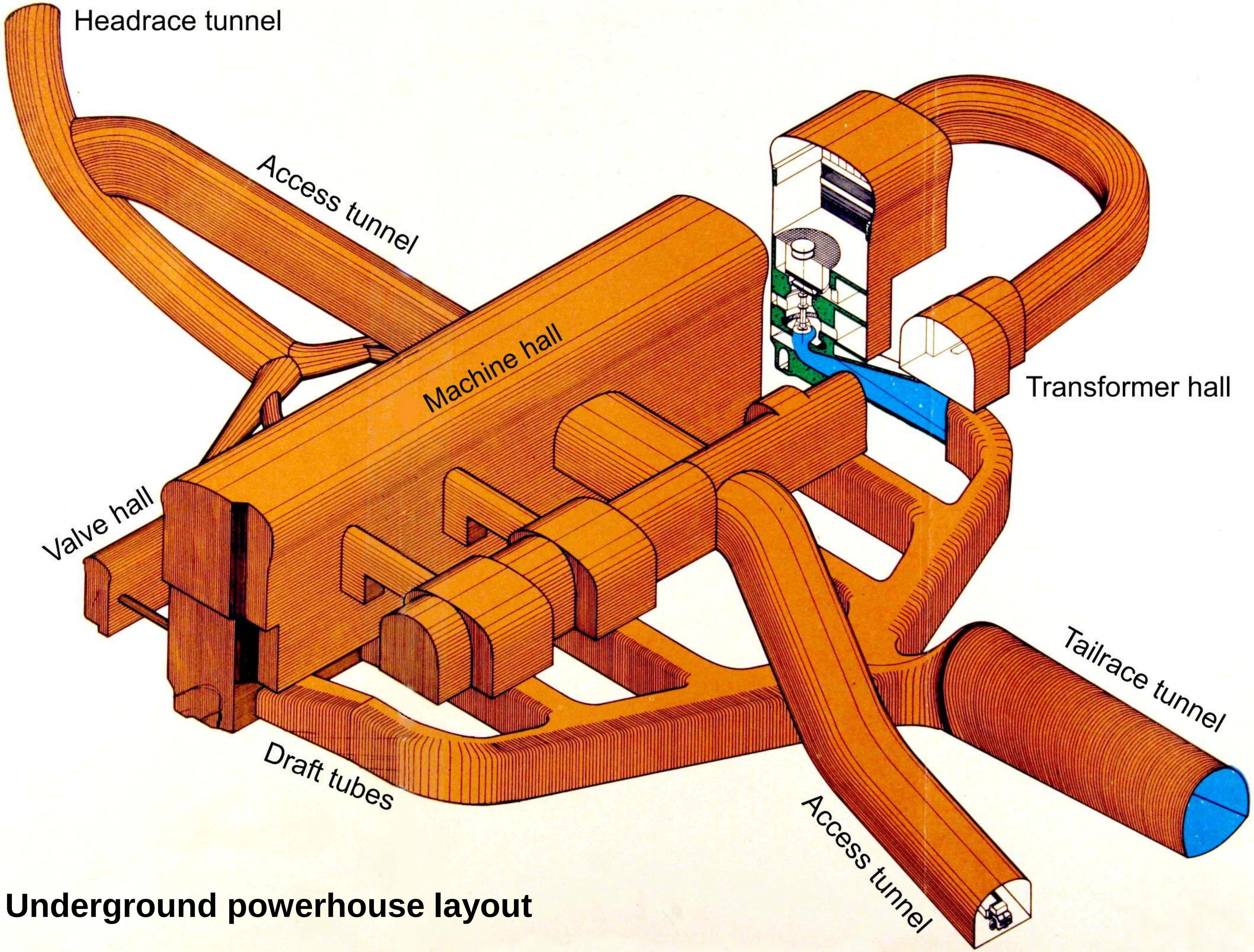
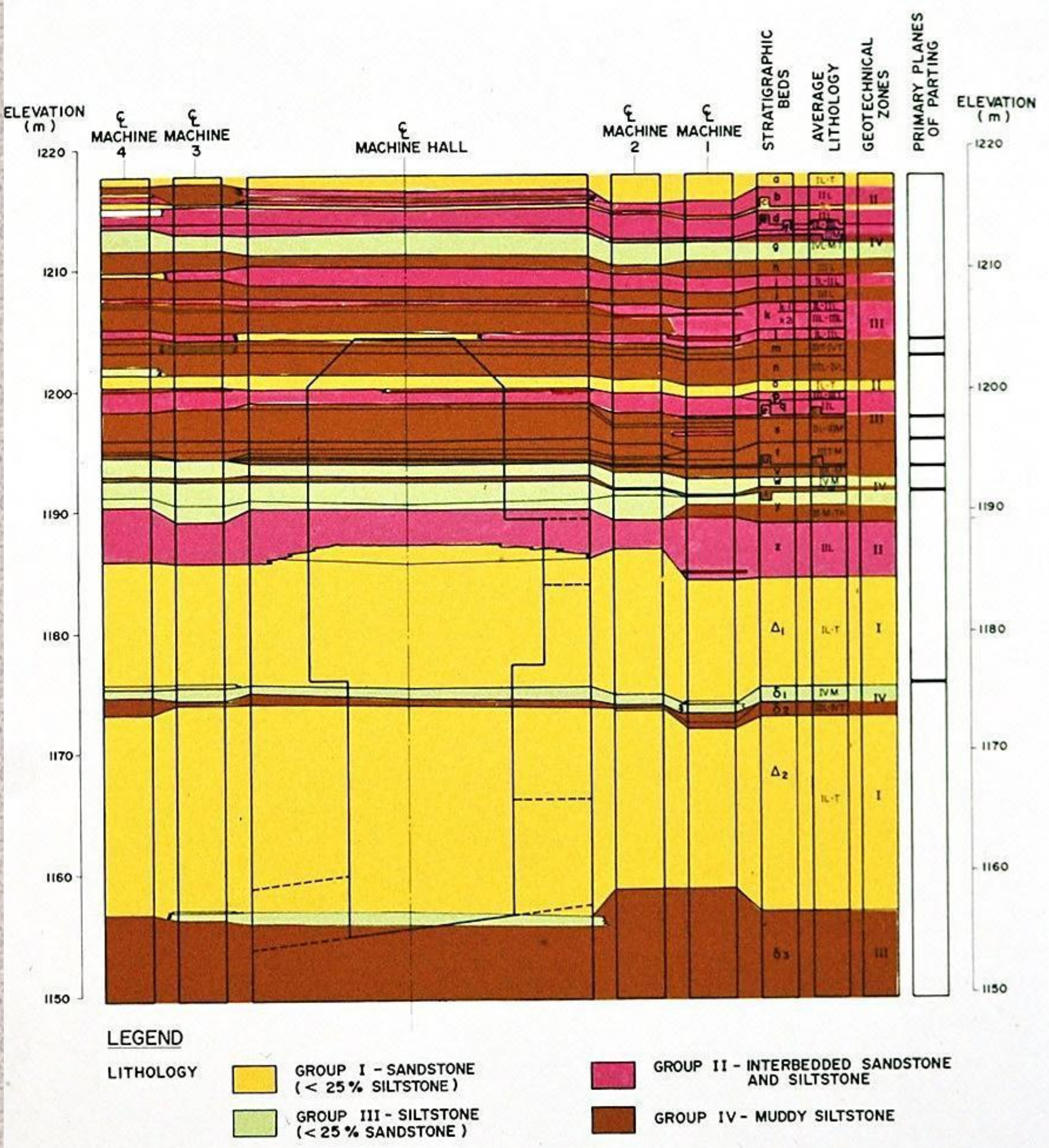
International Symposium on Practices and Trends for Financing and Contracting Tunnels and Underground Works. Athens. 22-23 March 2012.

Alternative ground control strategies in underground construction

Evert Hoek, Consulting Engineer, Vancouver, Canada



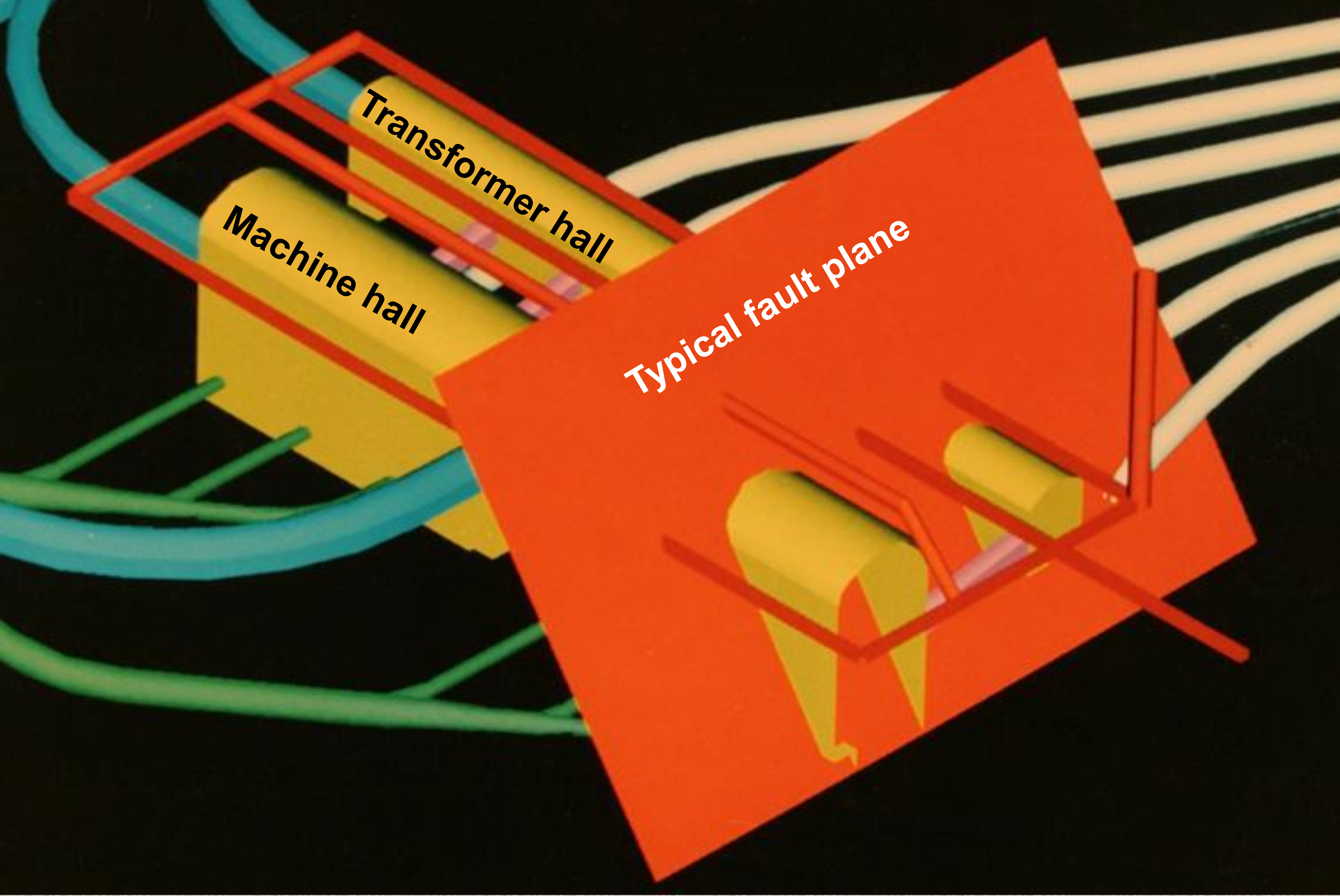
Underground powerhouse layout



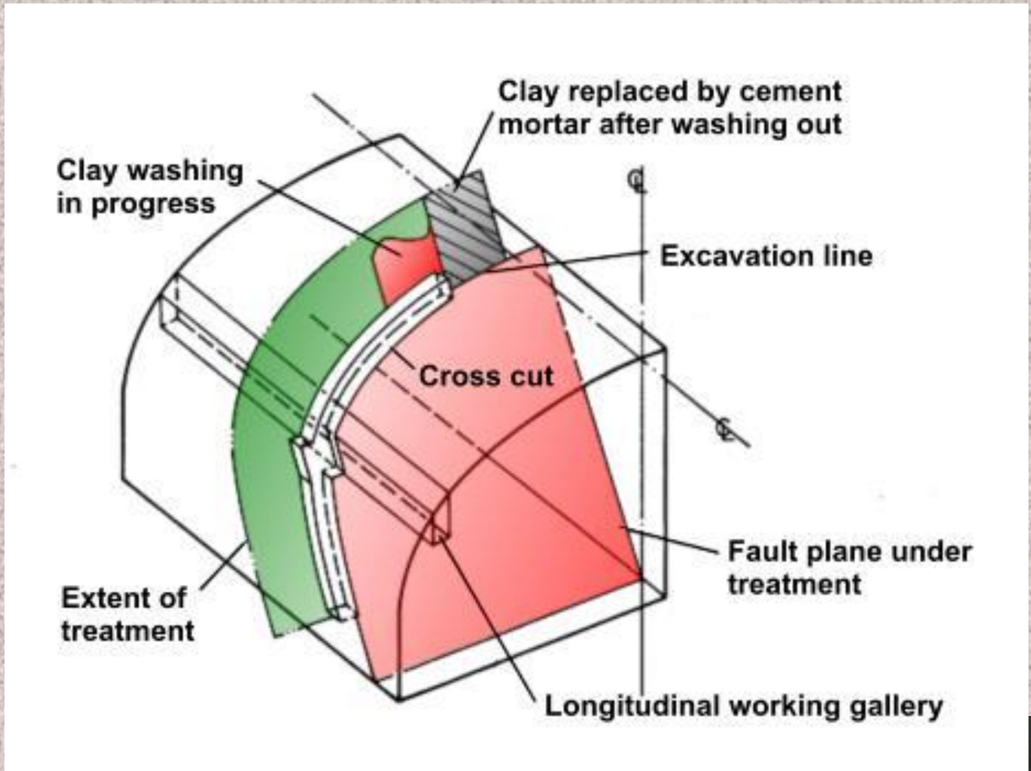
Geological model for an underground powerhouse project

In situ stress measurements

In situ plate bearing test to determine rock mass deformation modulus

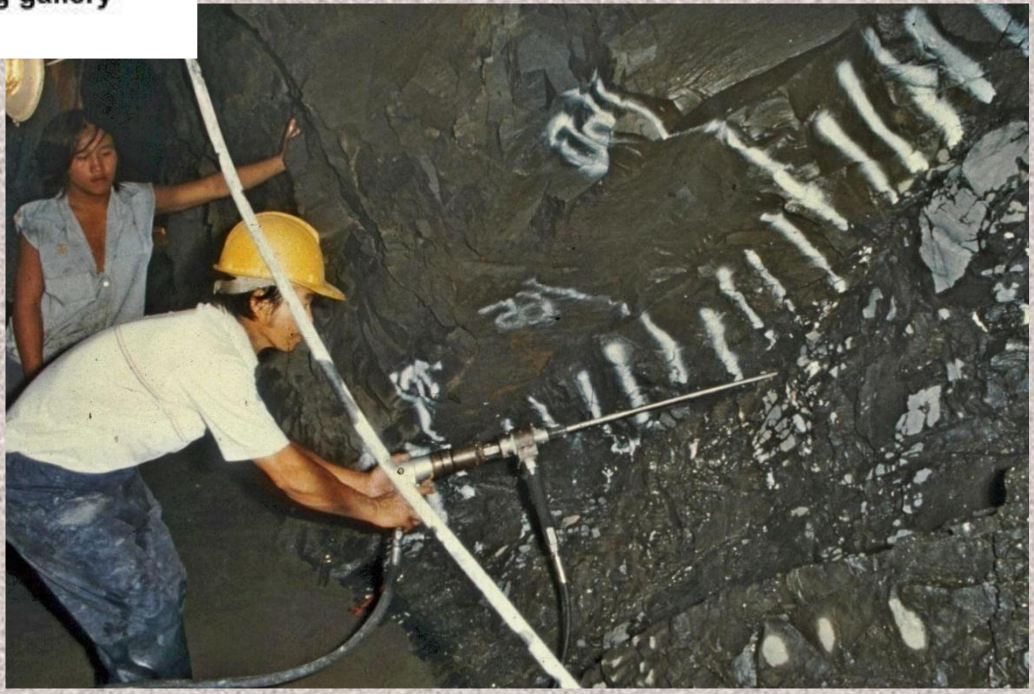


Mingtan Pumped Storage Project, Taiwan – underground excavations



Working arrangement for replacement of clay seams in crown of machine and transformer halls

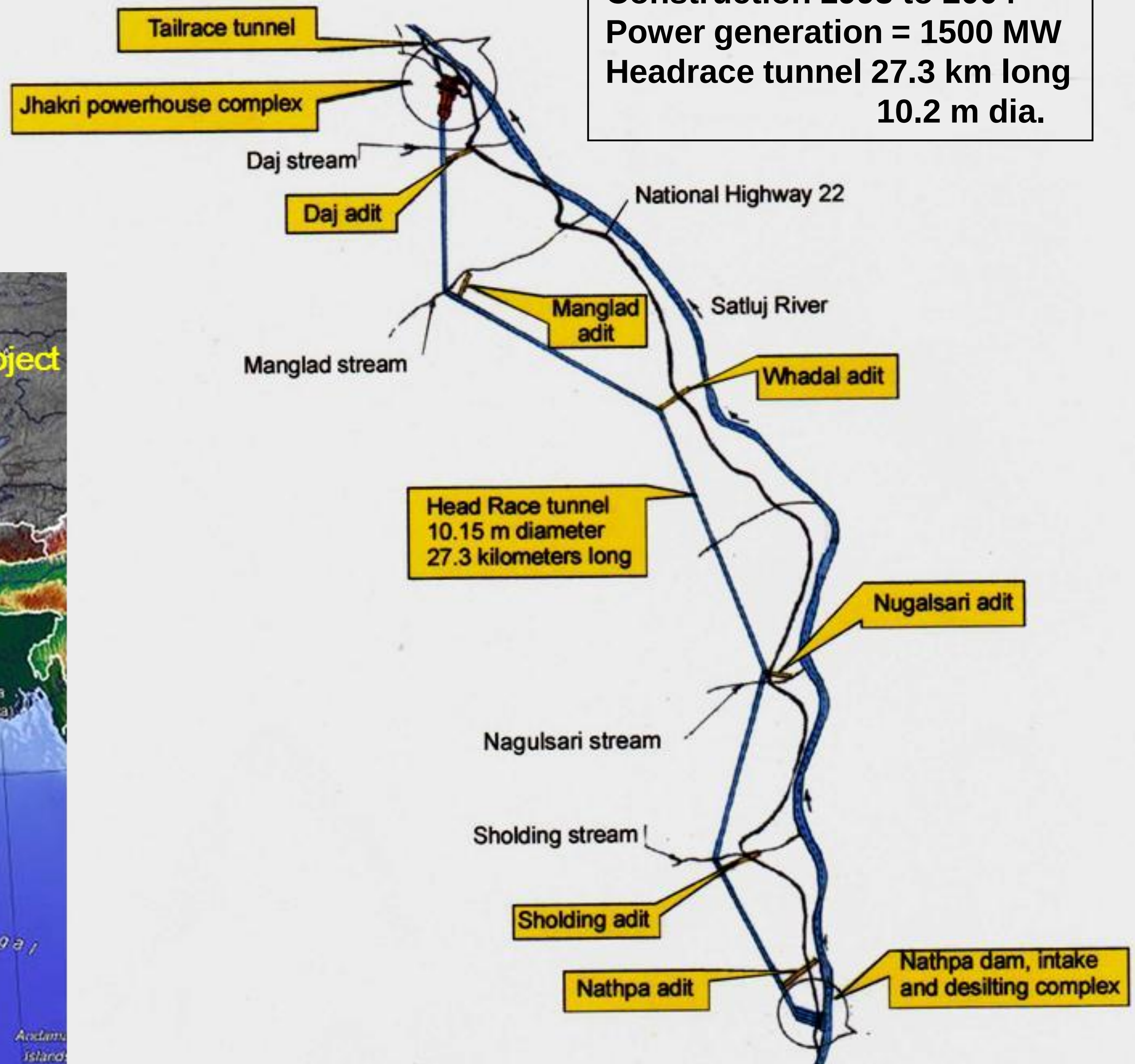
Washing out of thin clay seams using a very high pressure water jet



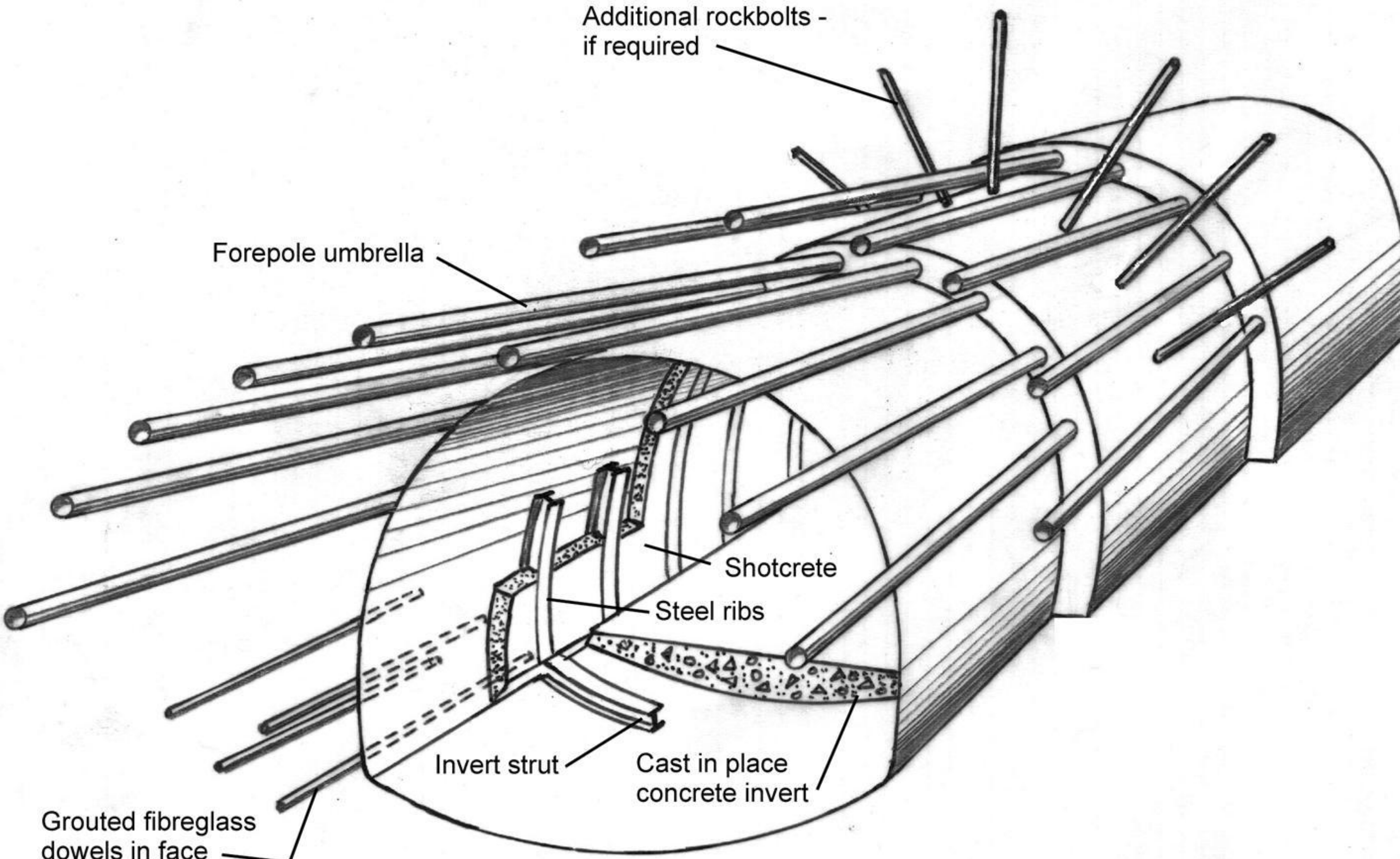
The Mingtan Project involved a preliminary contract in which remedial work was carried out. The main contract was a simple fixed price contract which was bid on the basis that the cavern would be excavated in “good” ground.

Nathpa Jhakri Hydroelectric Project, India

Construction 1993 to 2004
Power generation = 1500 MW
Headrace tunnel 27.3 km long
10.2 m dia.



Squeezing of a headrace tunnel top heading in the Daj Khad fault zone, Nathpa Jhakri Hydroelectric Project, Himachel Pradesh, India

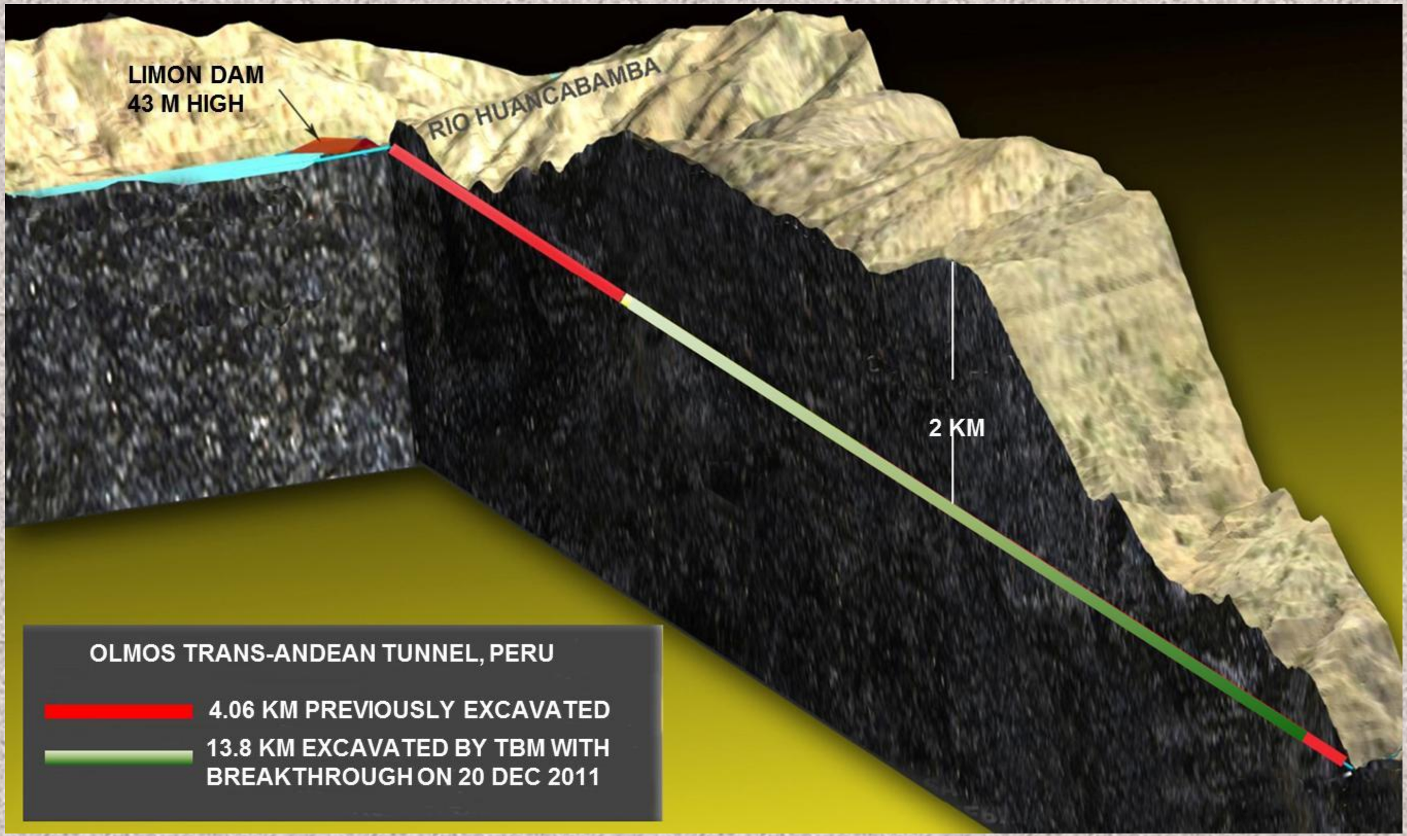


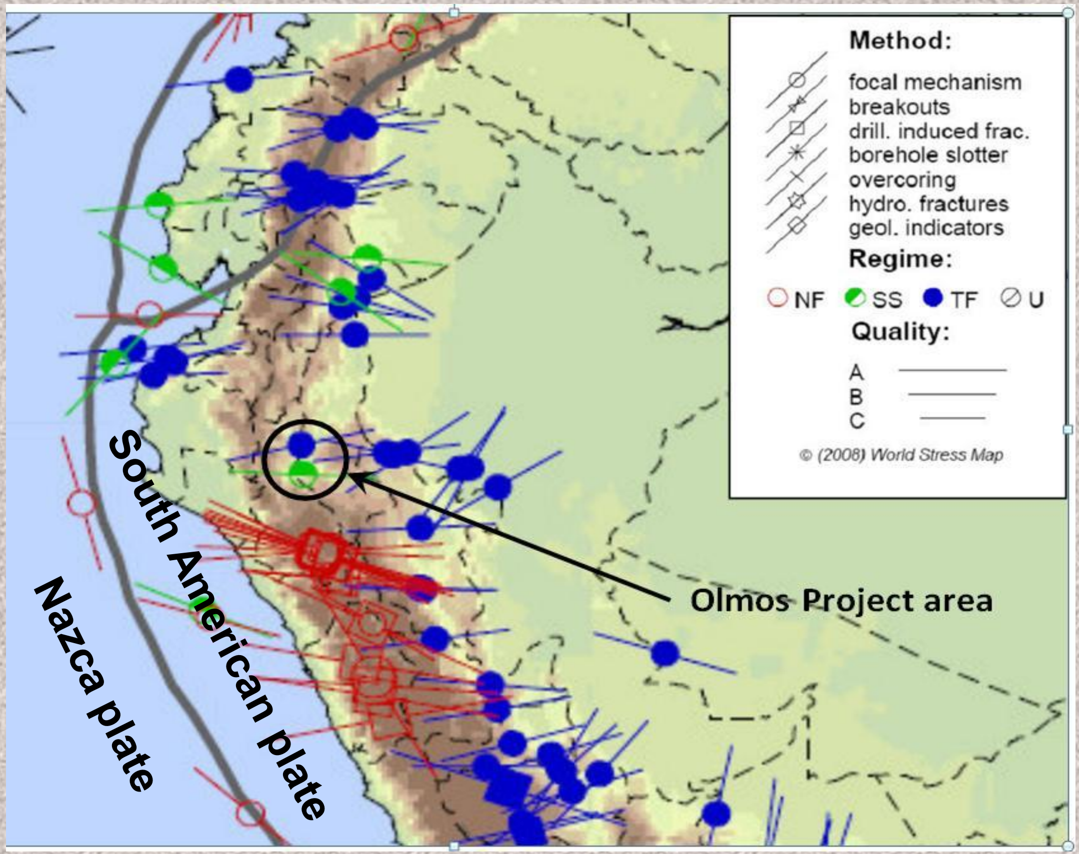
Advancing a tunnel under a forepole umbrella

Forepole installation in the Daj Khad fault zone

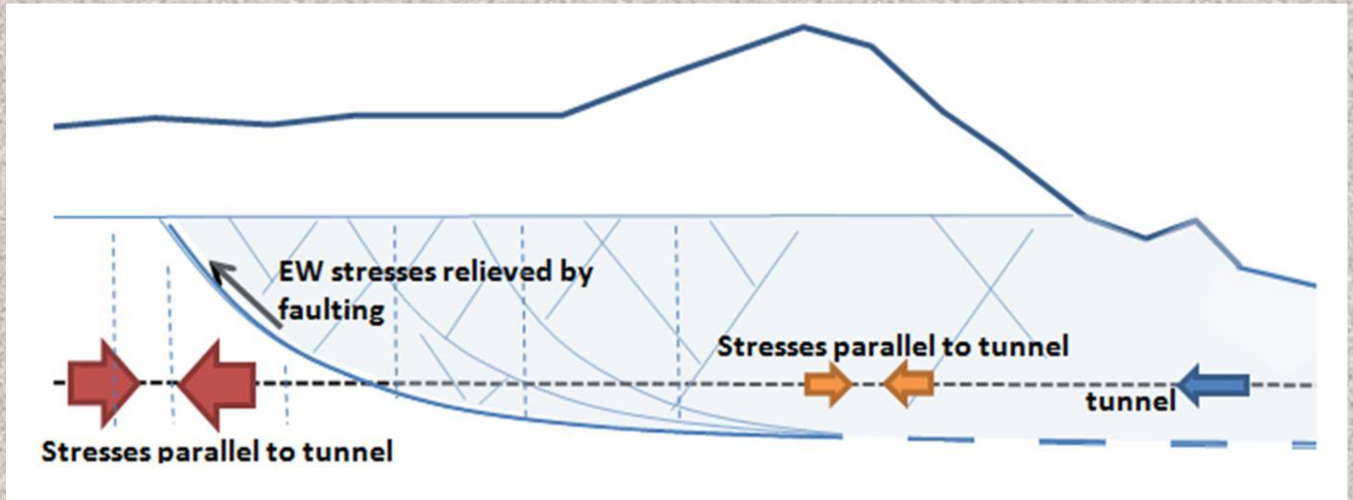
In July 2004 a 20 year Design-Build-Own-Operate-Transfer concession was awarded for the construction of the Olmos Project. This will transfer water 20.1 km from the Huancabamba River to the arid Pacific Coastal Watershed. The Trans-Andean tunnel has been driven by drill and blast and by TBM at depths of up to 2 km below surface.

High in situ stresses are a major issue in tunnels driven at this depth.

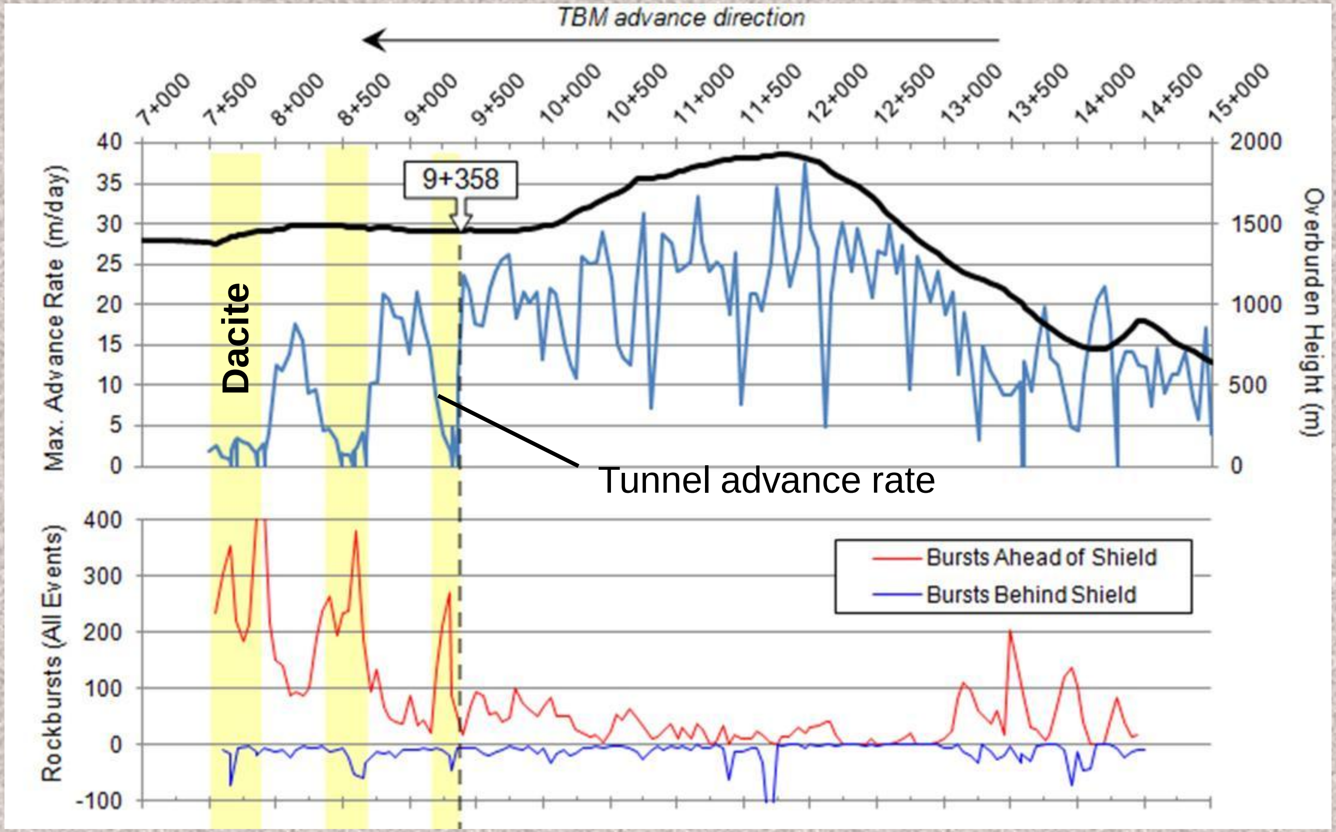




Direct measurement of in situ stresses is not possible at depths in excess of a few hundred metres. Some indication of the orientation of the maximum horizontal in situ stress is given by the World Stress Map but no stress magnitudes are available.



The stresses are complicated by faulting induced by subduction of the Nazca plate under the South American plate



Rockburst record between February 2007 and November 2010.

After Eberhardt, 2011.

The main problem faced in driving the 2 km deep tunnel was the popping and bursting of the hard brittle rock (particularly Dacite) as a result of very high in situ stresses. One rockburst, on 28 April 2010, caused severe damage to the TBM which took 3 months to repair.

Damage ahead of the TBM face (above), the shield rams (top right) and behind the machine (right). The steel ribs and mesh provide protection for the workers in the tunnel, even if severely deformed.

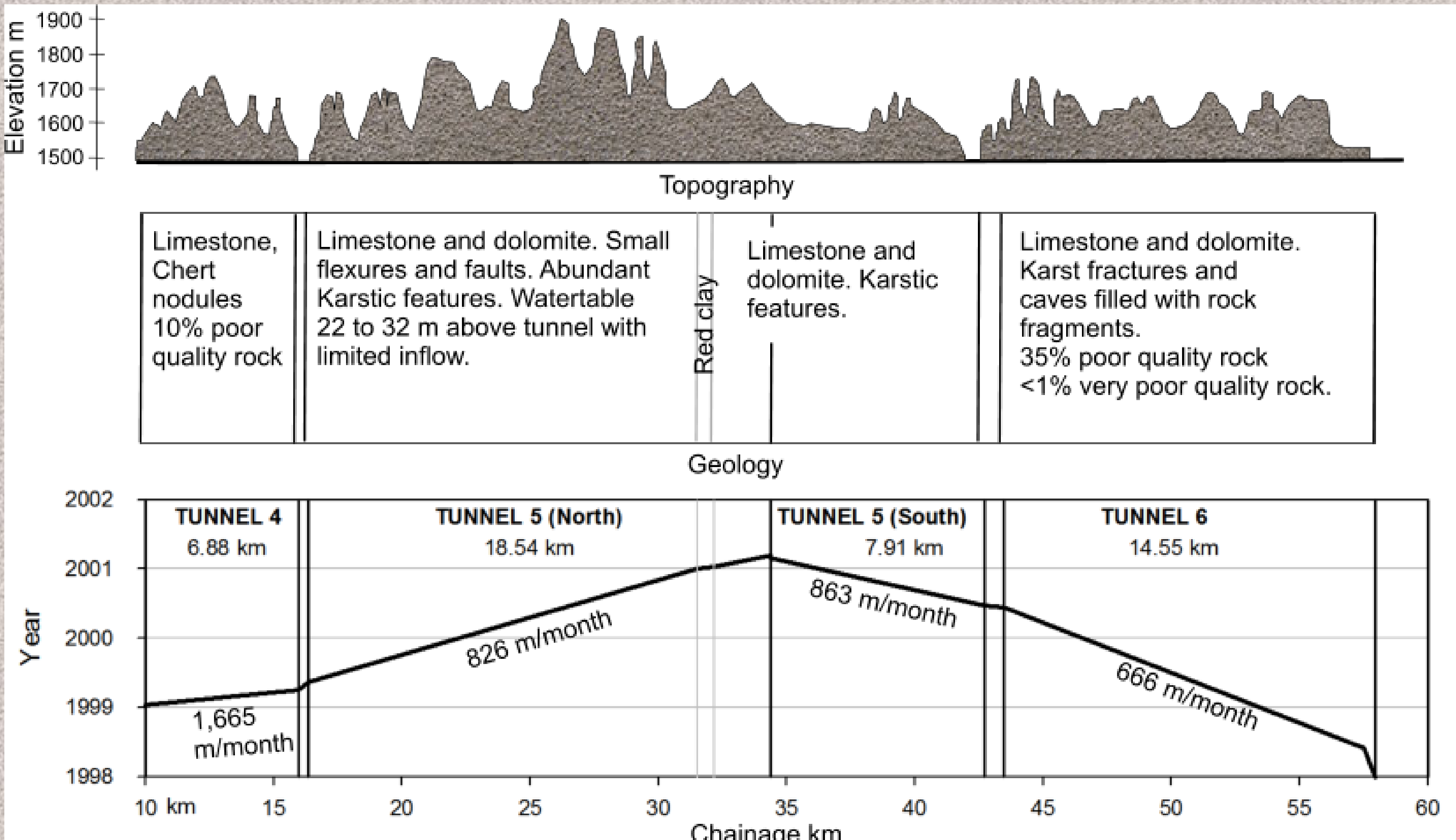
Demonstration assembly of steel rib support

Detail of pre-cast concrete invert segments


Completed Olmos TBM tunnel, ready for final lining installation

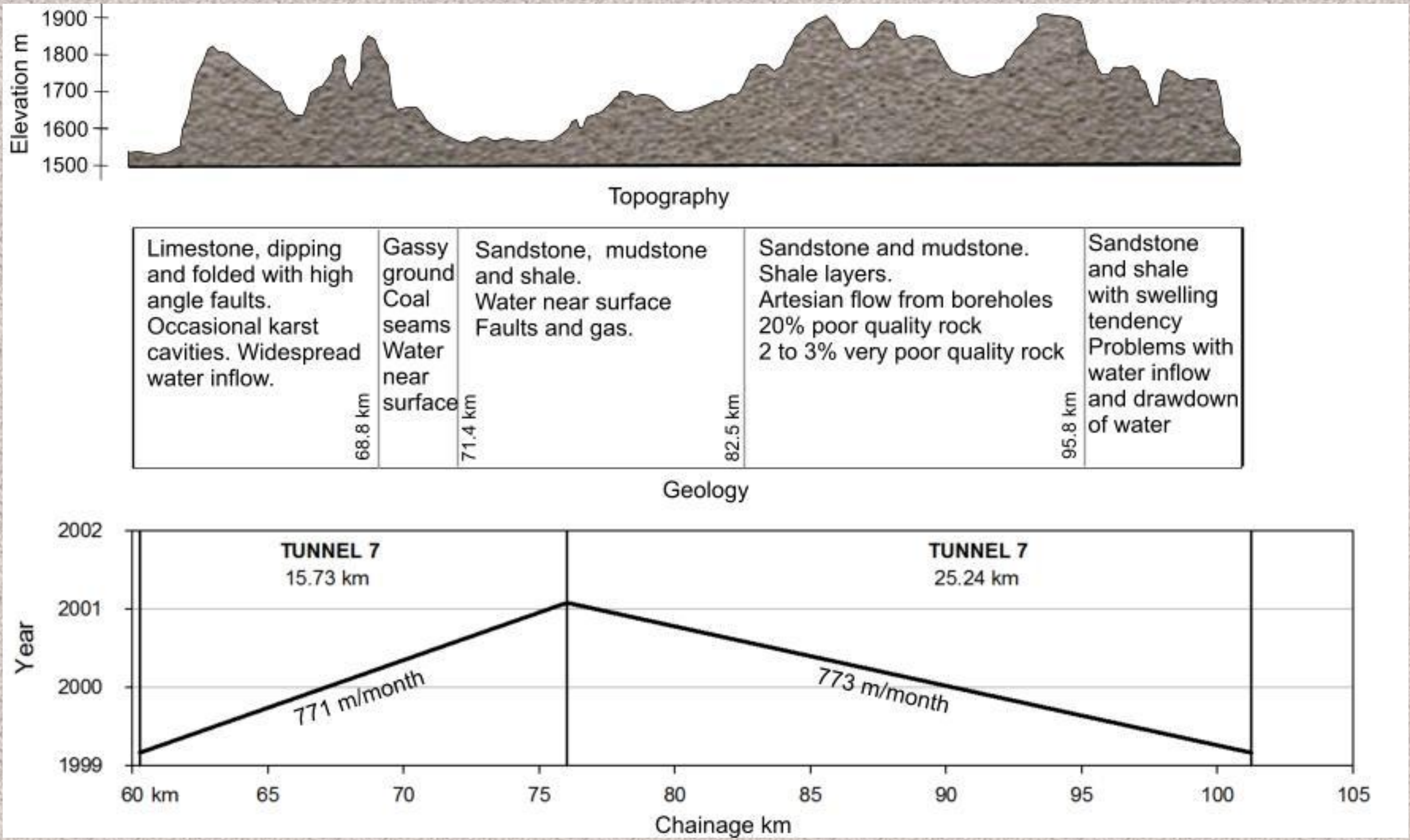
Yellow River Diversion Project, China

Tunnels 4, 5 and 6



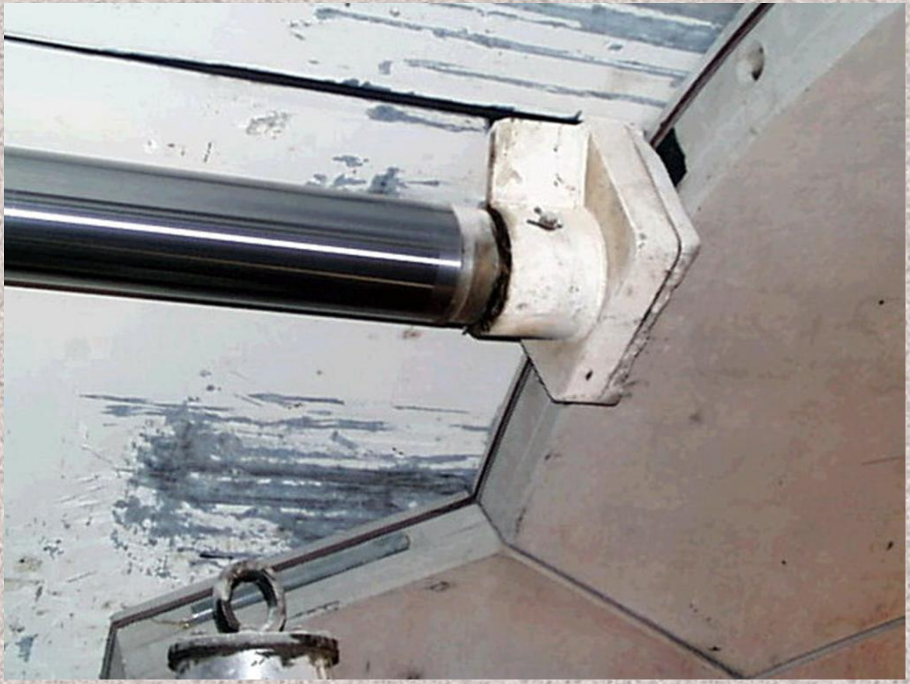
Yellow River Diversion Project, China

Tunnel 7



Honeycomb segmental concrete lining installed behind double shield TBM

Invert detail



Segment installation

Double shield TBM with segments

Advantages

- Insensitive to ground conditions
- Routine unaffected by rock conditions
- Early protection against rock falls
- Reduced number of trained personnel
- Ability to handle high water inflows
- Segments sealed to prevent leakage
- Pipes on hangers can be attached to segments
- Low long term maintenance costs
- High average advance rate ~ 600 meters per month per tunnel

Disadvantages

- High cost of precast segments
- Heavy use of access roads
- Strict adherence to means and methods specifications

Reference

Wallace, S. Record setting TBMs on Yellow River Drives. *Tunnel Talk.* Jan 2001 http://www.tunneltalk.com/China-Yellow-River-TBMs.php