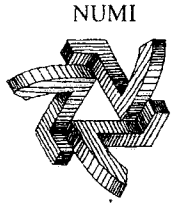


The Implications of Geology, Environment and Construction for Existing and Future Machines

Chris Laughton

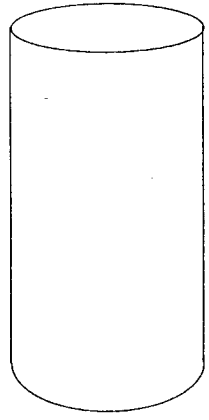
NuMI Project

Model/Design Input

- Geology
  - Local through Regional
- The Subsurface Environment
  - Stresses
  - Hydrology
- Construction
  - In soils
  - In rocks

Small Geo-Scale

- The "Lab" Scale
  - Millimeters to decimeters
  - Testing intact specimens
- Model/Design from Sample Testing
  - Strength
  - Stiffness
  - Dynamic Response
- Time Dependent Displacements
  - Expansion
  - contraction



5-10cm Ø Samples

Time Dependent Ground Response

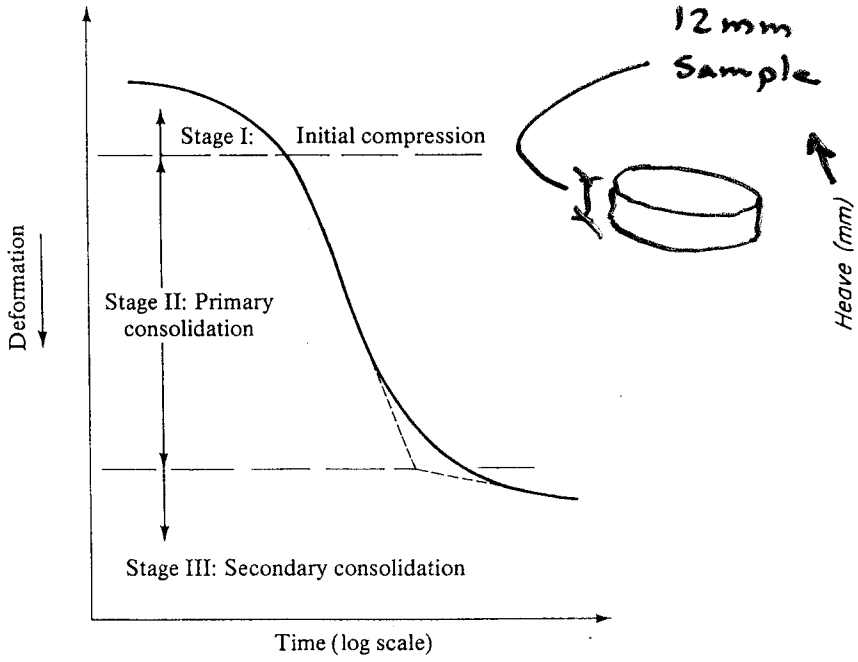


Figure 7.6 Time-deformation plot during consolidation for a given load increment

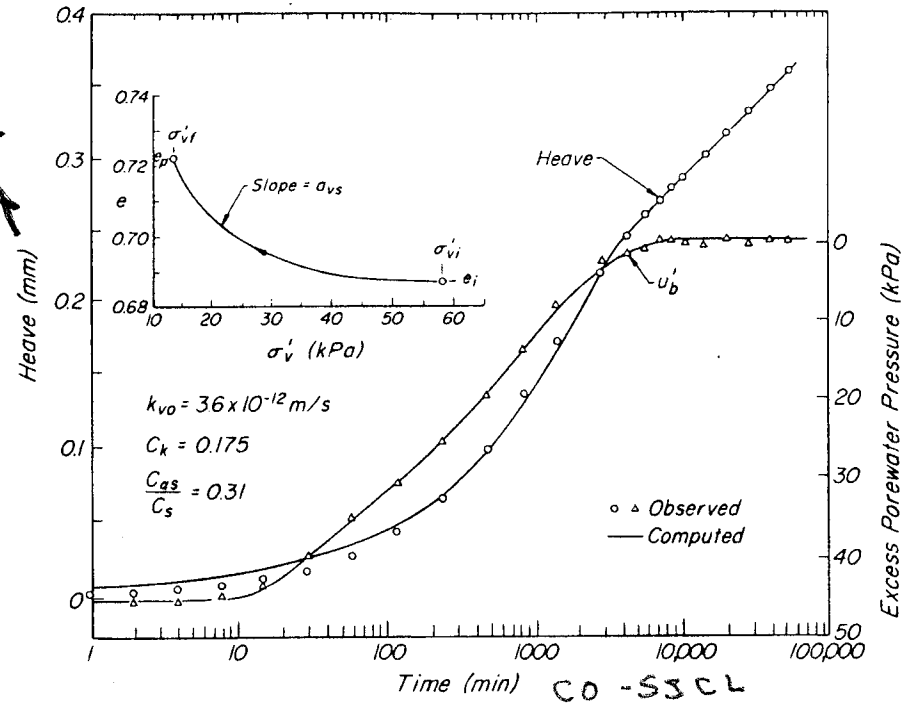


Figure 25.18 Observed and computed behavior of Pierre shale subjected to a decrement in expansion pressure.

Consolidation Settlement
- primary
- secondary

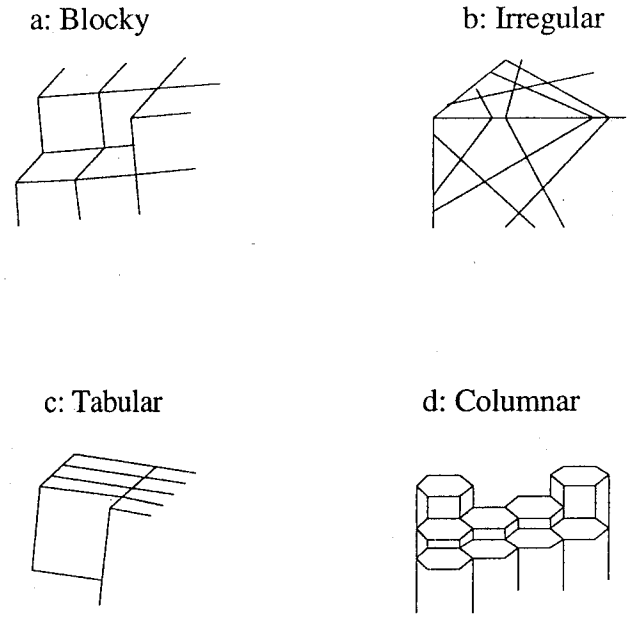
NC ?
OC ? stiffer

"Rebound"
Swell
Heave

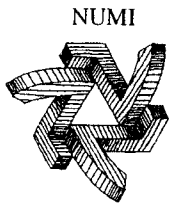
→ MARL
→ MOLASSE
→ GOMPHOLITE
→ contain swelling minerals

"Intermediate" Geo-Scale

- The Engineering Structure Scale
  - 10s of centimeters to 10s of meters
- Discontinuity Sets
  - Bedding
  - Jointing
- Geometric Characteristics
  - Geometry & density of fractures
- Fractures - Mechanical Characteristics
  - Rock surfaces
  - Fill materials
- Model/Design for Spatial Variation within Geologic Domains

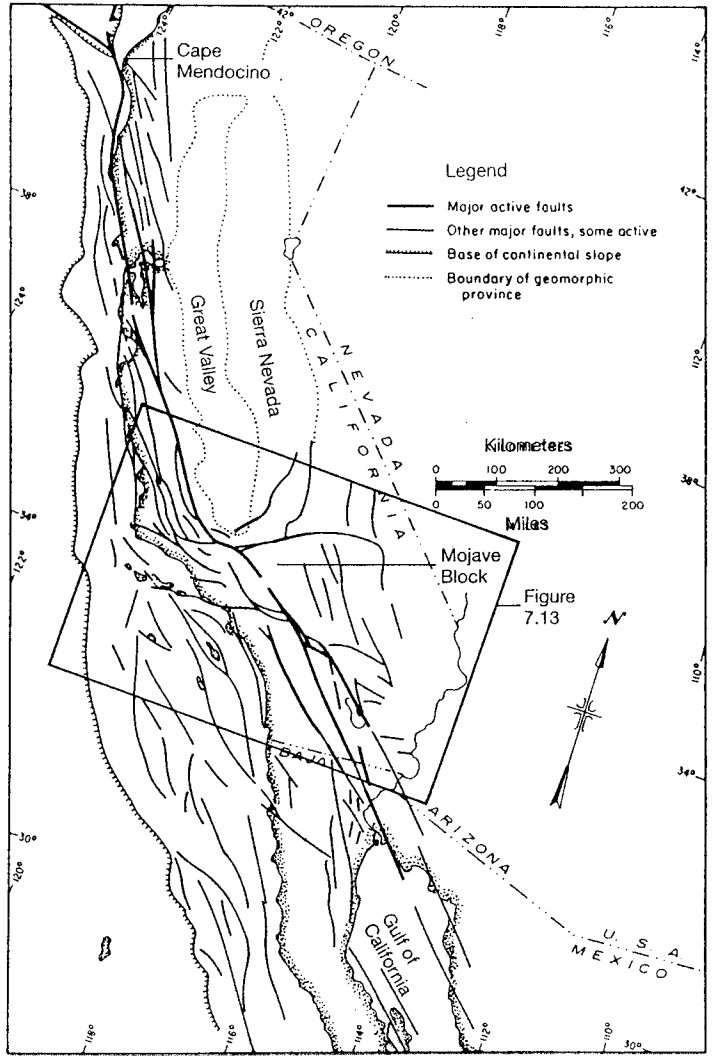


Rock Mass "Structure"



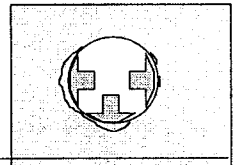
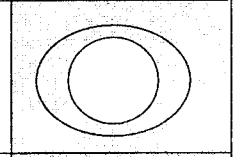
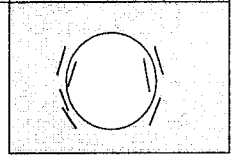
Large Geo-Scale

- Geologic Structure Scale
  - 100 meters to 100 kilometers
  - The geologic map
  - Conformity/Predictability?
  - Zones of Weaknesses?
  - Seismic/Aseismic Faulting
- Model/Design to Accommodate Variability
  - Between geologic domains
  - At boundaries between geologic domains



Rock Stress Issues

- In-Situ Stresses
  - Vertical stress ~ consistent with cover load
  - horizontal stress ~ *f* (geo-history)
- Swell Stresses ~ *f* (rock minerals)
- "Overstress" Responses to Construction

+ high gripper, machine loads on walls + weakened rock mass conditions = bearing capacity failures	
+ high in situ stresses + low intact strength = ductile failure / squeezing	
+ high in situ stresses + high intact strength = brittle failure / rock burst	

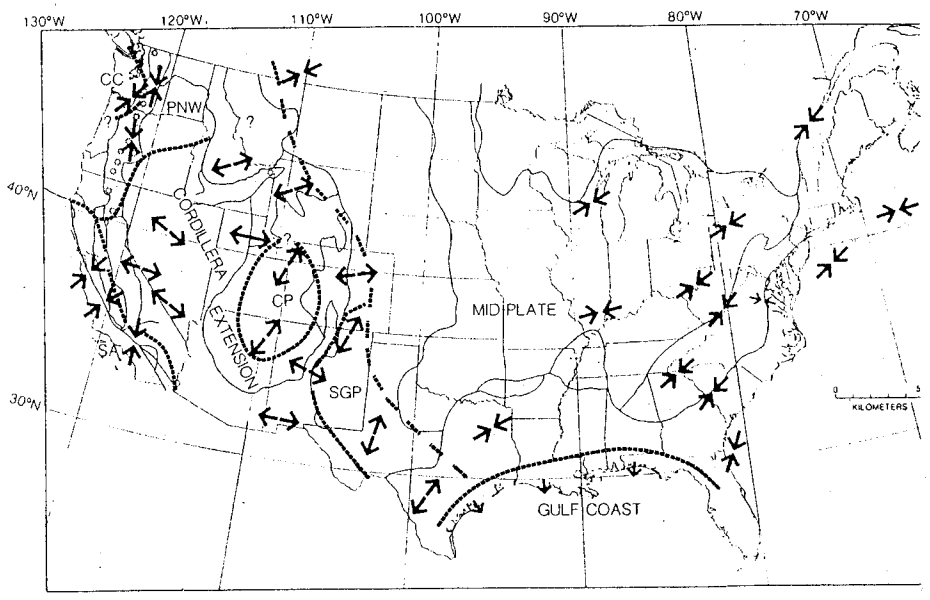


Figure 10.6 Regional stress field determinations. *A*. Worldwide distribution of principal stress orientations. *B*. Stress orientations in the coterminus United States.

Water Concerns

- Fluctuations in water level of "submerged tunnels" may cause ground movements
- Extraction of water/oil/gas or mining of minerals below the tunnel may cause ground settlement
- Reduced Pore Water Pressures may cause ground movements:
  - NC Clay Settlement
  - OC Clay Expansion

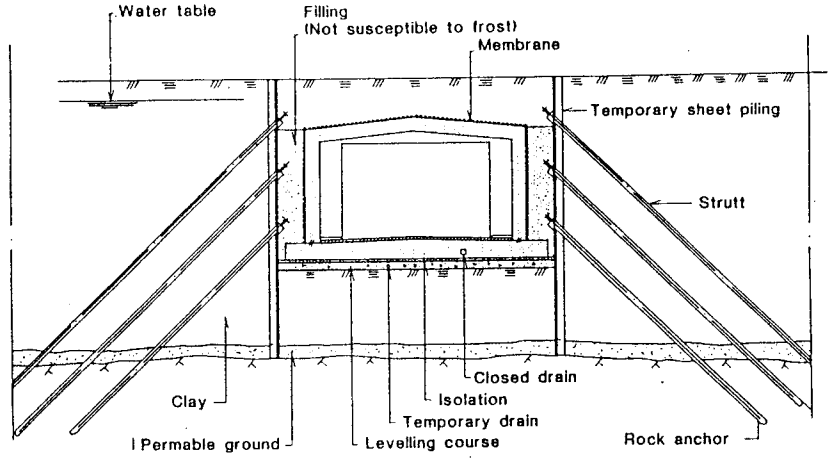


Figure 13.2 Example of a two-lane tunnel under water table

Cut & Cover Sections

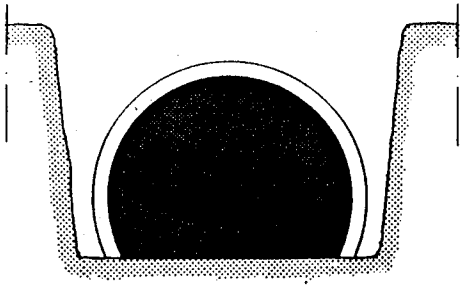


Figure 11.2 Rounded form

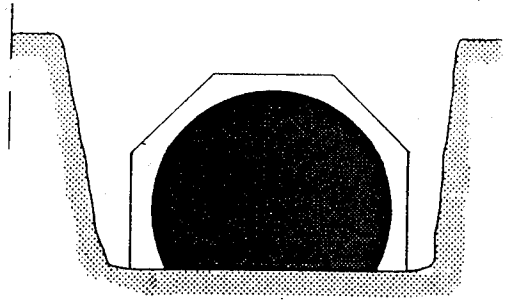


Figure 11.3 Straight form

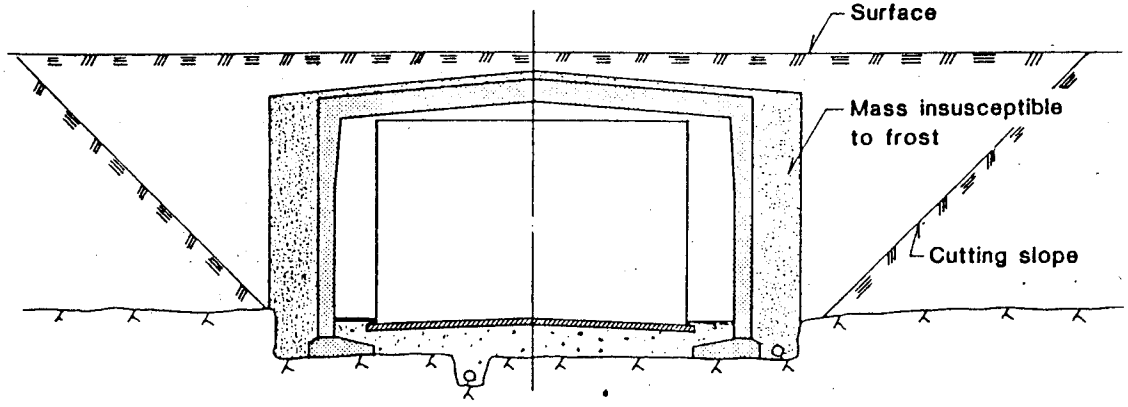
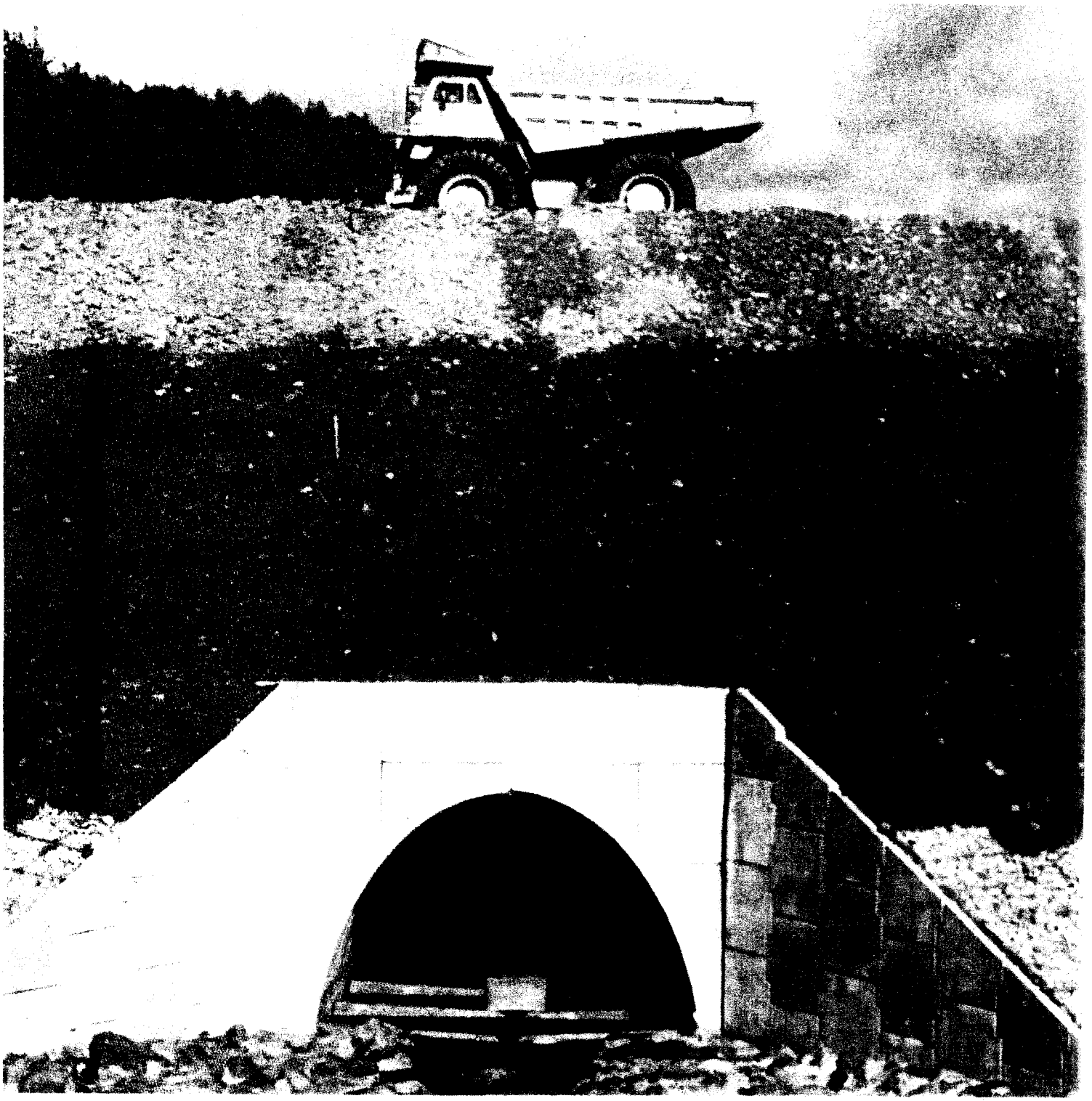
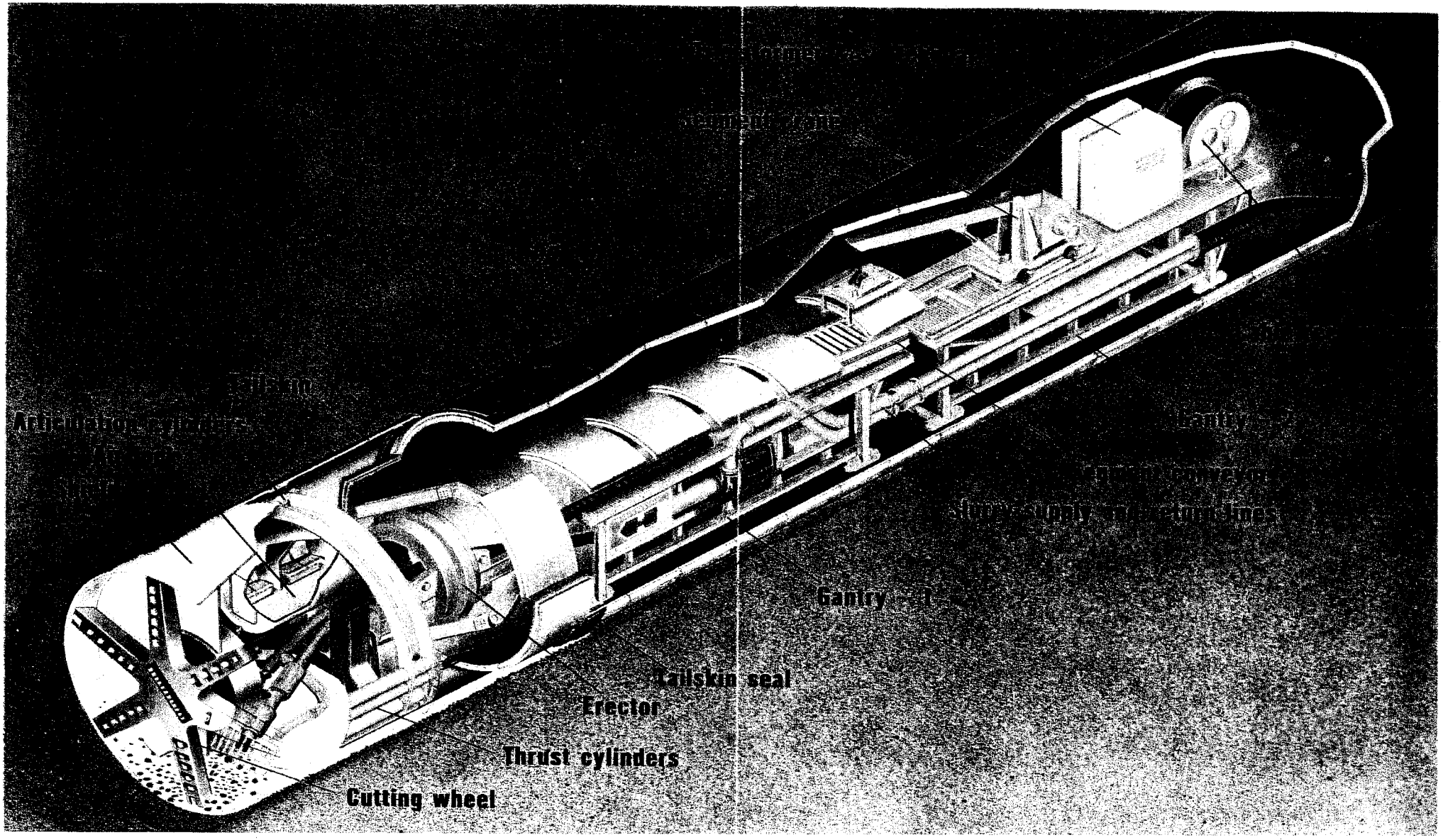


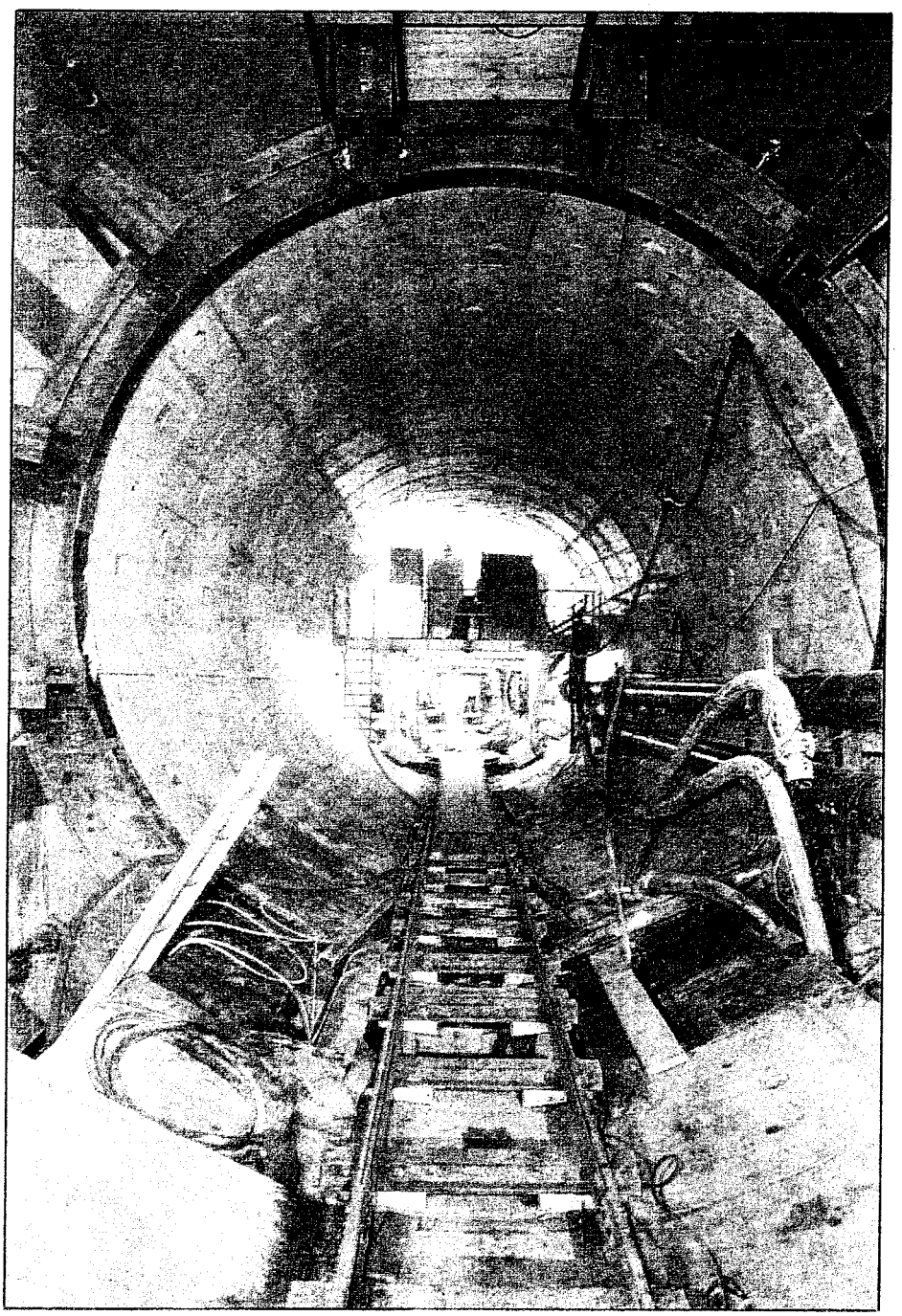
Figure 13.1 Example of a drained two-lane tunnel

- Cast-in-place or Pre-Cast Concrete Boxes
- + water = waterproofing systems



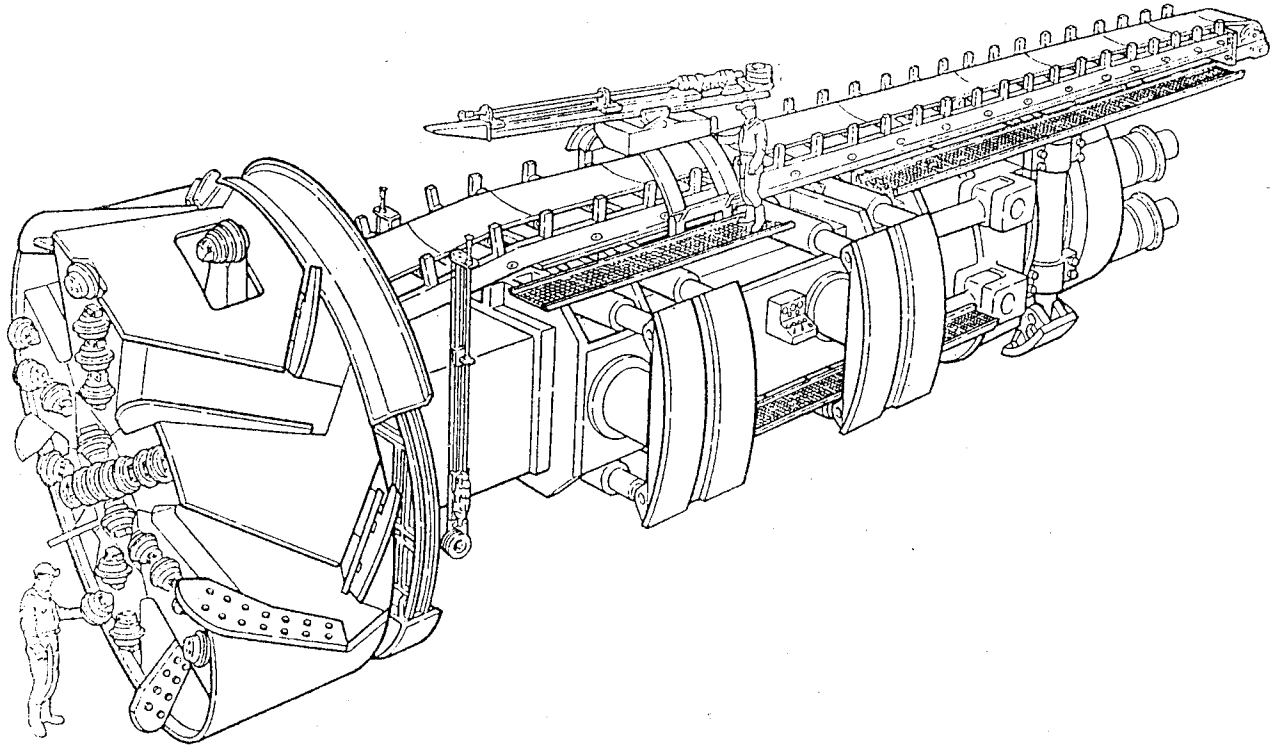

Tailskin seal
Erector
Thrust cylinders
Cutting wheel

Pre-Cast Segmental Lining



Hard Rock Tunneling

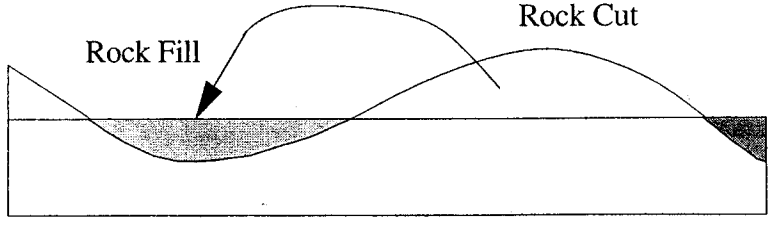
- Bolting upon excavation/lining (if any) after mining



+ water = ground treatment/grouting

Key Deformation Areas

- Abrupt Transitions/Contrasts in Sub-Grade Stiffness
  - Compacted fill - undisturbed ground interface
  - Ground interfaces (within and between soils and rocks)
- Abrupt Transitions in Cross-Sectional Shapes/Sizes
  - Running tunnel to chamber



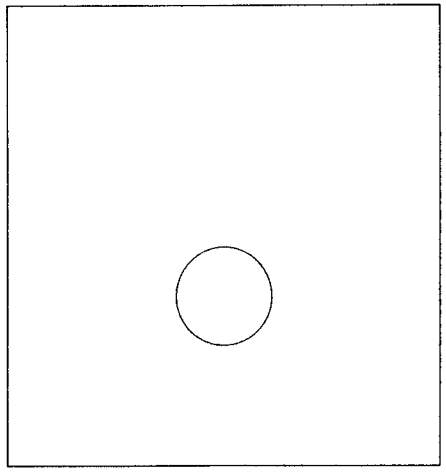
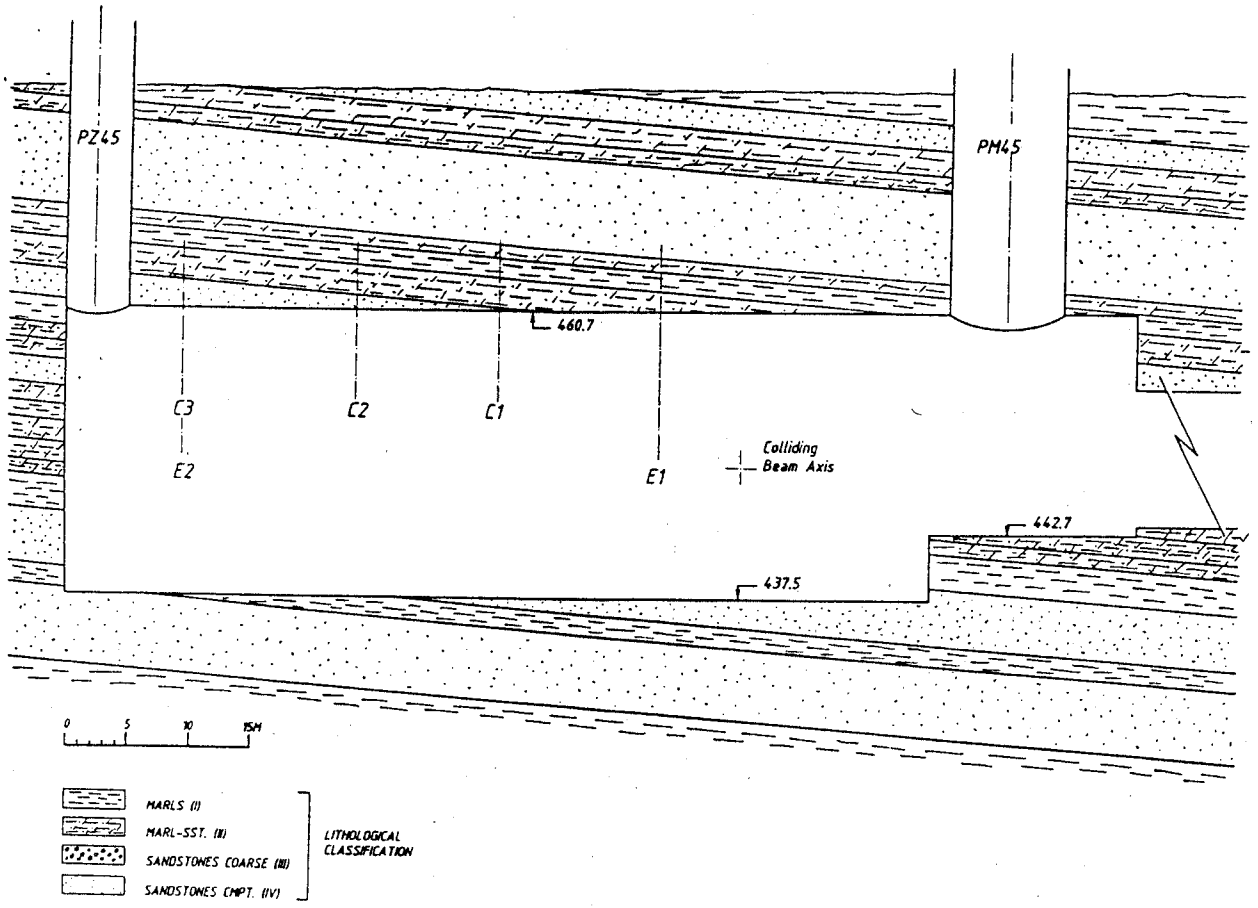


Fig. 3 - SIMPLIFIED LONGITUDINAL SECTION OF THE POINT 4 CAVERN SHOWING THE GEOLOGICAL STRATA & INITIAL CONVERGENCE SECTIONS



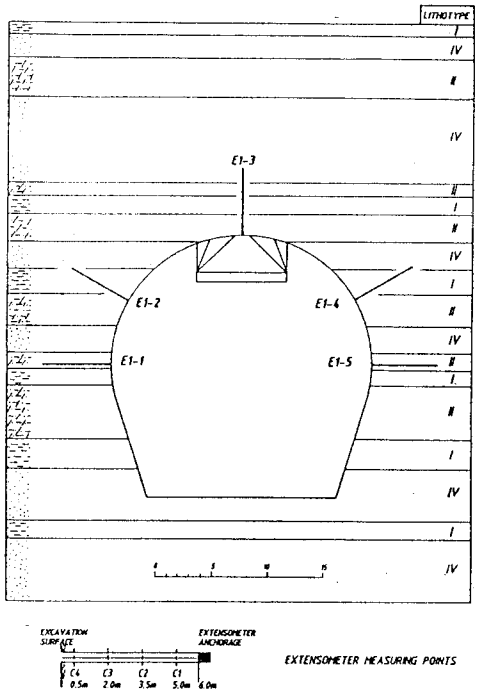
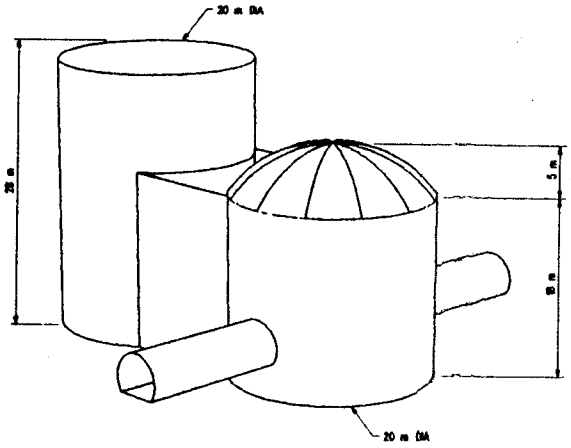
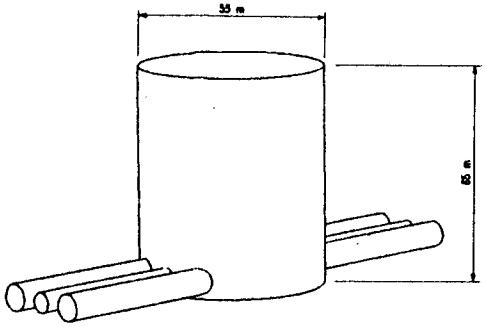


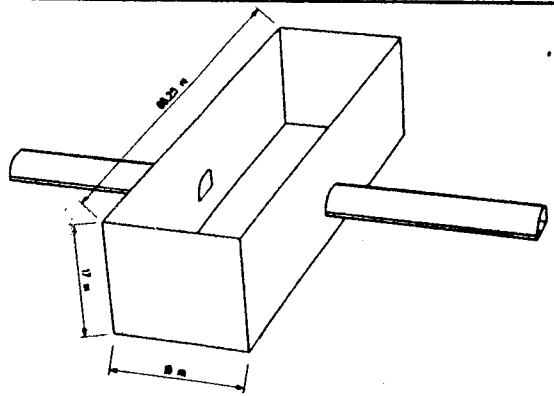
Fig. 6 - CAVERN CROSS-SECTION SHOWING CONVERGENCE & EXTENSOMETER CONFIGURATIONS



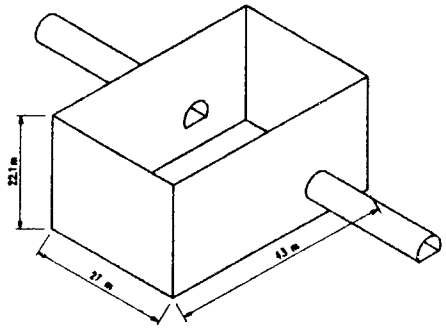
CERN - LSS5



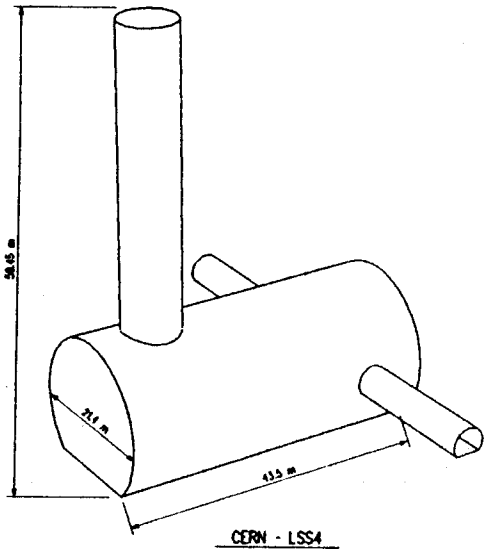
CHANNEL TUNNEL



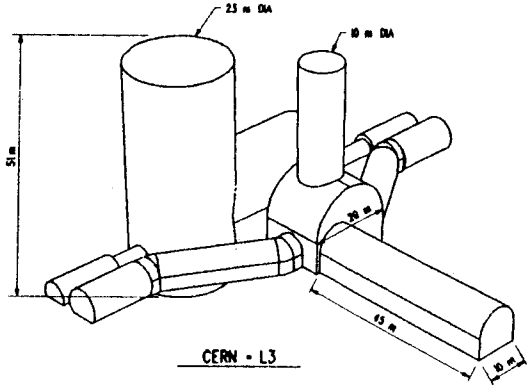
SLAC



HERA - NORD



CERN - LSS4



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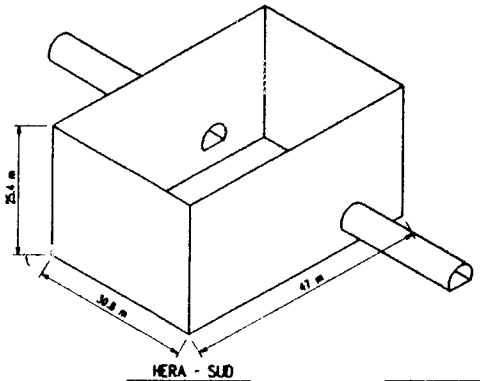

HERA - SUD

DATE: 9-3-90
BETTY:ADR/SSC/STATION-CHRISSO 20

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

DRAWN: D. SILVEIRA	DATE	APPROVED	DATE
CHECKED: C. LOUGHTON		APPROVED	
APPROVED		APPROVED	
APPROVED		APPROVED	
APPROVED		CONTRACT NUMBER DE-AC02-89ER40486	

CONVENTIONAL CONSTRUCTION DIVISION

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SUPERCONDUCTING SUPER COLLIDER LABORATORY
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DOCUMENT CONTROL NUMBER

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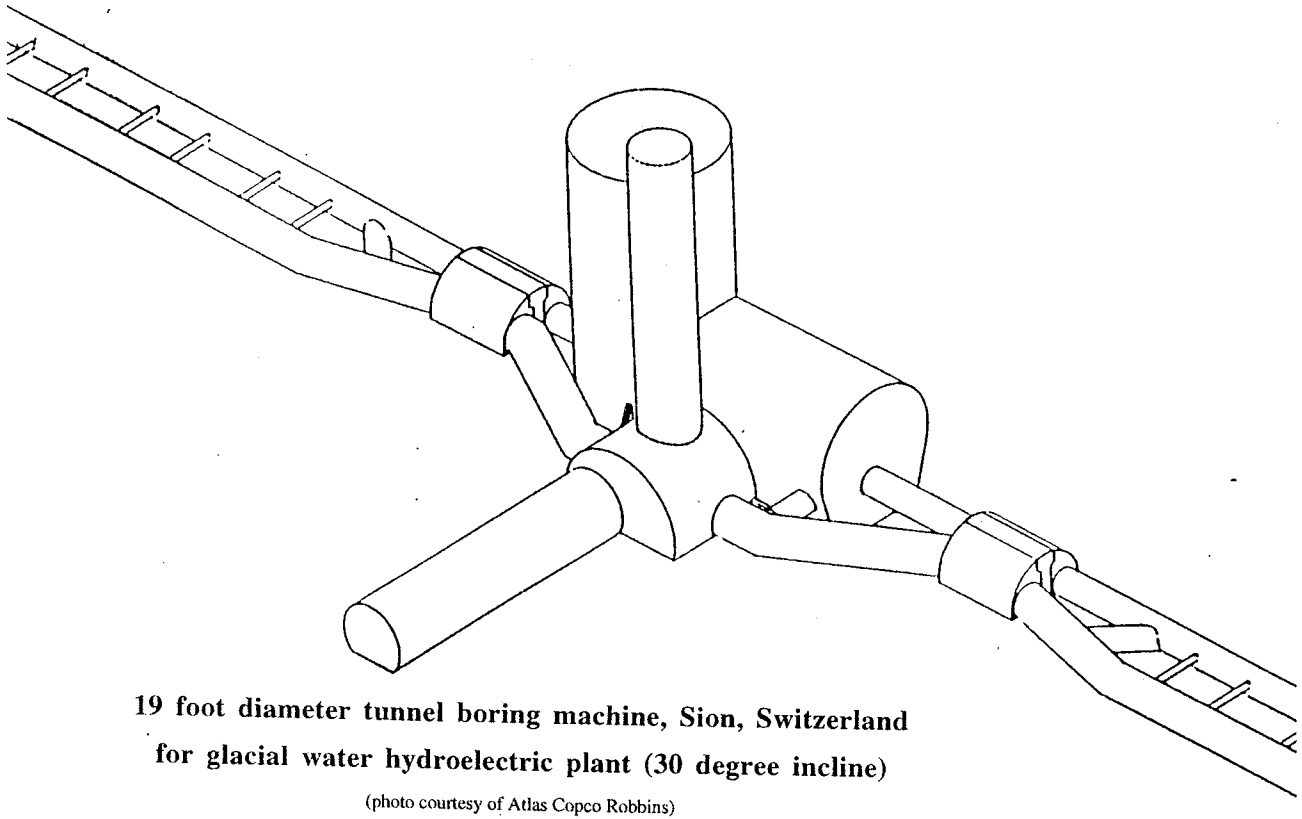
- -

SIZE	SCALE MTS	REVISION
D		0

SHEET OF

"Dream-Machine" Layouts

- Find "Good" Ground (consistent, predictable "easy mining")
  - verify compatibility with technical criteria, especially:
    - Stability? (1 mm/km/year? -> likely to be $-prohibitive at many sites)
    - Humidity? ("a tunnel is a structure that leaks" -> don't ask for perfection)
- Design to Build, Install, Operate, Maintain:
  - Keep it simple, avoid "tunnel gymnastics", such as:
    - High gradient alignments
    - Multiple tight curves/right-angles
    - Multiple cross-sections and floor levels
  - Encourage design flexibility - match mined-sections to:
    - Preferred (contractor-owned/familiar) equipment
    - Efficient (contractor-familiar) treatment/support methods and means
    - Standardize for routine operations (reuse of equipment)
    - Use experienced designers and builders, from R&D concepts to construction



19 foot diameter tunnel boring machine, Sion, Switzerland for glacial water hydroelectric plant (30 degree incline)

(photo courtesy of Atlas Copco Robbins)

PICCADILLY CIRCUS
The Heart of London

A Special Exhibition at the

London Transport Museum

The Piazza, Covent Garden
25 May - 26 November 1989
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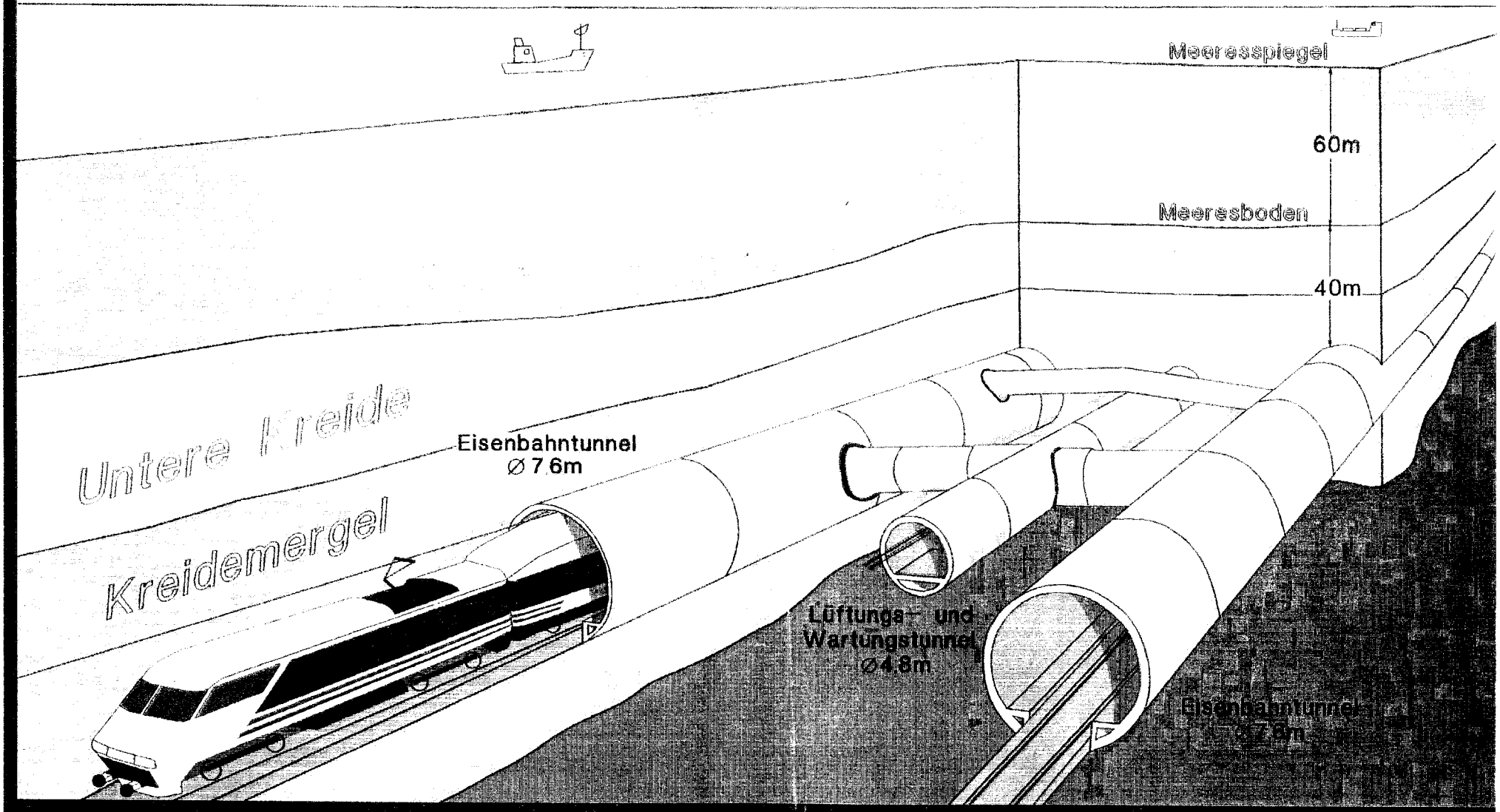
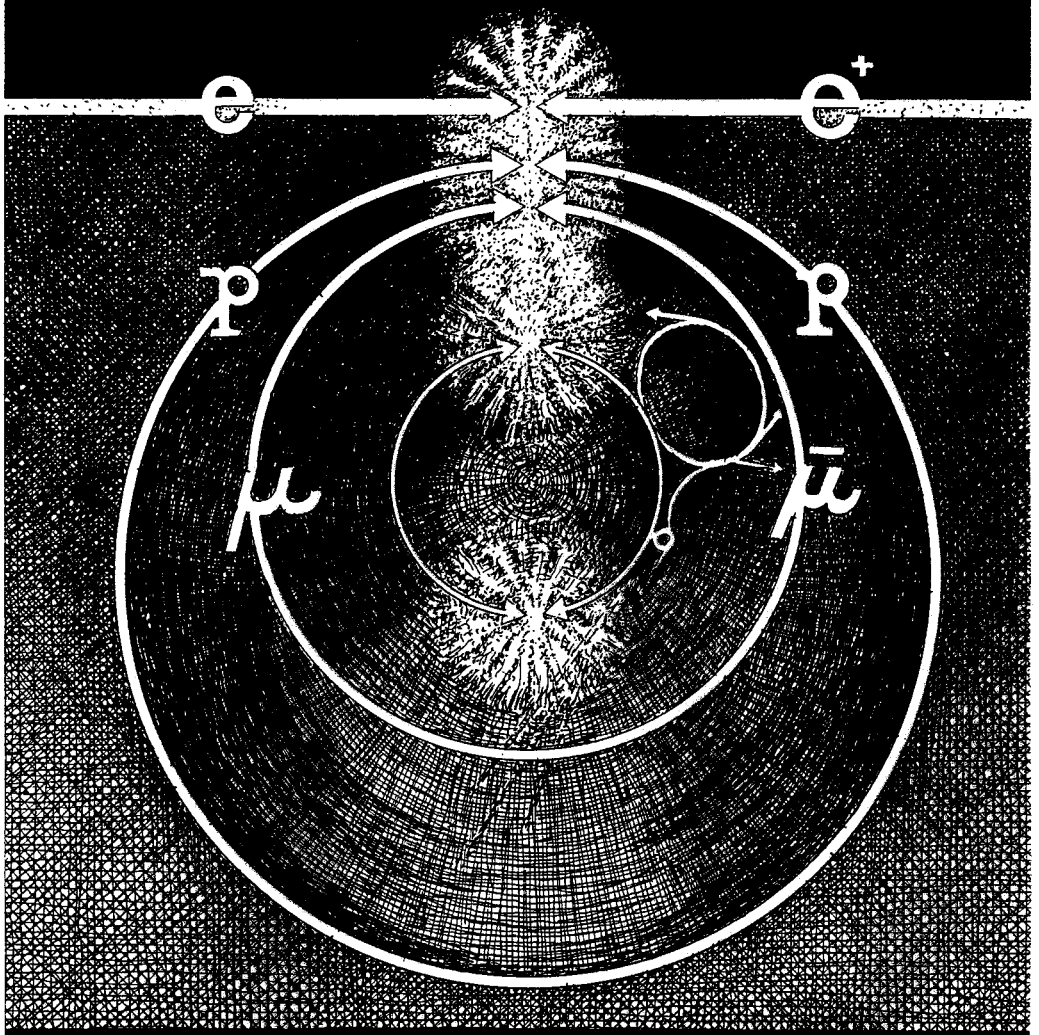


Tunnel Visions



Tunnel Visions is a series of eight two hour sessions on possible future accelerator options for Fermilab. The leading proponents of Linear Colliders, Muon Colliders, and Very Large Hadron Colliders will be challenged by a group of four conveners in each session.

Fermi National Accelerator Laboratory, 1 West between 3:00 pm and 5:00 pm

Friday, February 5, 1999
Overview of Linear colliders • T. Raubenheimer, SLAC

Thursday, March 25, 1999
The NLC • M. Ross, SLAC

Thursday, April 8, 1999
CLIC • J. Delahaye, CERN

Thursday, May 6, 1999
TESLA • R. Brinkman, DESY

Thursday, May 13, 1999
Muon Colliders • R. Palmer, BNL

Thursday, May 27, 1999
Neutrino Beams at a Muon Collider Facility • F. Geer, Fermilab

Thursday, June 3, 1999
VLHC High Field Option • P. Limon, Fermilab

Thursday, July 1, 1999
VLHC Low Field Option • W. Foster, Fermilab

For transparencies of the talks or changes in the program:
Fermilab Home Page: http://www.fnal.gov

For questions: alvin@fnal.gov and holtkamp@fnal.gov

Cost/Schedule Comments

- Kenny Construction Estimate for the 3TeV
  - 34 km of 3.6m Excavated Diameter Tunnel
  - ~125 m depth in Galena Platteville
  - $1240 / ft (TM-2048)
- Can it be done more cheaply? Yes
  - Feedback from Industry - see Library Documentation
    - Tunnel Designers and Construction Managers
    - Contractors
    - Equipment Manufacturers (Robbins Report), Materials Suppliers