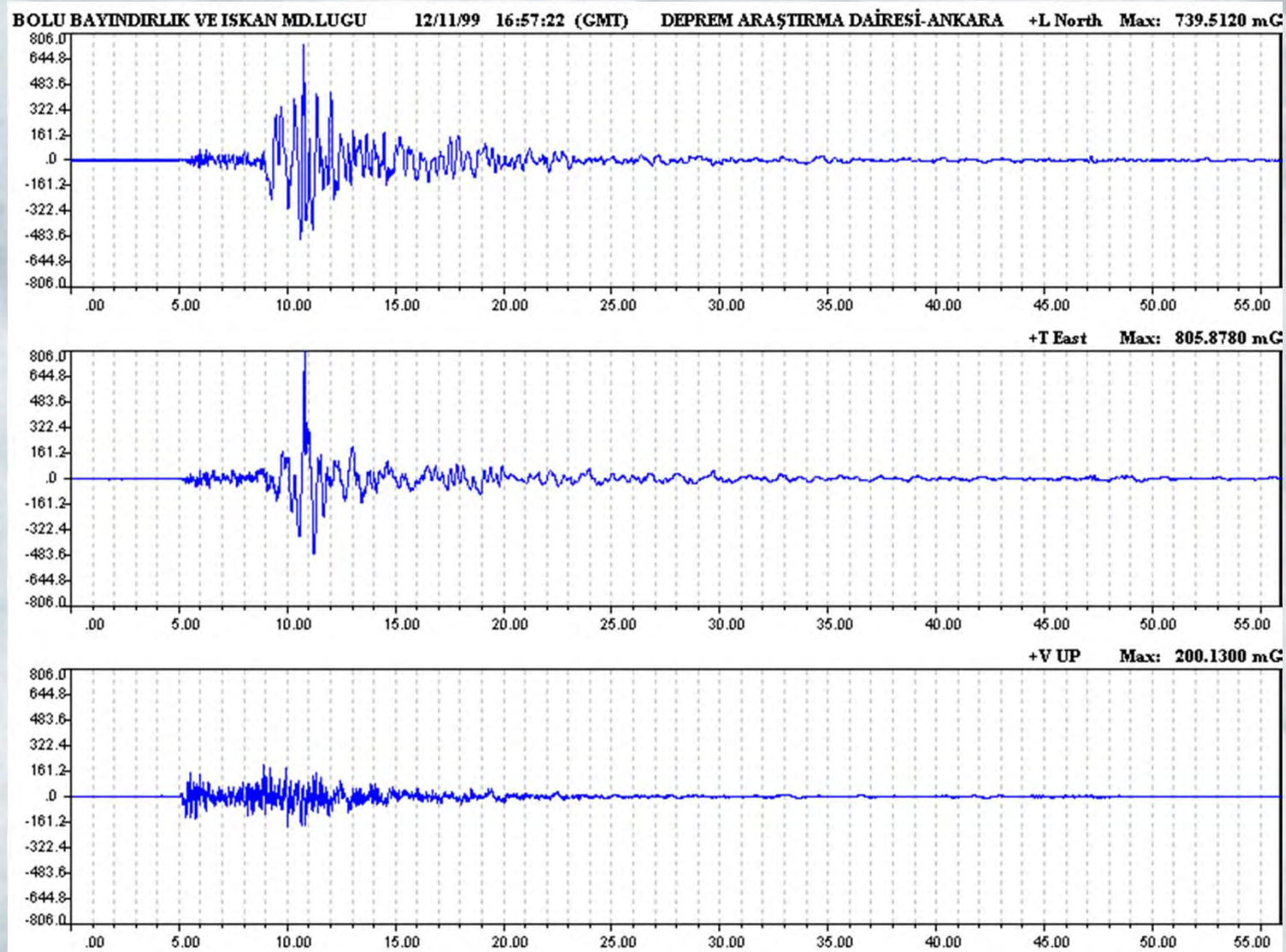
- 150 km west of construction site
- Magnitude 7.4
- Horizontal accelerations 0.2 – 0.3 g
- No damage to tunnels and viaducts

November 1999

– Düzce Quake

- 20 km west of construction site
- Magnitude 7.1
- Horizontal accelerations 0.6 – 0.8 g
- Severe damages to tunnels and viaducts

Seismic Record of Düzce Quake 1999



Damages due to Düzce Earthquake

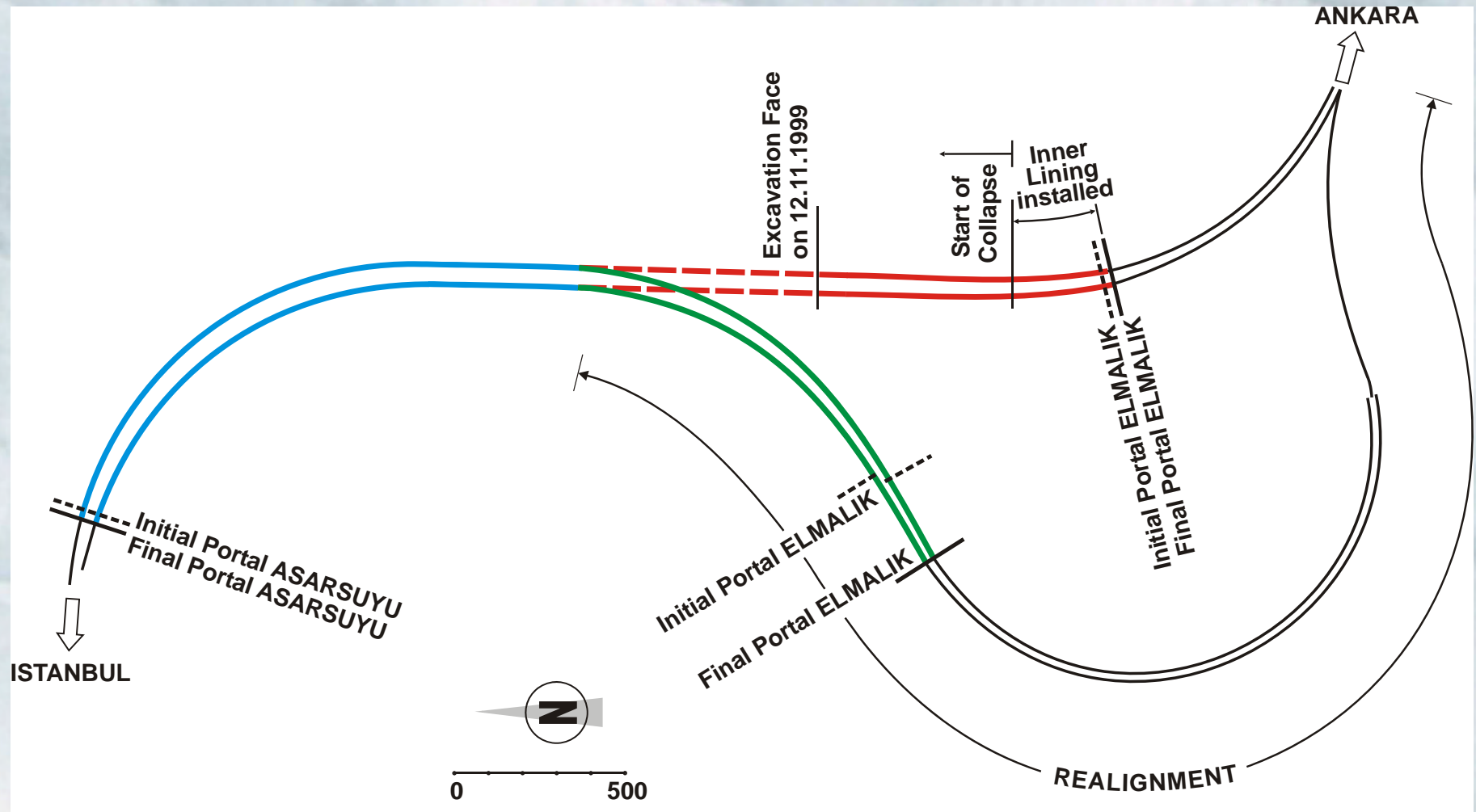


Damage to Pilot Tunnel

Sinkhole above Tunnel



Realignment after Earthquake on Nov. 12, 1999



Alignment of Bolu Mountain Crossing



Seismic Joints in Inner Concrete Lining



Seismic Joints at Concrete Invert



Opening of the Bolu Tunnel to Traffic in December 2006

