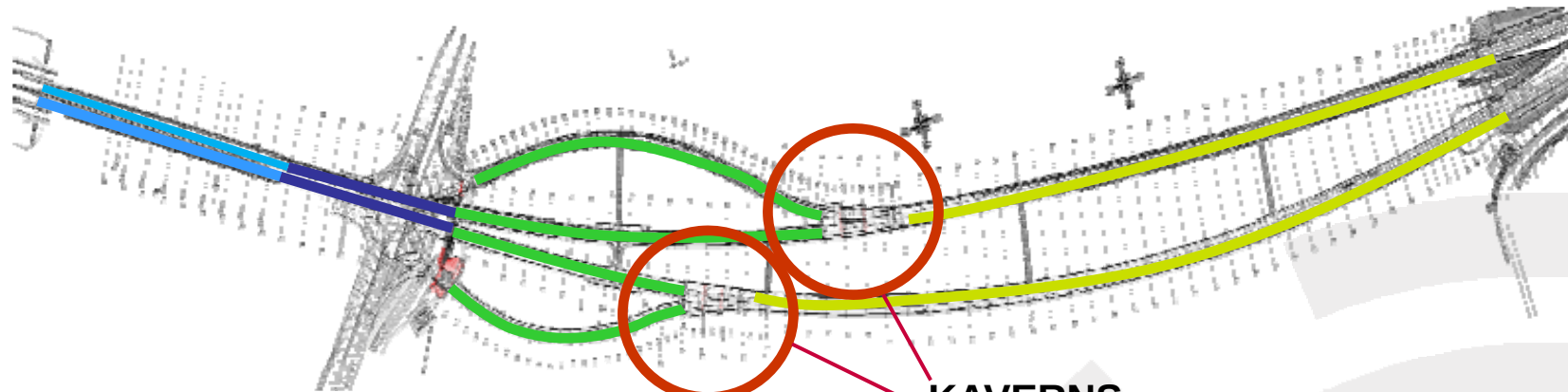


DESIGN AND CONSTRUCTION OF LARGE TUNNELS IN SOIL AND FAULTED ROCK

SENTVID TUNNEL – MOTORWAY BYPASS OF LJUBLJANA

Josef Daller, iC consulenten, Vienna - Austria

LAYOUT OF SENTVID MOTORWAY TUNNEL

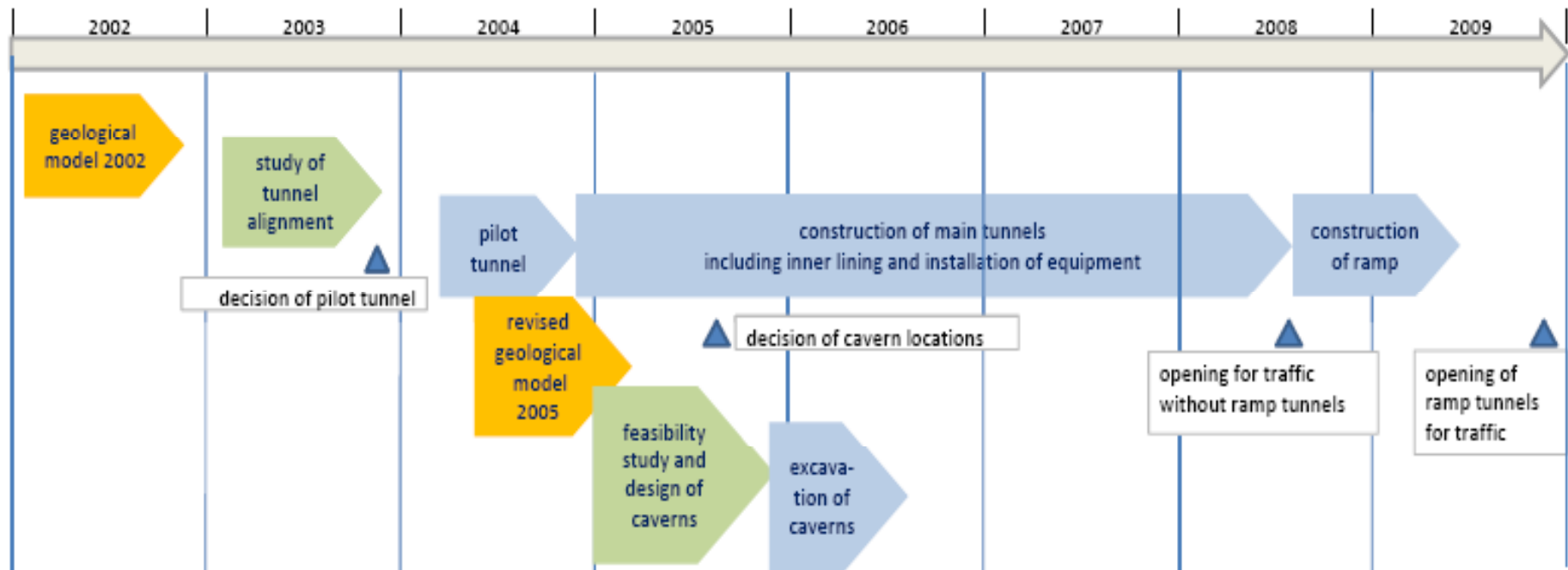


- OLD C&C TUNNELS
- NEW C&C TUNNELS
- 2-LANE TUNNELS
- 3-LANE TUNNELS

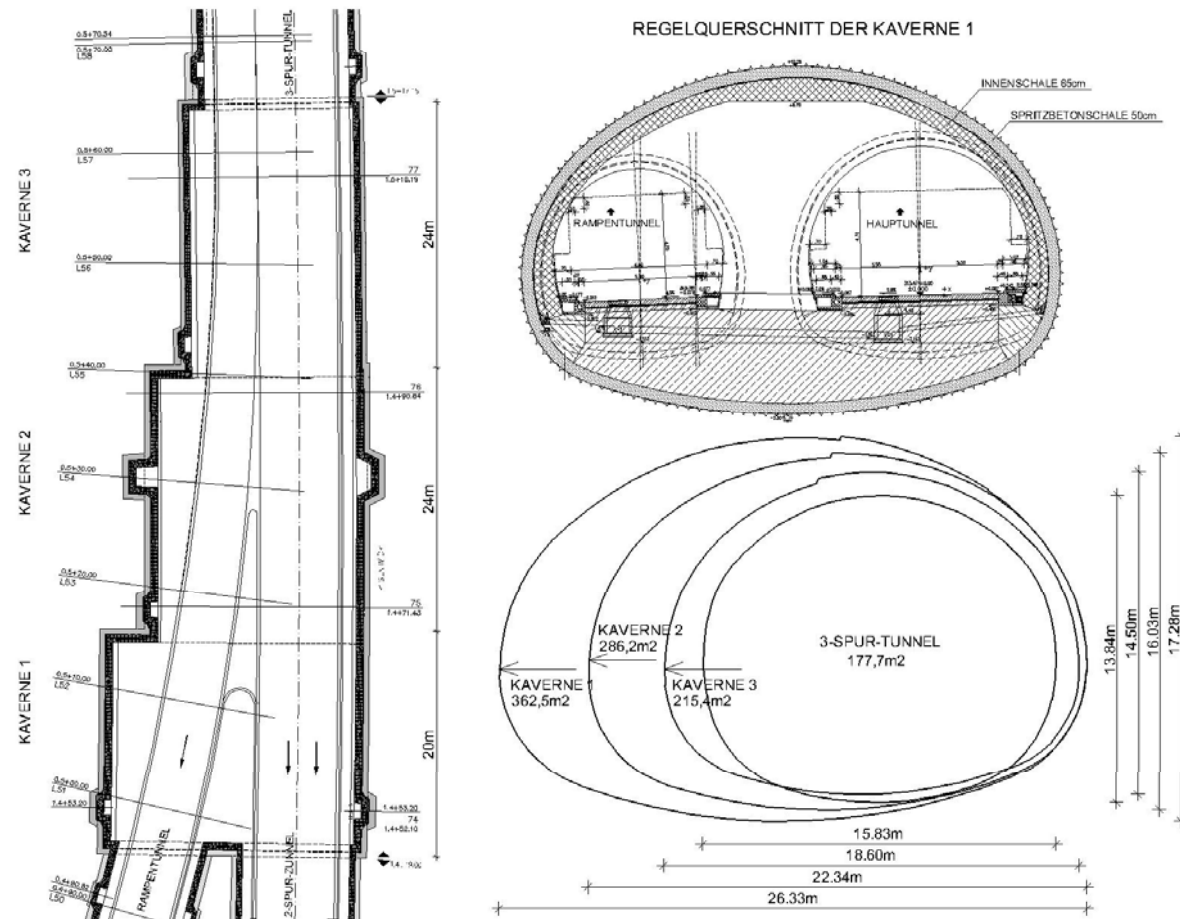
Section	Right Tube	Left Tube	Excavation Cross section
Cut & Cover	420 m	420 m	55 m ²
2 -lane	240 m	370 m	75 - 100 m ²
3 - lane	750 m	590 m	110 - 160 m ²
Cavern	84 m	84 m	180 - 360 m ²
Access/Exit ramps	255 m	360 m	70 - 95 m ²



SCHEDULE OF SENTVID MOTORWAY TUNNEL



LAYOUT OF KAVERN

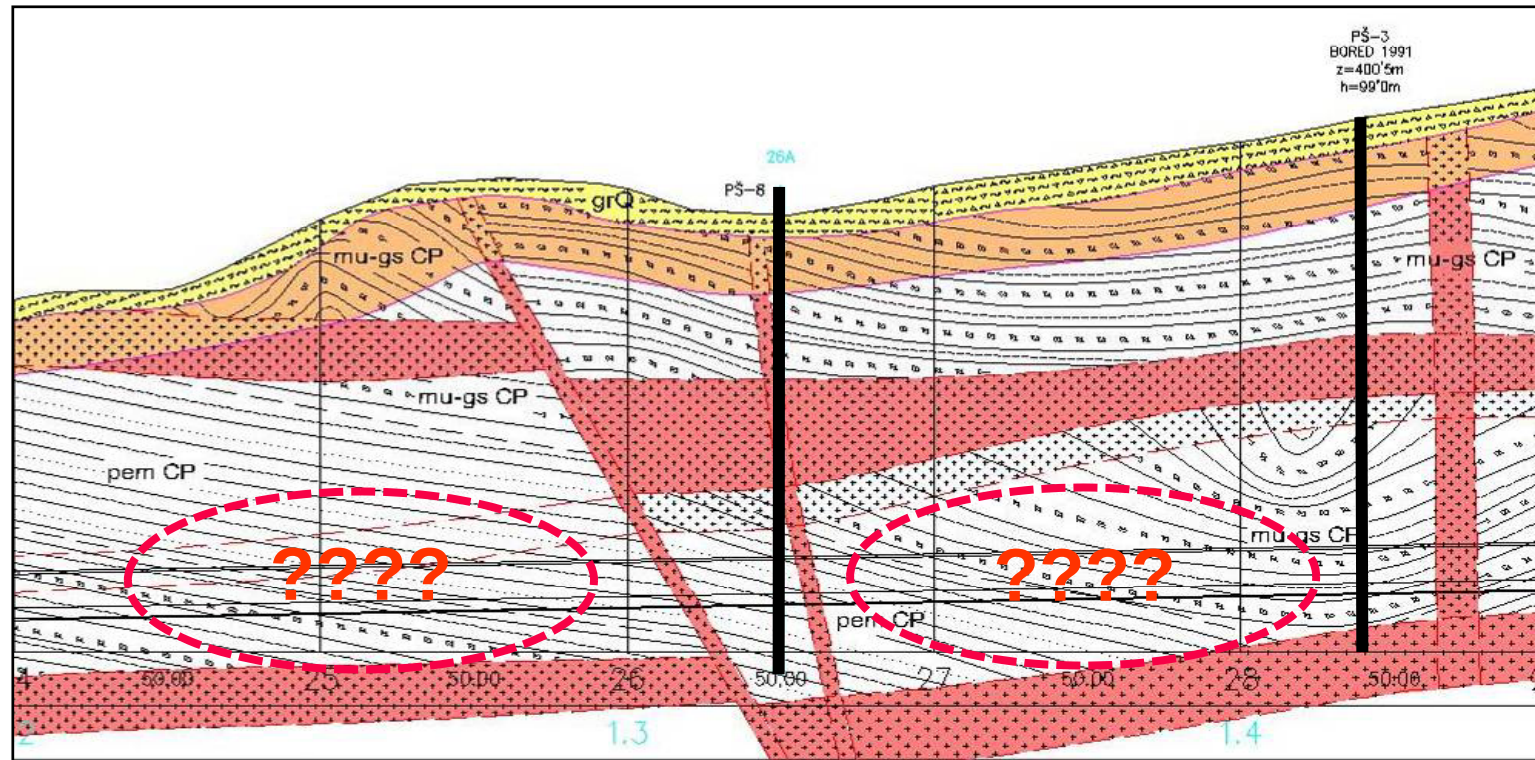


max. excavation: 360 m2

SENTVID TUNNEL – MAIN DESIGN TASKS

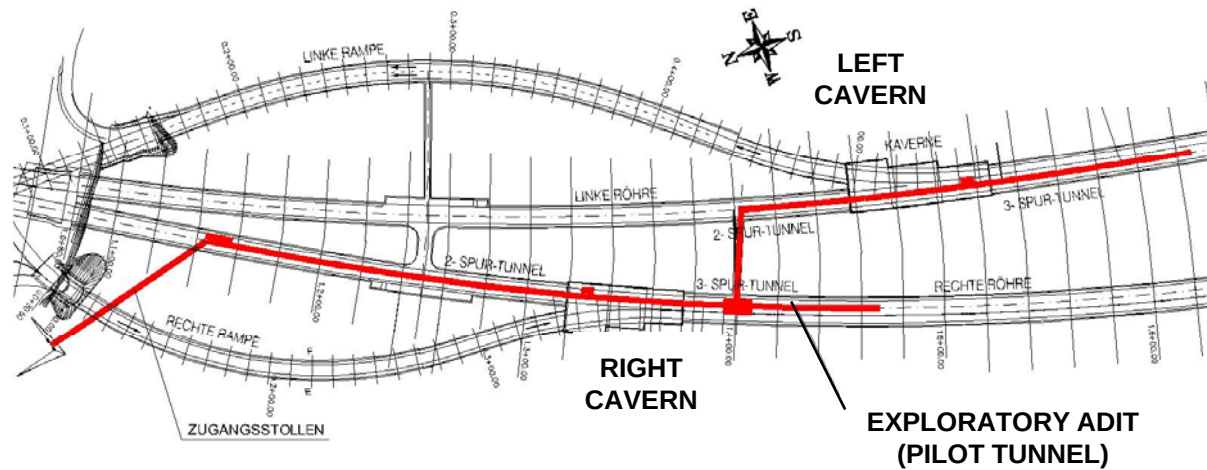
- Feasibility study based on revised/improved geological model, including risk analysis
- Design of adequate support system for reaching stability
- Support system must be compatible with expected deformations
- Design of proper excavation sequence
- Definition of deformation tolerances based on FE-analyses
- Design of monitoring programme

SENTVID TUNNEL – GEOLOGICAL MODEL 2002

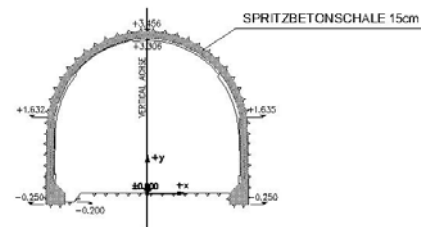


*Partly folded and tectonically disturbed meta-sand/siltstones & slates.
Fault breccias (< 20m) along low-angle thrusts and high-angle faults*

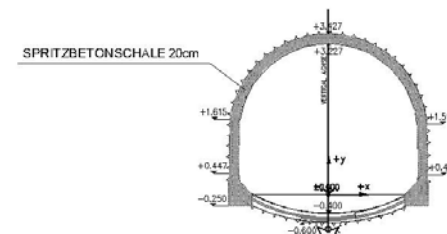
LAYOUT OF EXPLORATORY ADIT (PILOT TUNNEL)



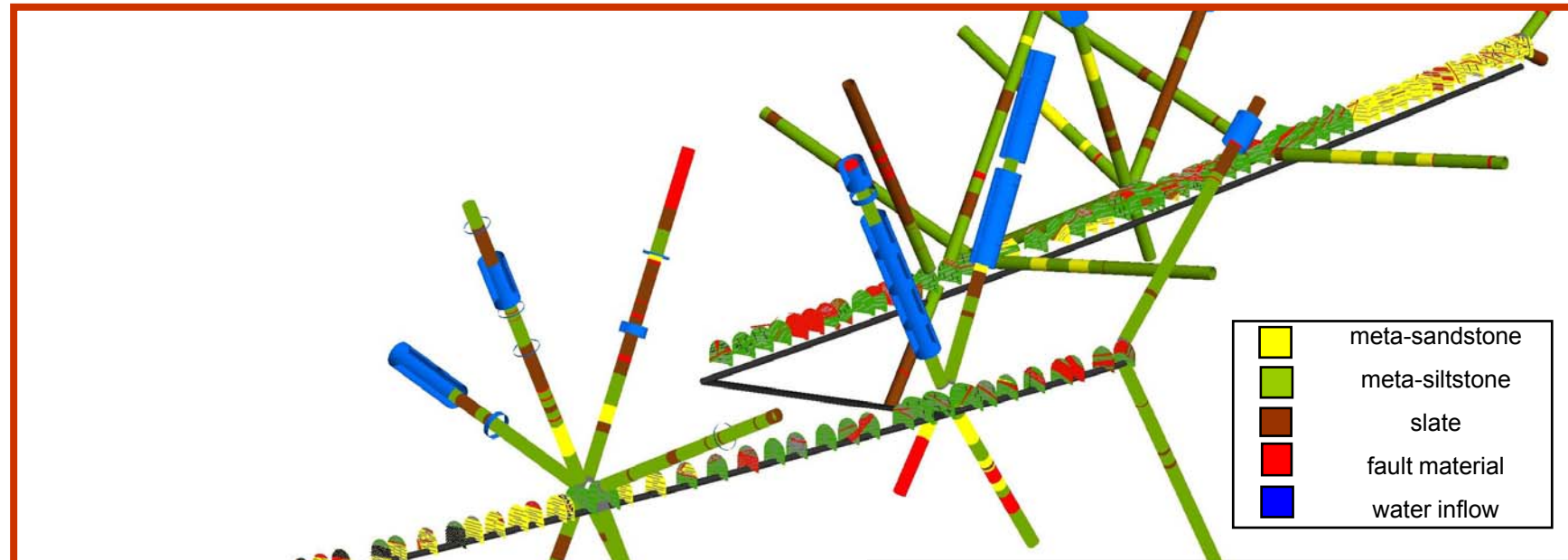
Geometrie Adit



Geometrie Adit

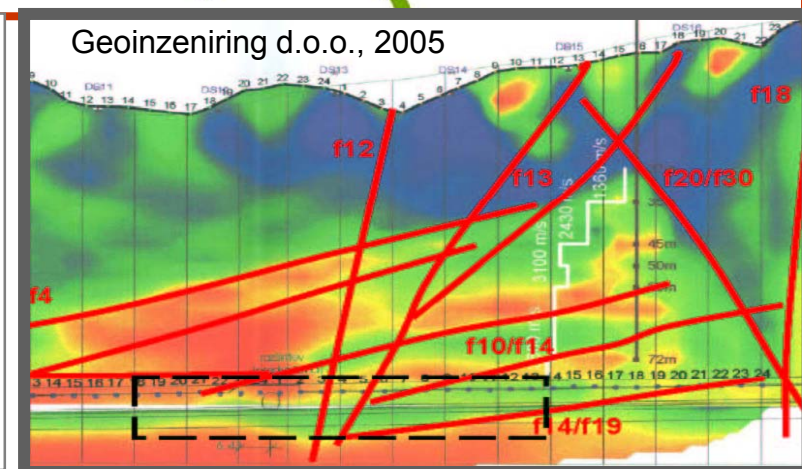


LAYOUT OF EXPLORATORY ADIT (PILOT TUNNEL)

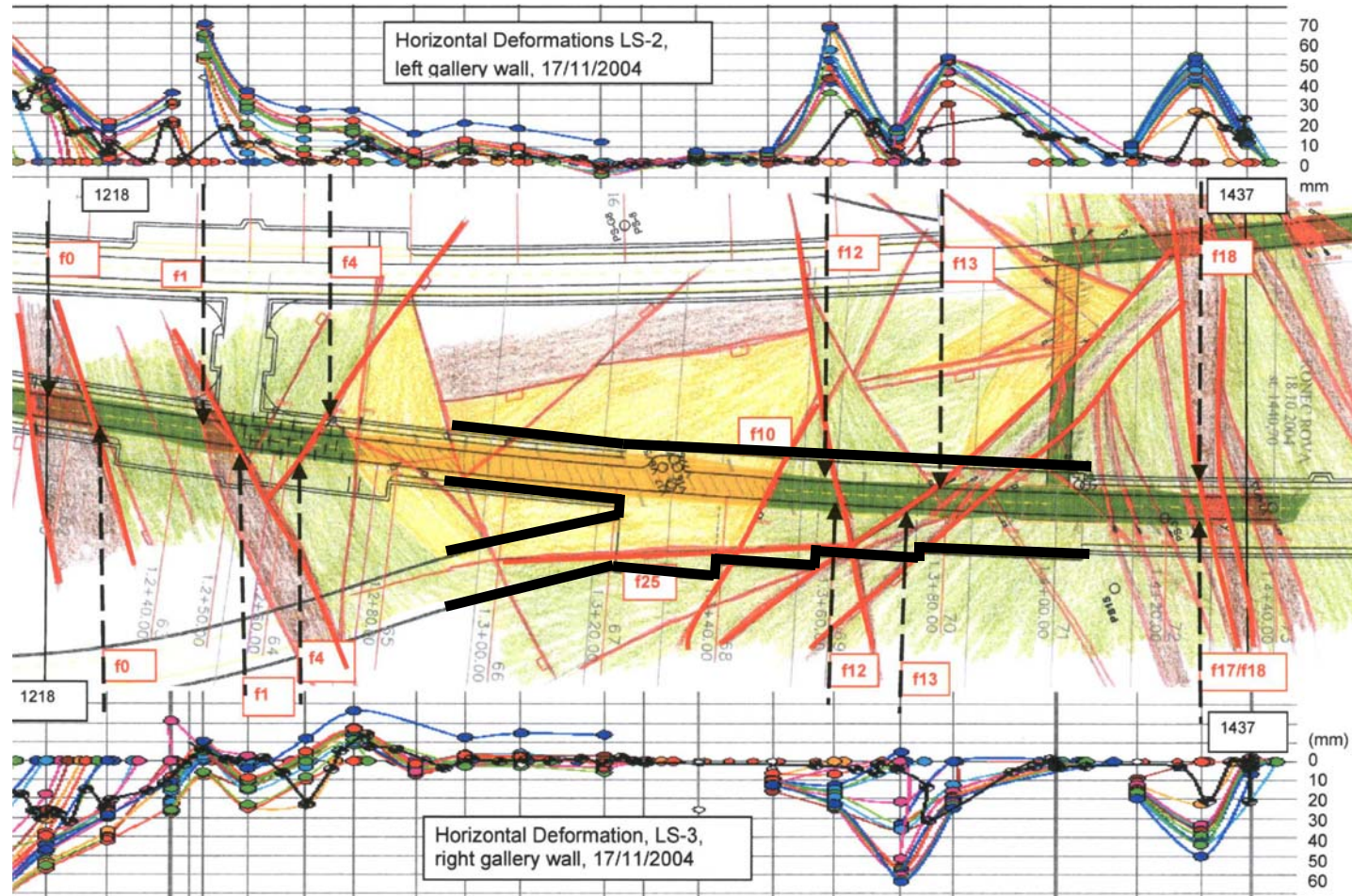


Investigation program for revised geological model 2005:

- geological documentation & core drilling in exploration gallery
- seismic survey (refraction & tomography)
- deformation measurement data from exploration gallery

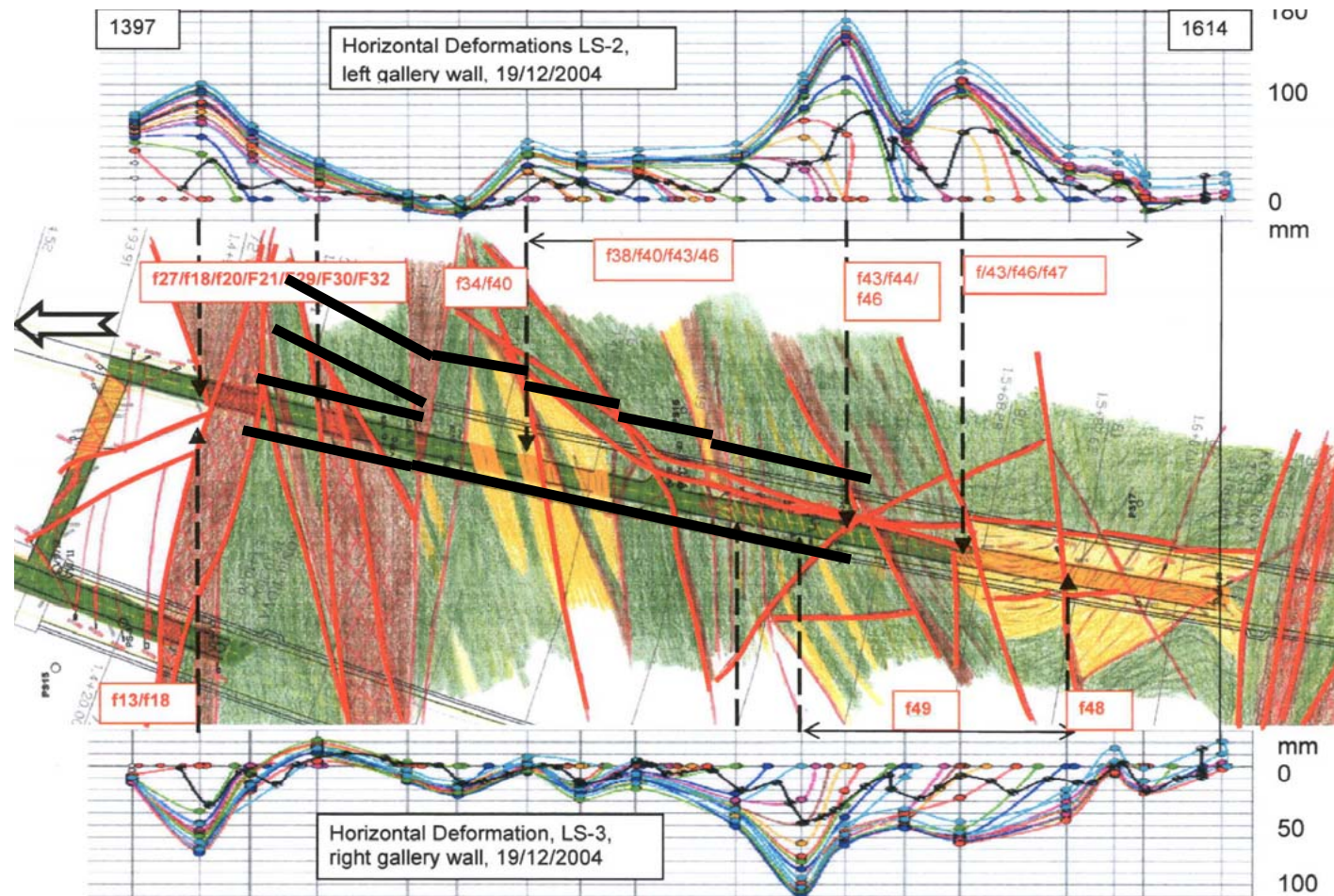


RESULTS OF EXPLORATORY ADIT – RIGHT TUBE



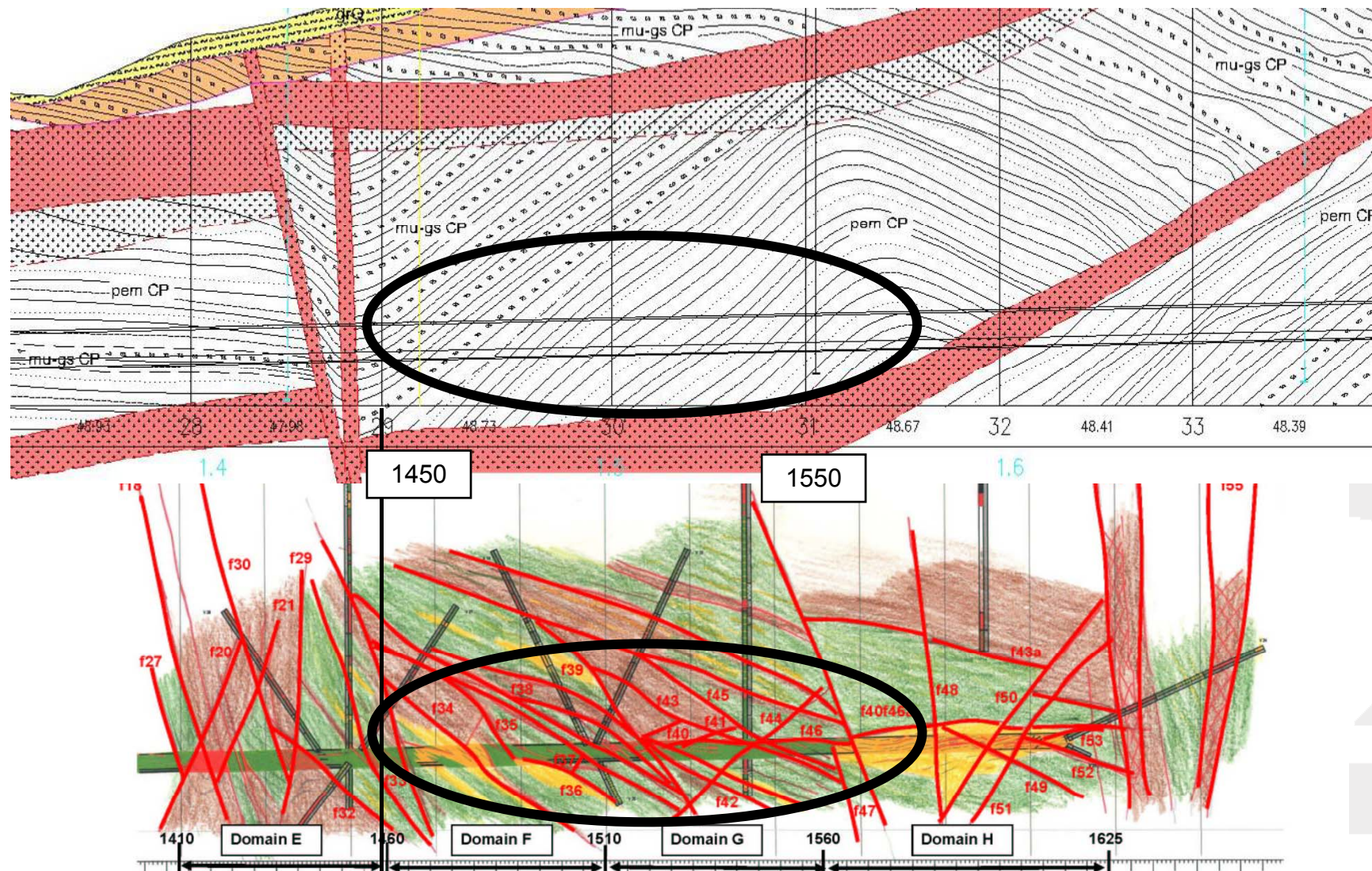
- RATHER CLEAR GEOLOGICAL SITUATION WITHIN THE PROPOSED CAVERN
- NORTHERN END OF CAVERN (LARGEST SECTION) IN FAVOURABLE SANDSTONE

RESULTS OF EXPLORATORY GALLERY – LEFT TUBE



- RATHER DIFFUSE GEOLOGICAL SITUATION WITHIN THE CAVERN; NEARLY NO SANDSTONE
- MAJOR FAULT ZONES AT THE NORTHERN END OF THE CAVERN

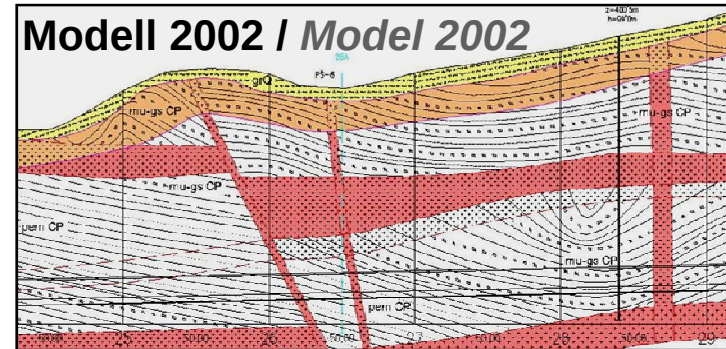
REVISED GEOLOGICAL MODEL 2005- LEFT TUBE



TUNNEL SENTVID – GEOLOGICAL MODELS (RIGHT TUBE)

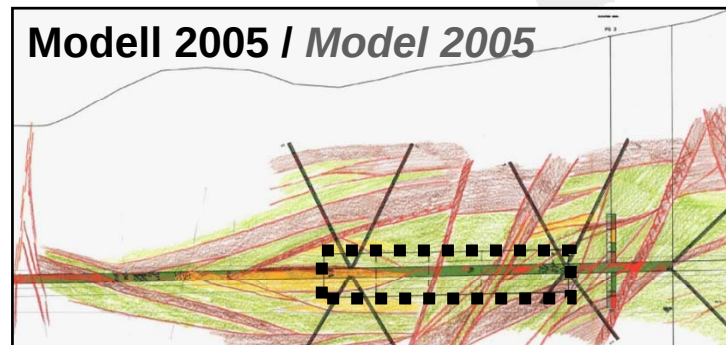
STANDARD INVESTIGATION

- SURFACE MAPPING
- CORE DRILLING

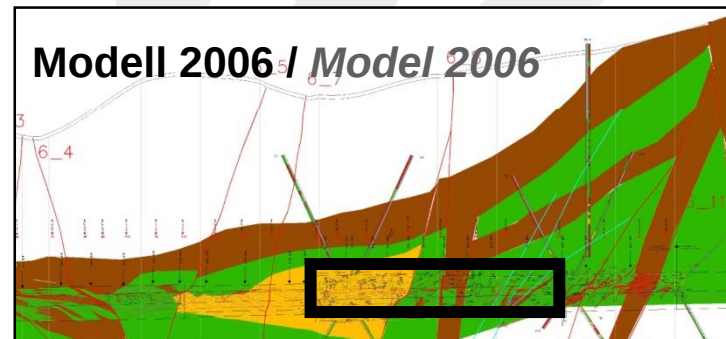


ADDITIONAL INVESTIGATION

- EXPLORATORY ADIT
- ADDITIONAL CORE DRILLING



EXCAVATION OF MAIN TUNNELS AND CAVERNS



TUNNEL SENTVID – DEFINITION OF ROCK MASS TYPES



ROCK MASS TYPE	PREVAILING ROCK TYPE	GSI	FRACTURING	TECTONIC DISTURBANCE
RMT 1	meta - sandstone	30 - 45	F4 (6-20 cm)	slightly to moderately sheared
RMT 2	meta - siltstone	20 - 30	F5 (2-6 cm)	moderately to highly sheared
RMT 3	slate	15 - 20	F6 (< 2 cm)	intensely foliated, highly sheared
RMT 4	fault gouge, fault breccia	< 15	F7 (< 2 cm)	very high, disintegrated

TUNNEL SENTVID – DEFINITION OF ROCK MASS BEHAVIOUR AND POTENTIAL FAILURE MODES

FM1: Gravity controlled block/wedge/slab failure	in jointed rock mass RMT1, RMT2, locally RMT3
FM2: Discontinuity controlled ravelling, instabilities due to lack of cohesion	In highly fractured rock mass RMT2, locally RMT3
FM3: Stress-induced deformations / failure of overall rock mass	In low-strength rock mass RMT3, RMT4, locally RMT2
FM4: Relaxation sliding / creeping along low-strength schistosity and/or fault planes	

TUNNEL SENTVID – DEFINITION OF POTENTIAL GEOTECHNICAL PROBLEMS

FM1: Gravity controlled
block/wedge/slab failure

Large-scale and sudden slab failure from roof,
triggered by undetected detachment plane

FM2: Discontinuity controlled
ravelling, instabilities due to lack of
cohesion

Rapidly progressing failure at roof and/or face
in case of elevated water inflow

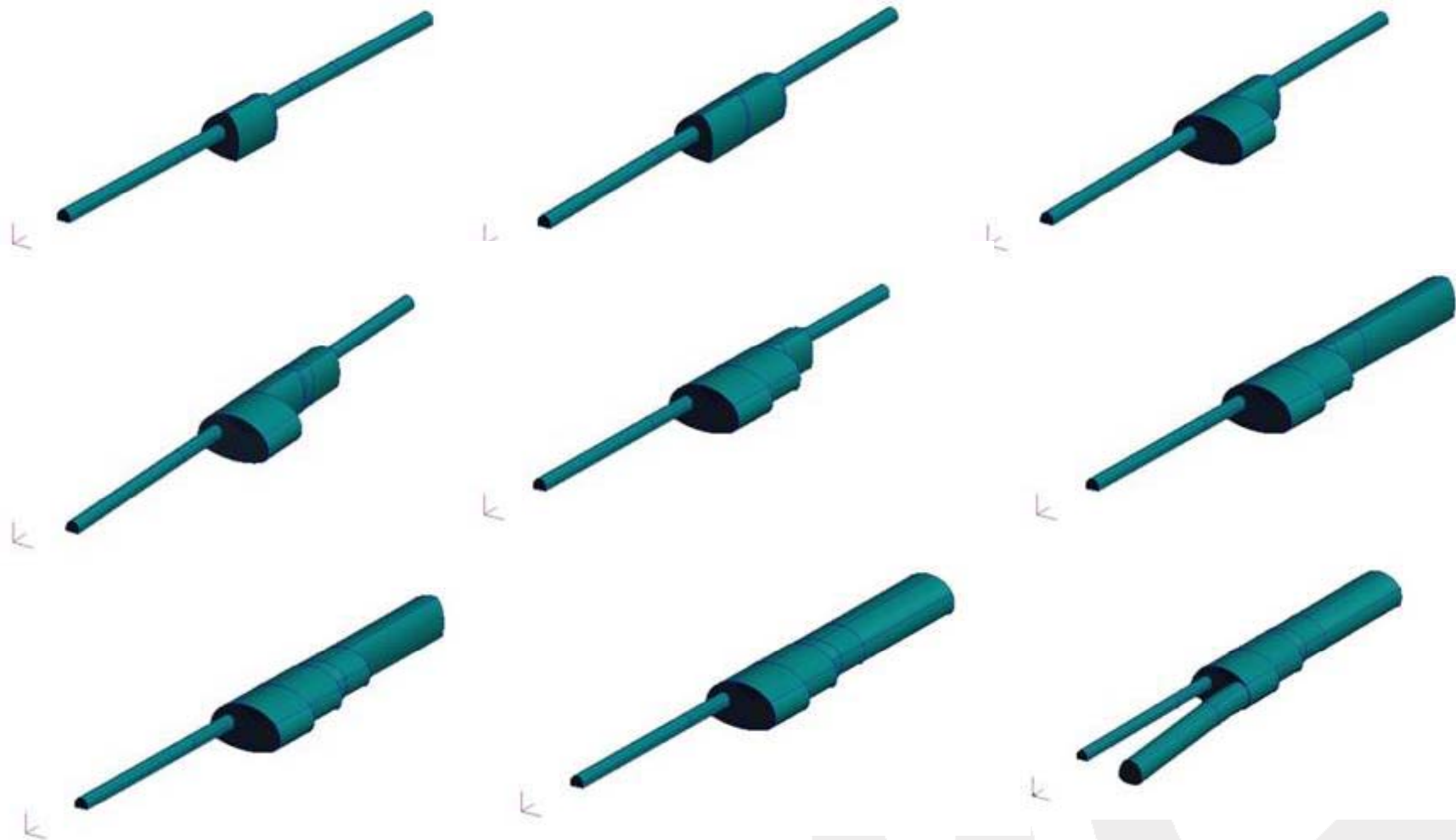
FM3: Stress-induced deformations /
failure of overall rock mass

Elevated and continuous radial convergence of
unforeseen dimension reducing designed
cross-section, requiring re-profiling

FM4: Relaxation sliding / creeping
along low-strength schistosity
and/or fault planes

Distinct deformation peaks cause elevated and
asymmetric loads on primary lining

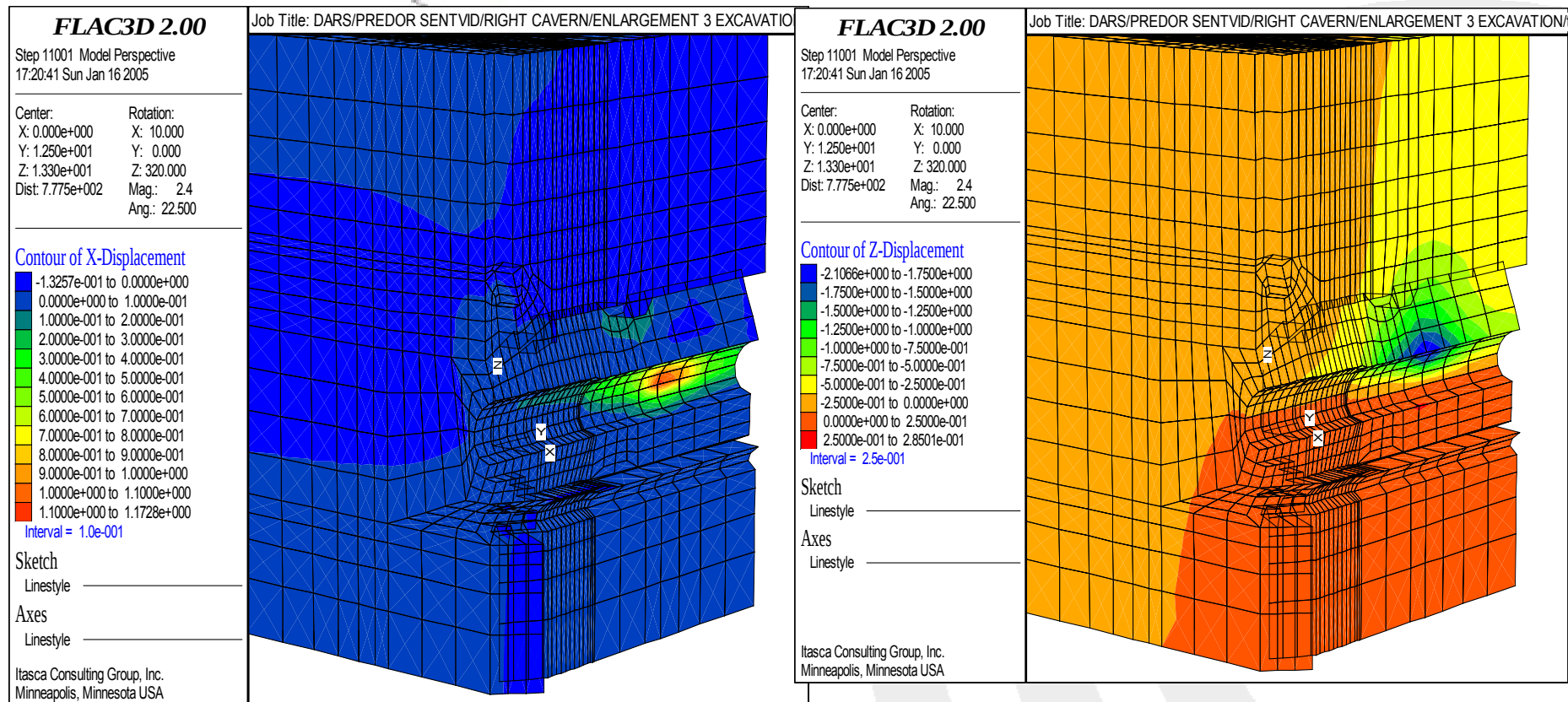
TUNNEL SENTVID – FEASIBILITY STUDY BY 3-D ANALYSES



TUNNEL SENTVID – DEFINITION OF DESIGN PARAMETER

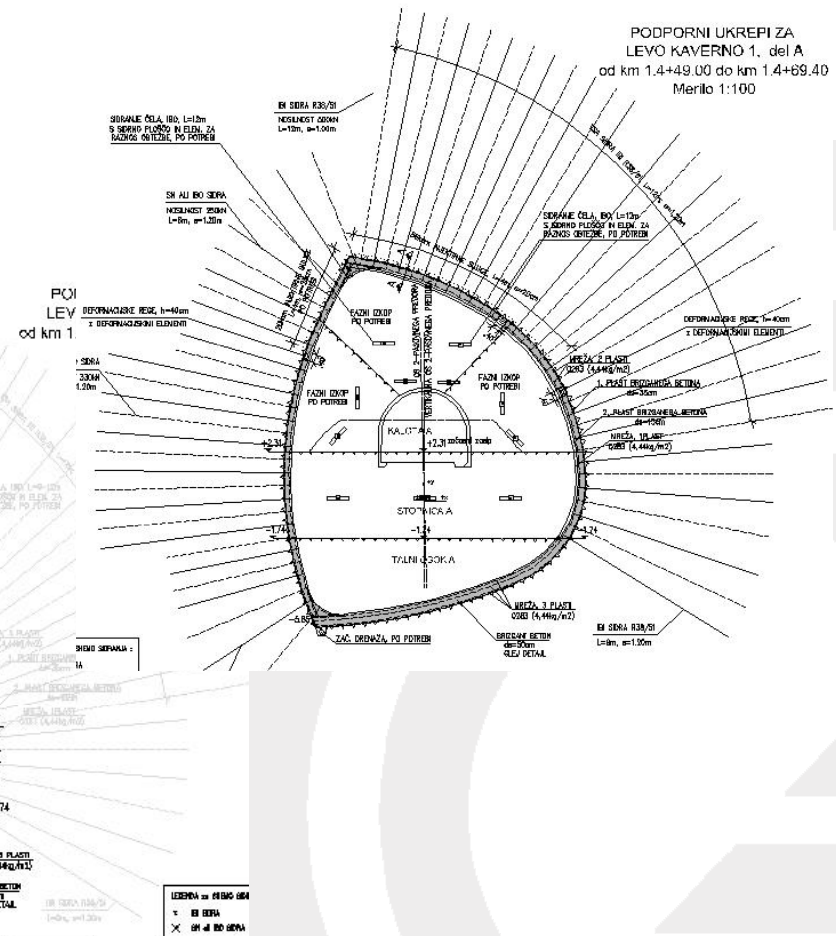
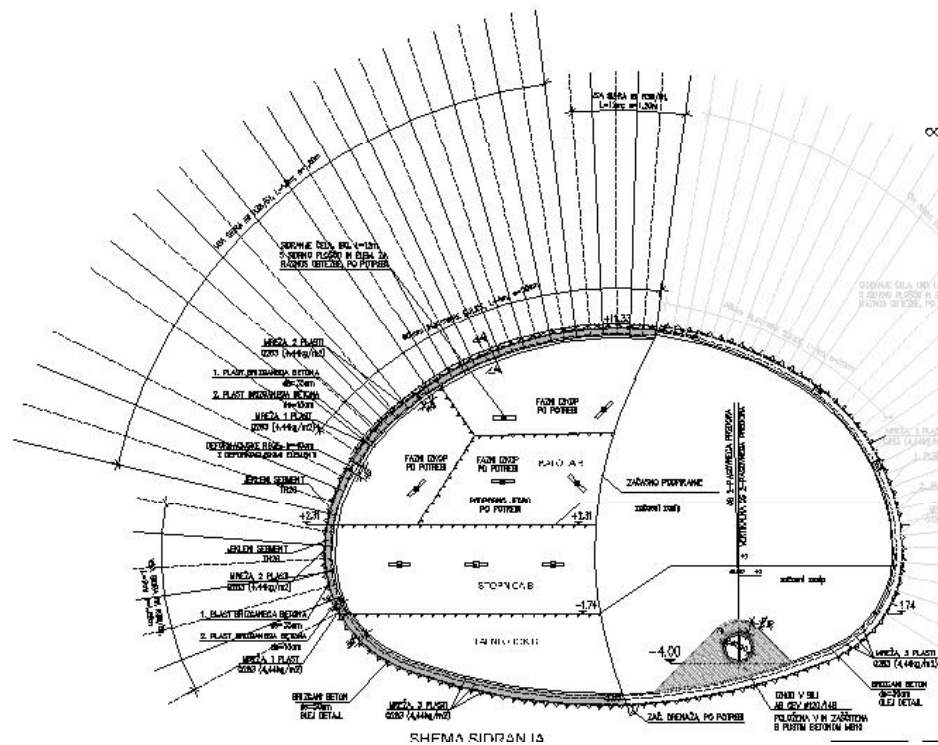
RMT	Unit Weight	Friction Angle	Cohesion	Young's Modulus
	γ	φ	c	E
	[kN/m ²]	[°]	MPa	MPa
RMT 1	26,5	40	0,25	1400
RMT 2	25,5	26	0,1	500
RMT 3	24,5	20	0,07	300
RMT 4	23	16	0,05	200

TUNNEL SENTVID – FEASIBILITY STUDY BY 3-D ANALYSES

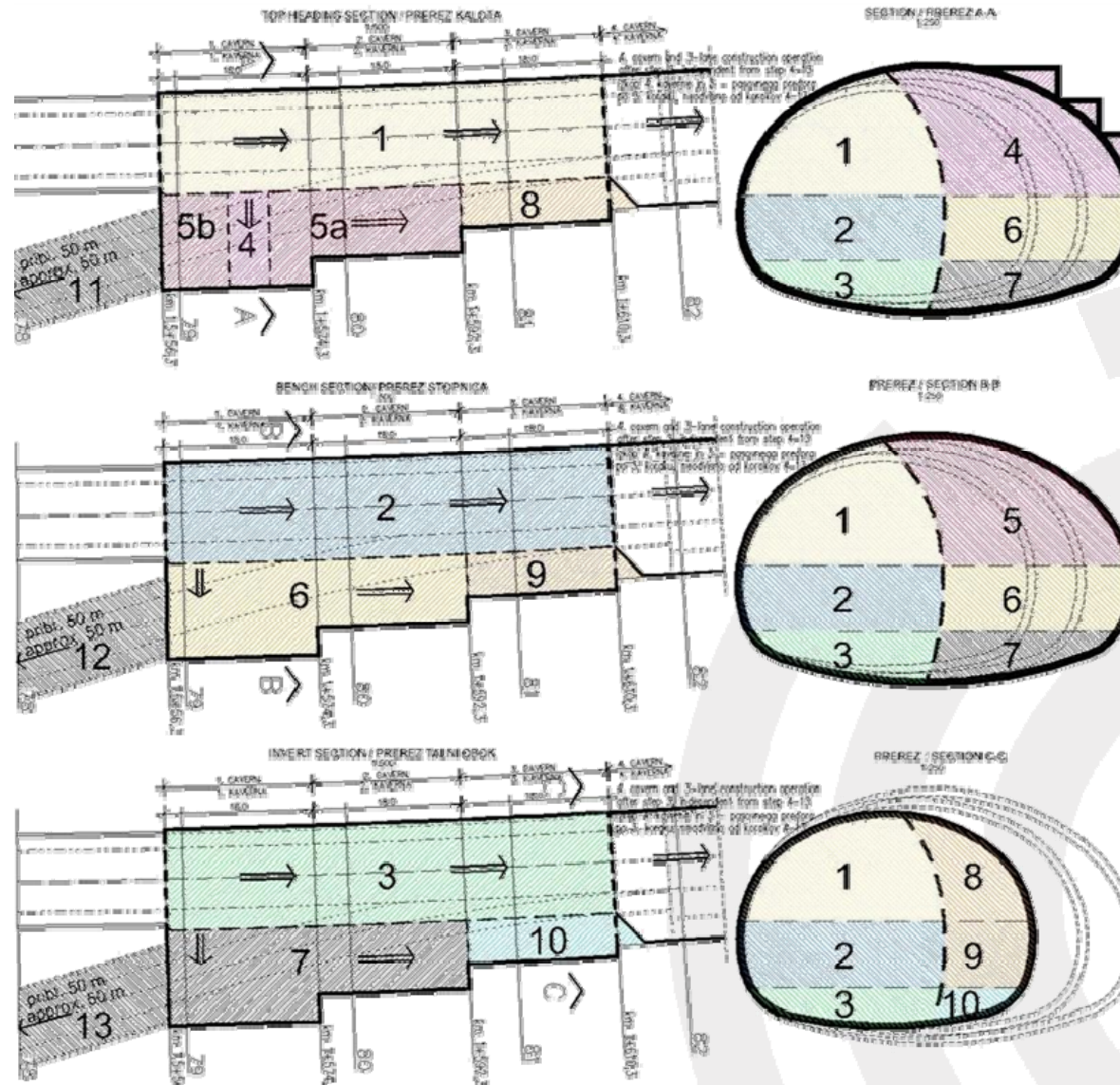


ROCK SUPPORT

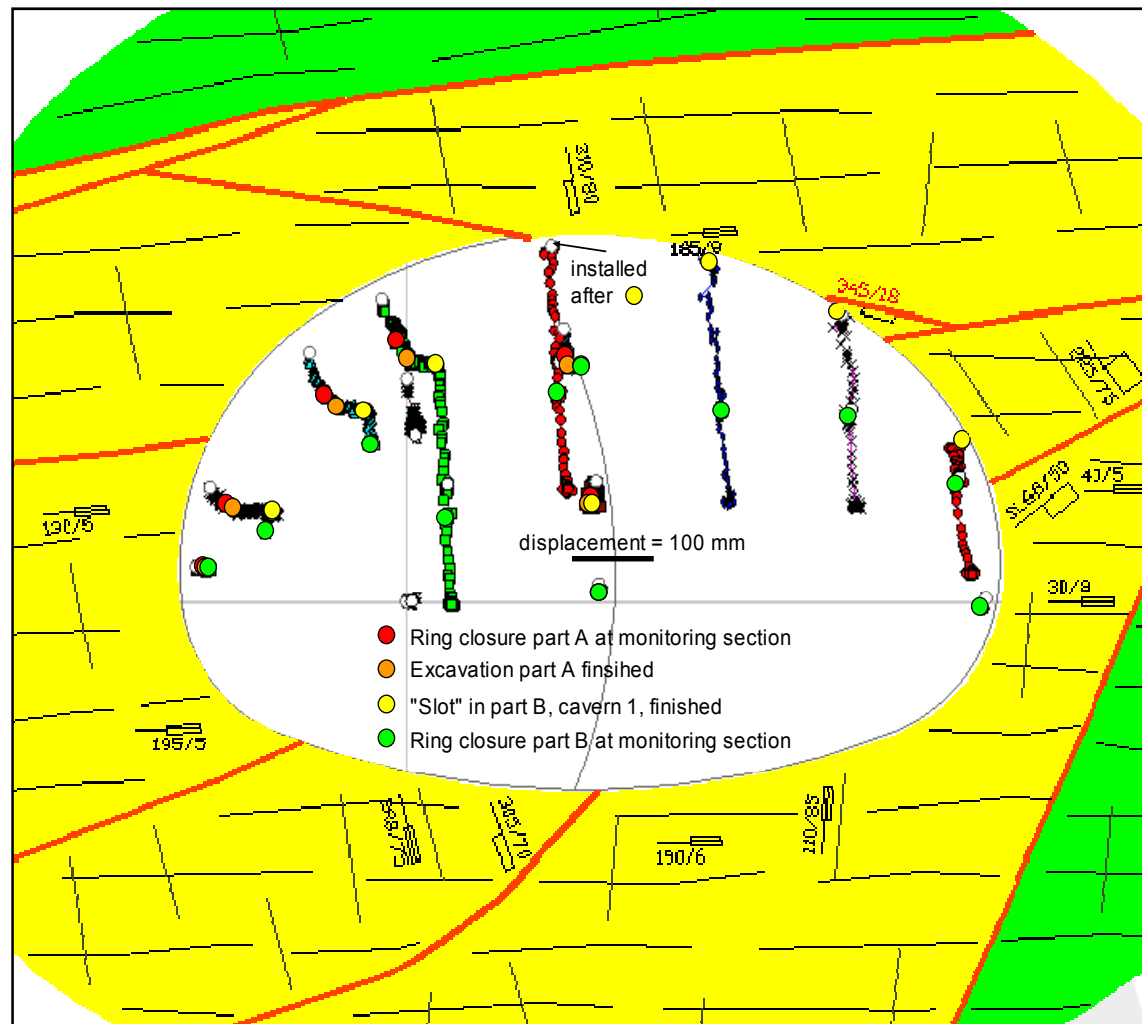
mainly IBI – rock bolts, 420 kN
L = 12 m; pattern: 1,0/1,0 or 1,2/1,2 m
Slots and yielding elements in shotcrete lining



CONSTRUCTION SEQUENCE OF CAVERN EXCAVATION

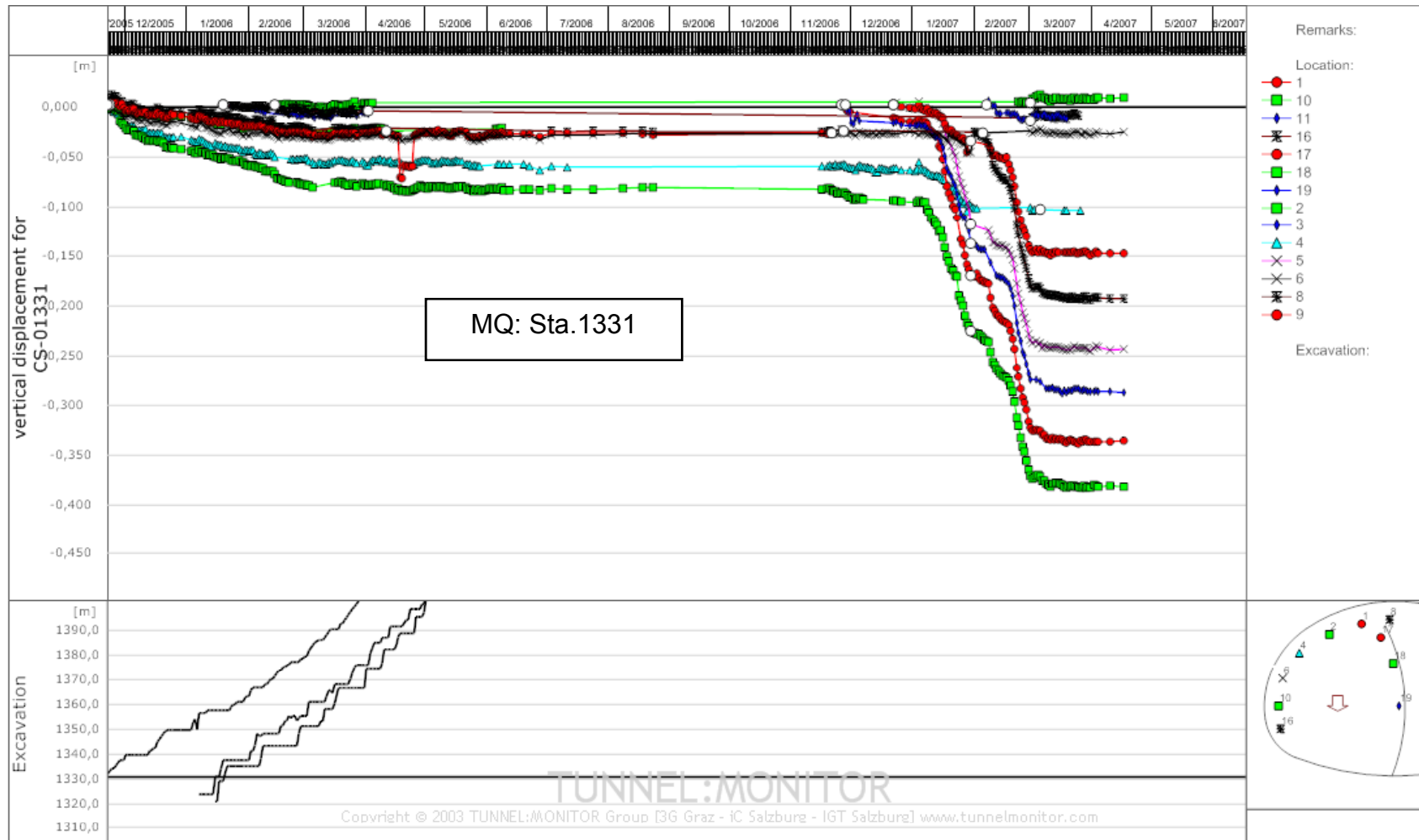


TYPICAL MONITORING RESULTS - RIGHT CAVERN

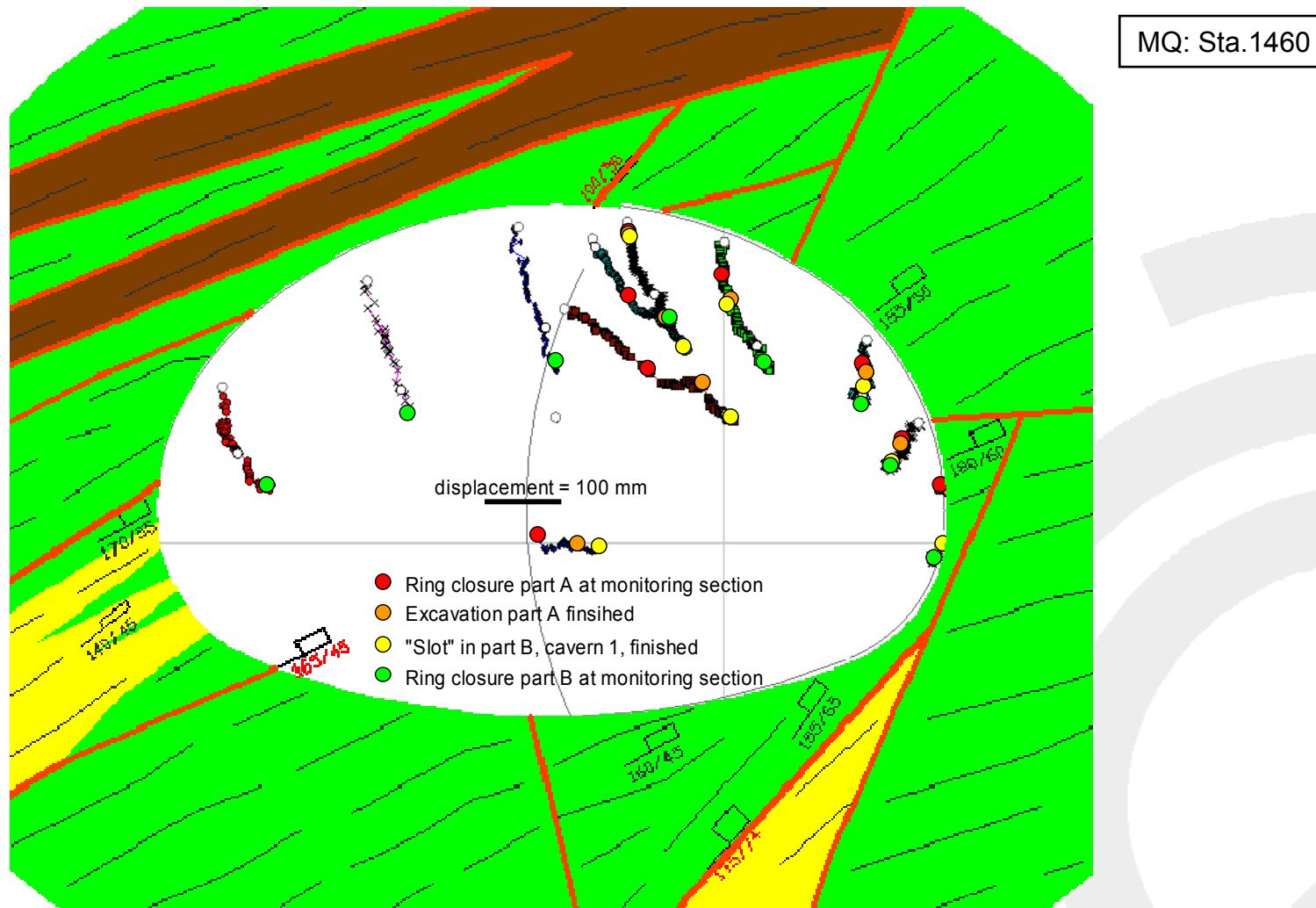


MQ: Sta.1331

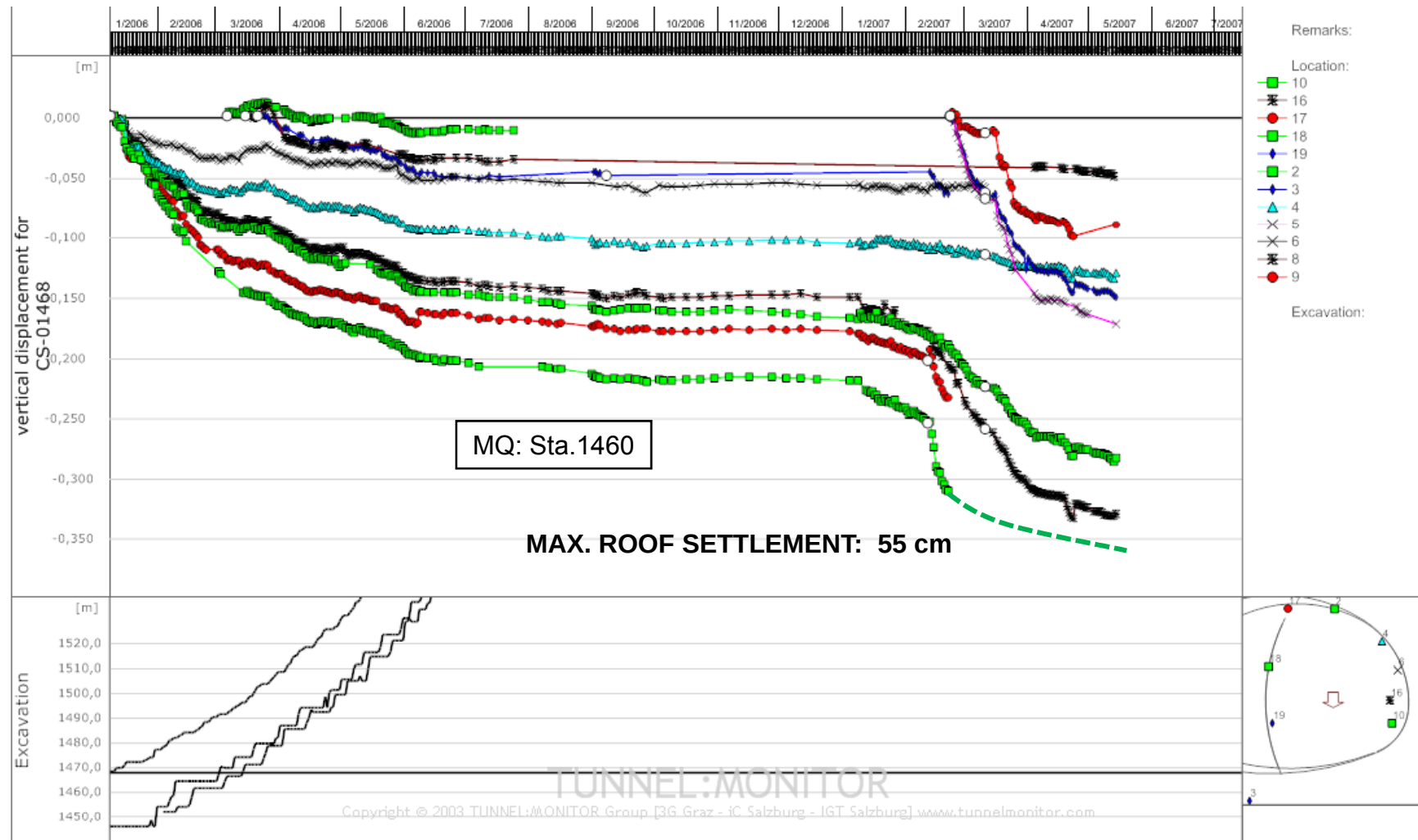
TYPICAL MONITORING RESULTS - RIGHT CAVERN



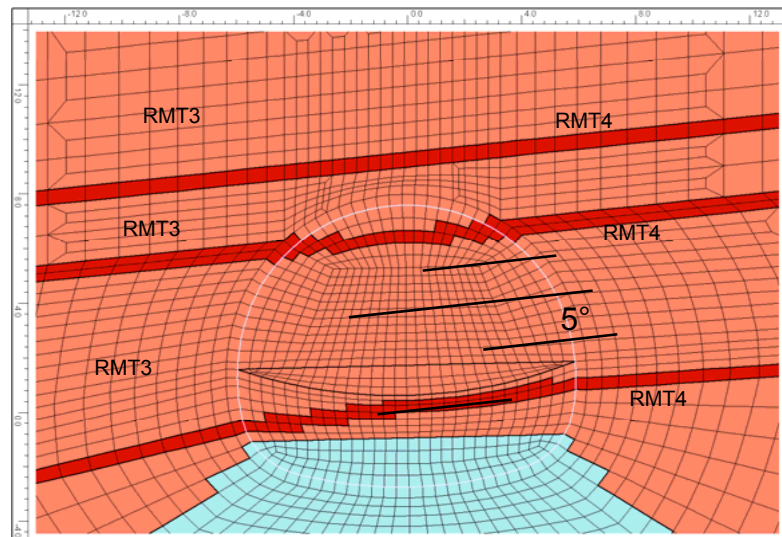
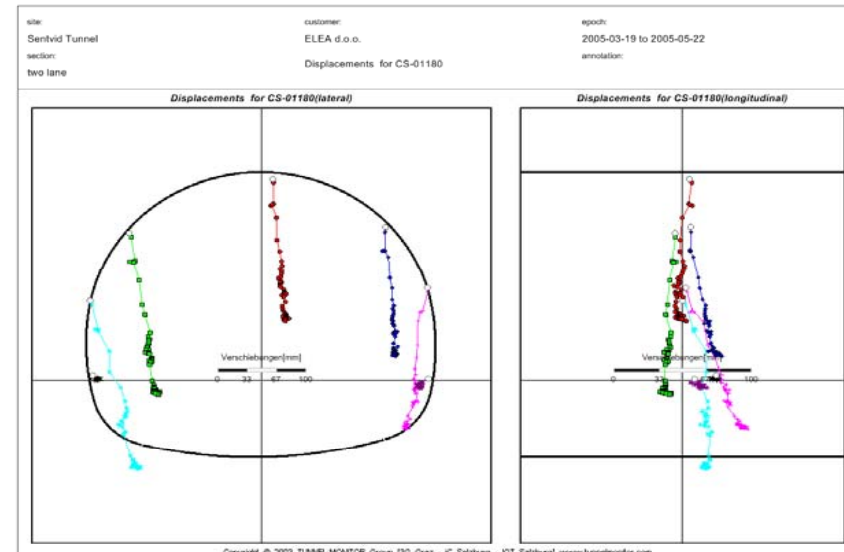
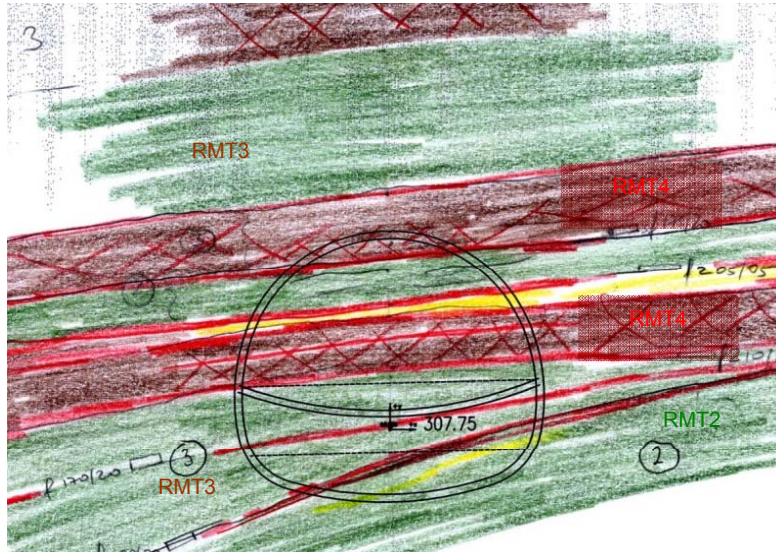
TYPICAL MONITORING RESULTS - LEFT CAVERN



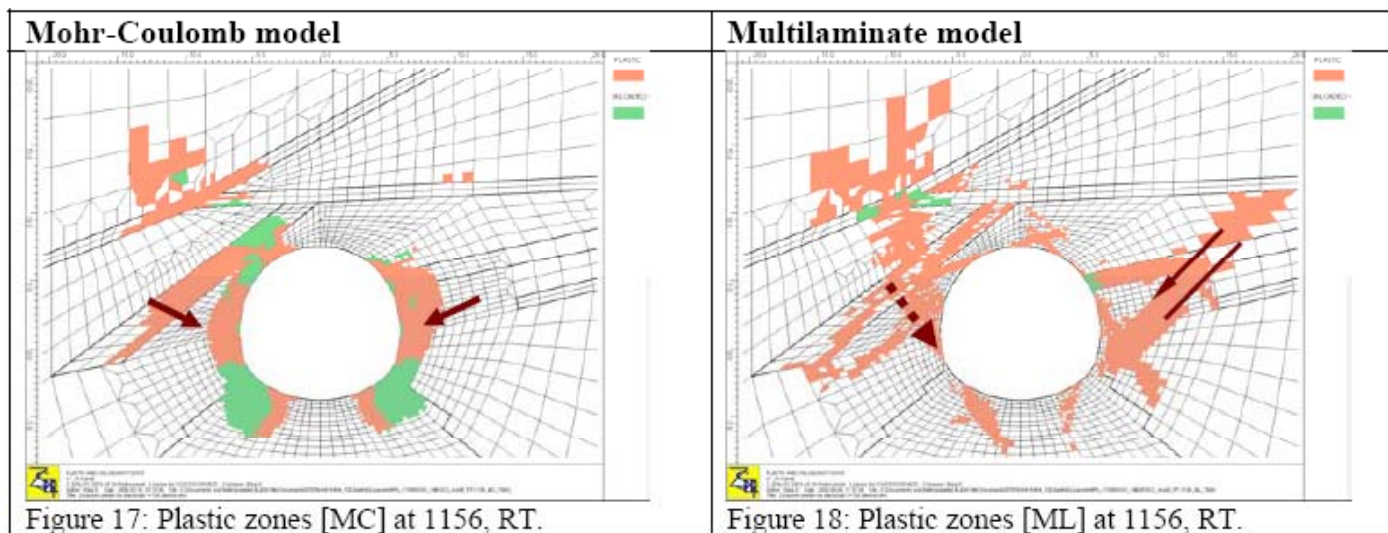
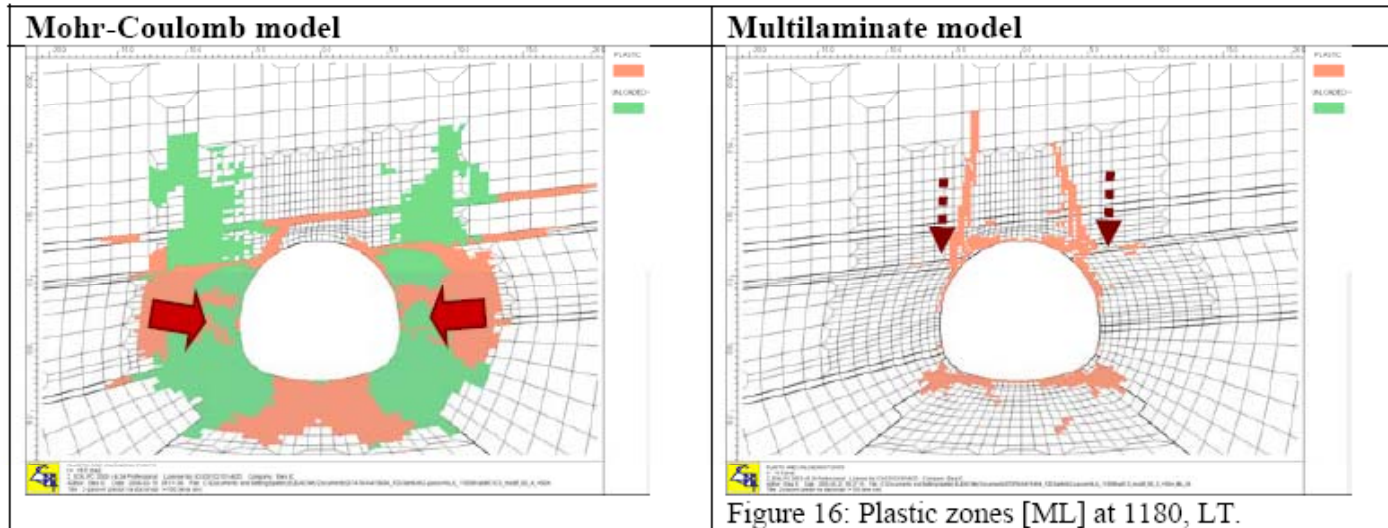
TYPICAL MONITORING RESULTS - LEFT CAVERN



TUNNEL SENTVID – BACK-ANALYSES



TUNNEL SENTVID – FE-ANALYSES



MOHR-COULOMB MODEL



- DISCONTINUITY CONTROLLED
- LARGE VERTICAL DISPLACEMENTS
- SHEAR DISPLACEMENTS
- OPENING OF LOW ANGLE DISCONTINUITIES

TOP HEADING PART „A“



CONSTRUCTION STEP 4



INVERT EXCAVATION – RIGHT CAVERN



INSTALLATION OF WATER PROOFING MEMBRANE



INNER LINING CONCRETE



SENTVID TUNNEL – MOTORWAY BYPASS OF LJUBLJANA

