

TUNNELS

TERMINOLOGY for UNDERGROUND STRUCTURES

- Adit.....galeri
- Tunnel.....tünel
- Subway.....metro
- Shaft.....baca
- Chamber.....oda
- Portal.....ana giriş veya çıkış
- Pilot adit.....yan galeri, pilot galerisi
- Centre.....merkez, eksen
- Face.....ayna
- Wall ~ site.....yan, kenar, duvar
- Floor.....taban
- Roof.....tavan

- Overbreak.....aşırı sökülme
- Excavated profile.....kazi profili
- Natural arching.....doğal kemerlenme
- Load.....yük
- Support.....destek, iksa
- Failure.....yenilme, çökme
- Gentle failure.....yavaş yenilme
- Rock burst.....kaya patlaması
- Squeezing ground.....sıkışan zemin
- Swelling ground.....şişen zemin
- Clay-filled joint.....kil dolgulu eklem
- Long term stability.....uzun süreli duraylılık
- Ground treatment.....zemin iyileştirmesi
- Support before excavation....kazi öncesi destekleme

- **Jet grouted roof cover**.....jet grouting ile iyileştirilmiş tavan örtüsü
- **Shotcrete initial lining**.....püskürtme beton başlangıç çizgisi
- **Jet grouted floor cover**.....jet grouting ile iyileştirilmiş döşeme
- **Top heading**.....kalot (Crown)
- **Invert**.....stros (Bottom excavation)
- **Bench**.....üzengi çizgisi
- **Final concrete lining**.....sonuncu beton kaplama (nihai beton kaplama çizgisi)
- **SHIELD tunnelling method**.....**KALKAN Yöntemi**
- **CUT & COVER tunnelling method**....**AÇ-KAPA Yöntemi**
- **TBM (Full face ~ Total Boring Machine)**.....**TÜM KESİT KAZI MAKİNASI**

TERMINOLOGY for EXCAVATIONS of ROCKS & SOILS

- **DRILLING**.....Sondalama
 - Hardness.....Sertlik
 - Toughness.....Dayanım – direnç
 - Abrasiveness.....Aşındırıcılık
 - Structure.....Jeolojik yapı
 - Drilking fluids.....Sondaj sıvısı
- **AUGERING**.....Burgulama
- **MACHINE BORING**.....Mekanize tünel açma
 - Total Boring Machine (TBM)
 - Full face excavation
- **BLASTING**.....Patlatma

• **SCRAPING**.....Kazıma (makinala)

• **RIPPING**.....Kırarak kazıma

• **DIGGING**.....Kazma

• **GROUND WATER**.....yeraltısuyu

- Control of groundwater
- Groundwater flow
- Rate of flow
- Volume of flow
- Boundaries

Gas bursts.....gaz patlaması

Rock falls.....kaya düşmesi

Rock bursts.....kaya fırlaması

Squeezing ground.....şişen – kabaran

zemin

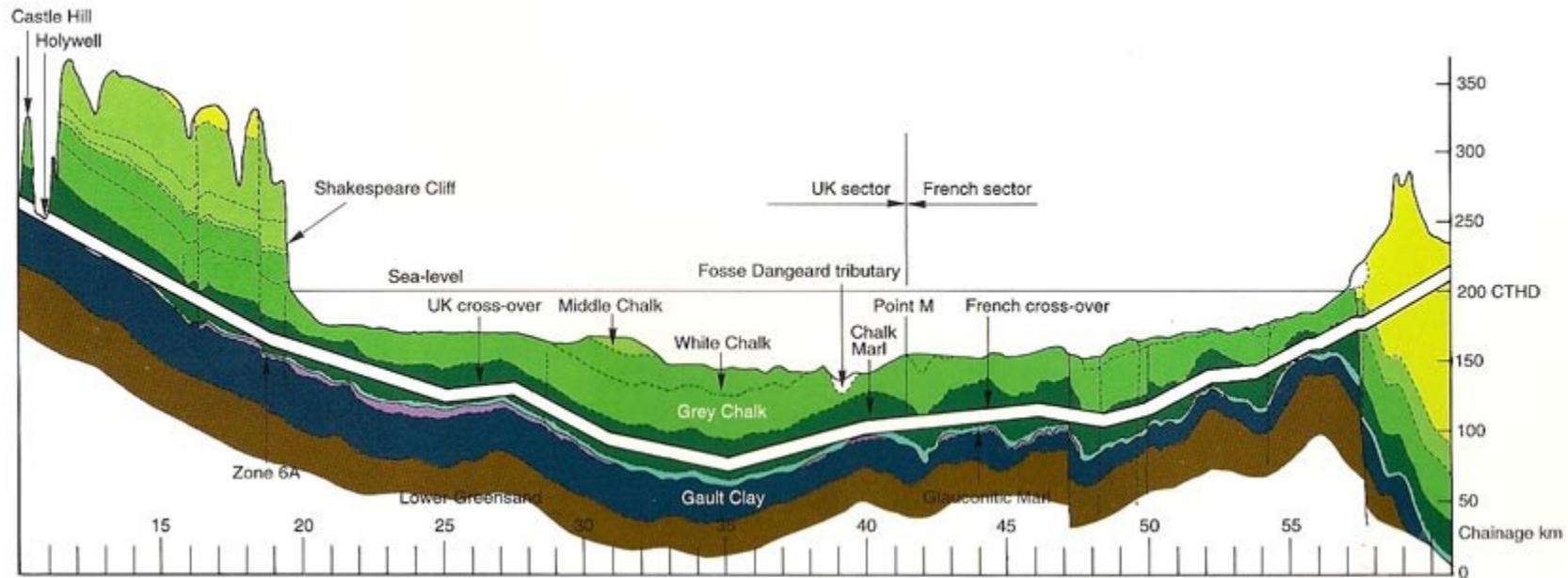
Temperature

Subsidence

TUNNEL DESCRIPTION

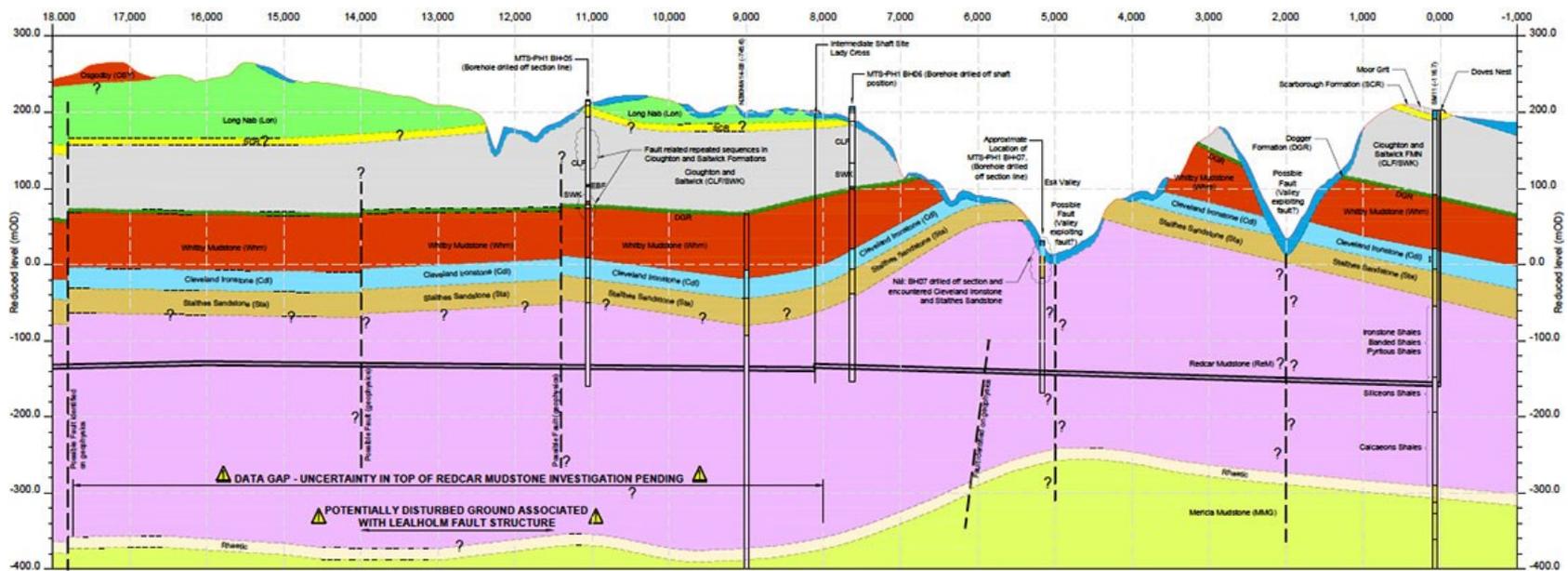
1. Made into natural material (rocks)
2. Empty inside
3. Carry the loads itself
4. Both ends are open to atmosphere
5. Generally horizontal
6. Thick walled structure looks like cylinder

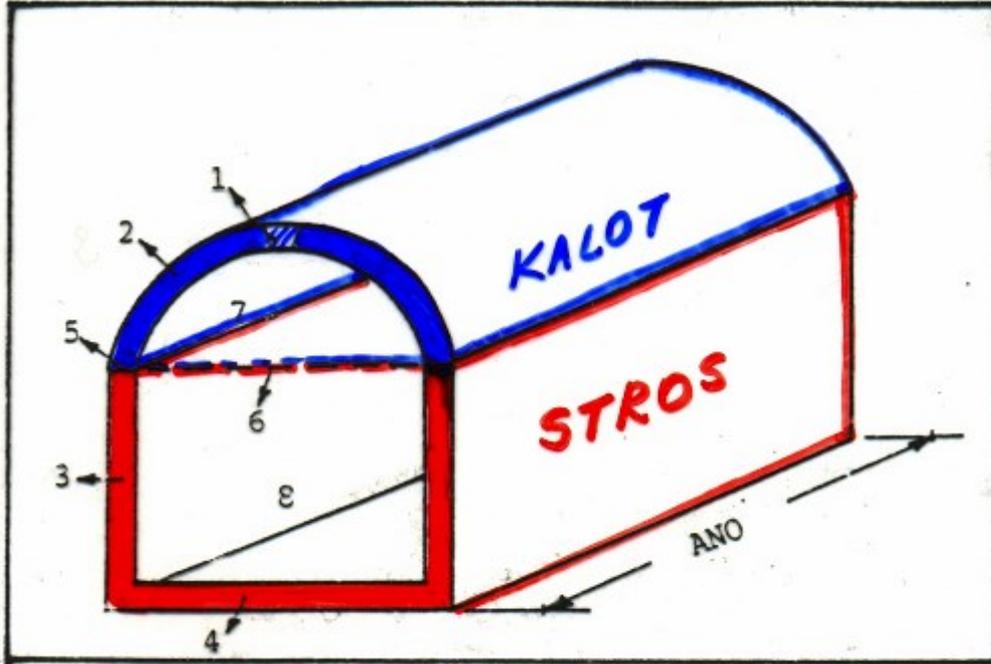
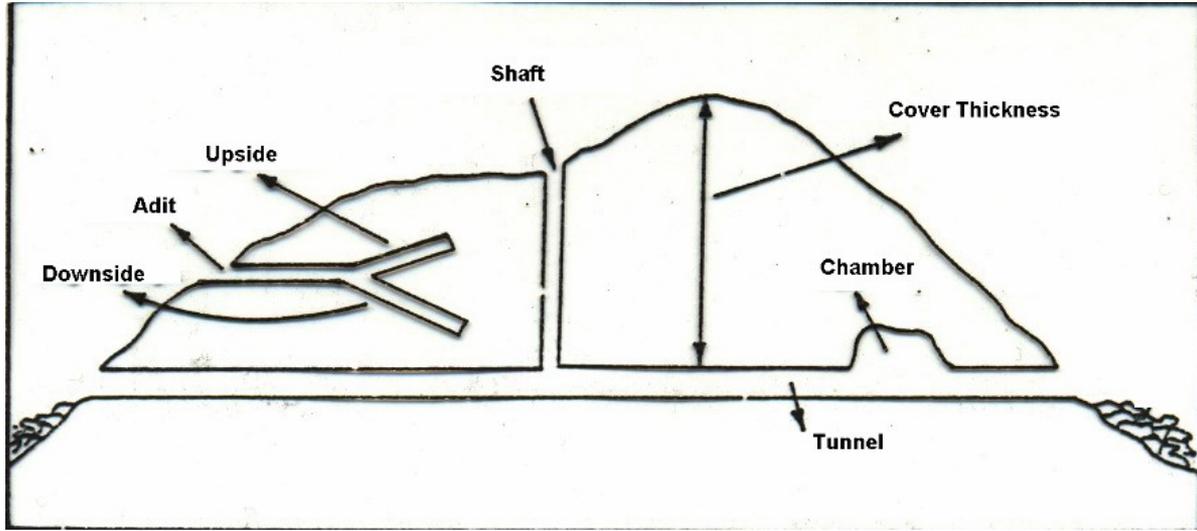
- The tunnel is classified according to opening purposes and terrain type;
 - To shorten transportation
 - To bring water
 - Turning river water into dam lake
 - To evacuate city waste and sewage
 - To reduce traffic jam
 - Underground passage
 - Providing water to hydroelectric power plants
 - Removing stone-earth-mine from underground
 - Storing liquid fuel underground
 - It is used for factory-parking-market or military purposes.



Geological plan and cross section of the tunnel

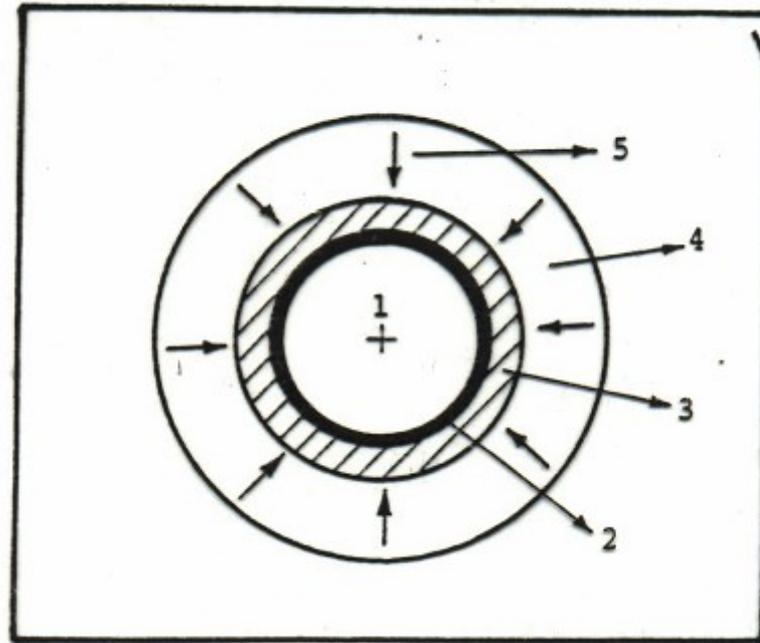
CTHD - Channel Tunnel height datum.
Mean sea-level equivalent to 200 CTHD





- 1- Kilit (anahtar) taşı.....Key stone
- 2- Kemer.....Arch
- 3- Ayak (duvar).....Wall
- 4- Taban.....Floor
- 5- Üzengi.....Bench
- 6- Üzengi çizgisi (düzeyi).....Bench line or plane
- 7- Kalot.....Top heading
- 8- Stros.....Invert
- 9- Ano.....Ano (unit)

Tunnel Section for Swelling Ground



1- Digging section

2- Support

3- Swelling section

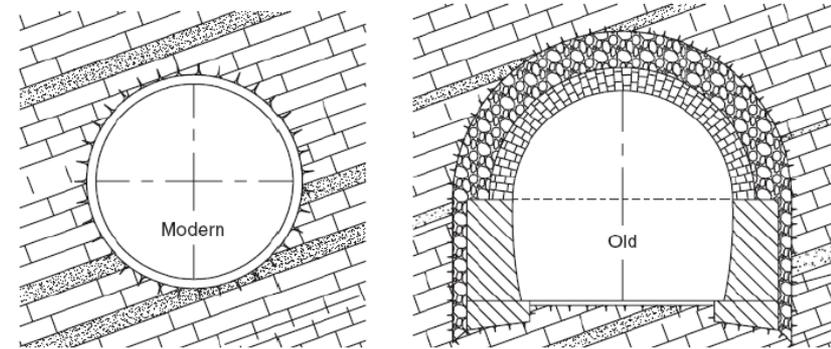
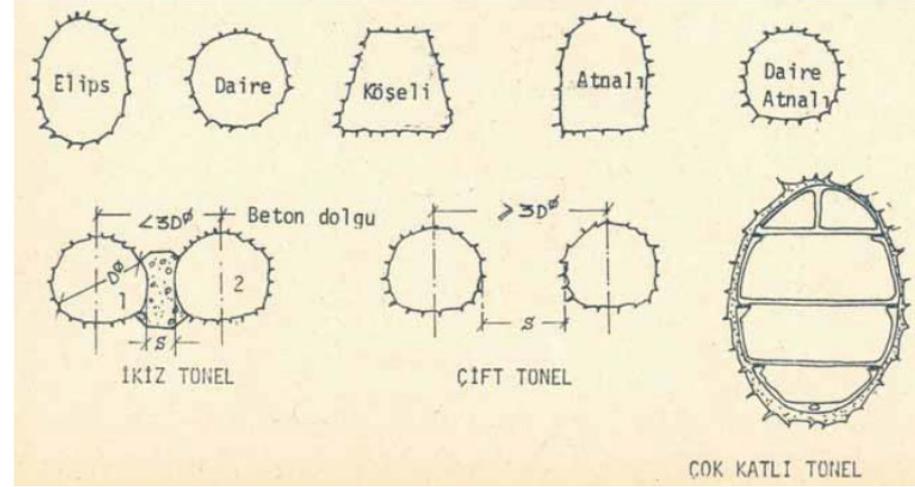
4- Pressurized area

5- Flow direction of water

Tunnel Types

Although the tunnel cross-section is variable, usually ranges from 8 m to 6 m. It is more economical that the tunnel is circular (modern).

1. Dairesel kesitler, makina ile açılmaları daha kolaydır,
2. Since the circular section is not a cornered form, the tensioning belt formed in the excavation section does not create large stress concentrations,
3. They exhibit the best behavior under hydrostatic pressure,
4. Tangential stresses are low,
5. Good ventilation angle, less friction loss,
6. Energy saving is better than other sections,
7. In circular sections, more material is placed and dead spaces can be used.



Şekil 12.4.B) Yeni (modern) ve eski tip tünel kesitleri.

Factors Affecting Costs During Tunneling

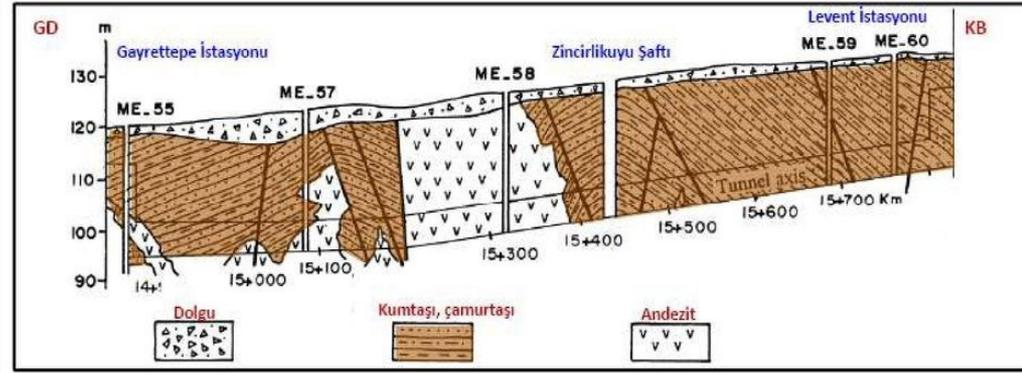
1. Geological and hydrogeological status of the tunnel route
2. Tunnel support and type of support
3. Depth from surface to tunnel
4. The diameter and shape of the tunnel
5. The length of the tunnel
6. Workmanship
7. Working days
8. Machine malfunctions



Tunnel Geology Studies

- Preliminary geological surveys
- Detailed geological surveys
- Work done while the tunnel is open
- Work done after tunnel opening

❖ Bir tünel projesi – İstanbul Metro Tüneli – için kaya puanlama sisteminin “RMR₈₉” uygulaması:



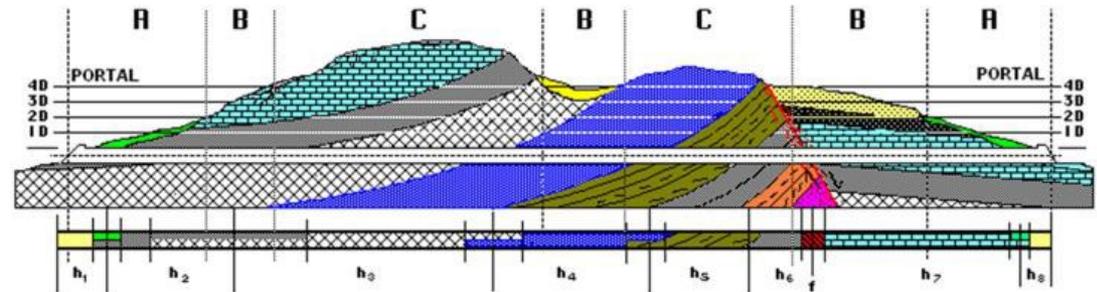
Kaya kütle parametreleri	Kumtaşı		Çamurtaşı		Fay zonu geçişleri	
	Mak.	Min.	Mak.	Min.	Mak	Min
Tek eksenli basınç dayanımı	136,4 MPa (12)	55 MPa (7)	37,5 MPa (4)	31 MPa (4)	9,4 MPa (2)	9,0 MPa (2)
RQD	50-75% (13)	25-50% (8)	50-75% (13)	25-50% (8)	25-50% (8)	<25% (3)
Süreksizlik aralığı	0,6-2 m(15)	60-200 mm (8)	200-600 mm (10)	60-200 mm (8)	200-600 mm (10)	<60 mm (5)
Süreksizliklerin durumu	Çok pürüzlü yüzeyler (20)	Çok pürüzlü yüzeyler (20)	Çok pürüzlü yüzeyler (20)	Pürüzlü yüzeyler (10)	Pürüzlü yüzeyler(10)	Az oyuklu>5 mm (0)
Yeraltı suyu	Islak (7)	Nemli (10)	Nemli (10)	Nemli (10)	Damlama (4)	Damlama (4)
Puan düzenlemesi	Çok uygun(0)	Orta (-5)	Çok uygun (0)	Orta (-5)	Uygun değil (-10)	Uygun değil (-10)
Toplam Puan	(67)	(48)	(57)	(35)	(24)	(4)
Sınıf numarası	II	III	III	IV	IV	V
Tanımlama	İyi kaya	Orta kaya	Orta kaya	Zayıf kaya	Zayıf kaya	Zayıf kaya

Kaynak:Doğaç, S, 2002.

PRE-GEOLOGICAL STUDIES / Creation of Geology-Engineering Geology model

They are studies to determine the tunnel route. It focuses on route and surface geology research.

- Lithological properties
- Structural features
- Cover thickness and natural stress
- Engineering properties of rocks
- Hydrogeological properties
- Heat problem
- Gas problem
- Seismicity



Tünel projelerinde bölgelendirme - Project zones of a tunnel

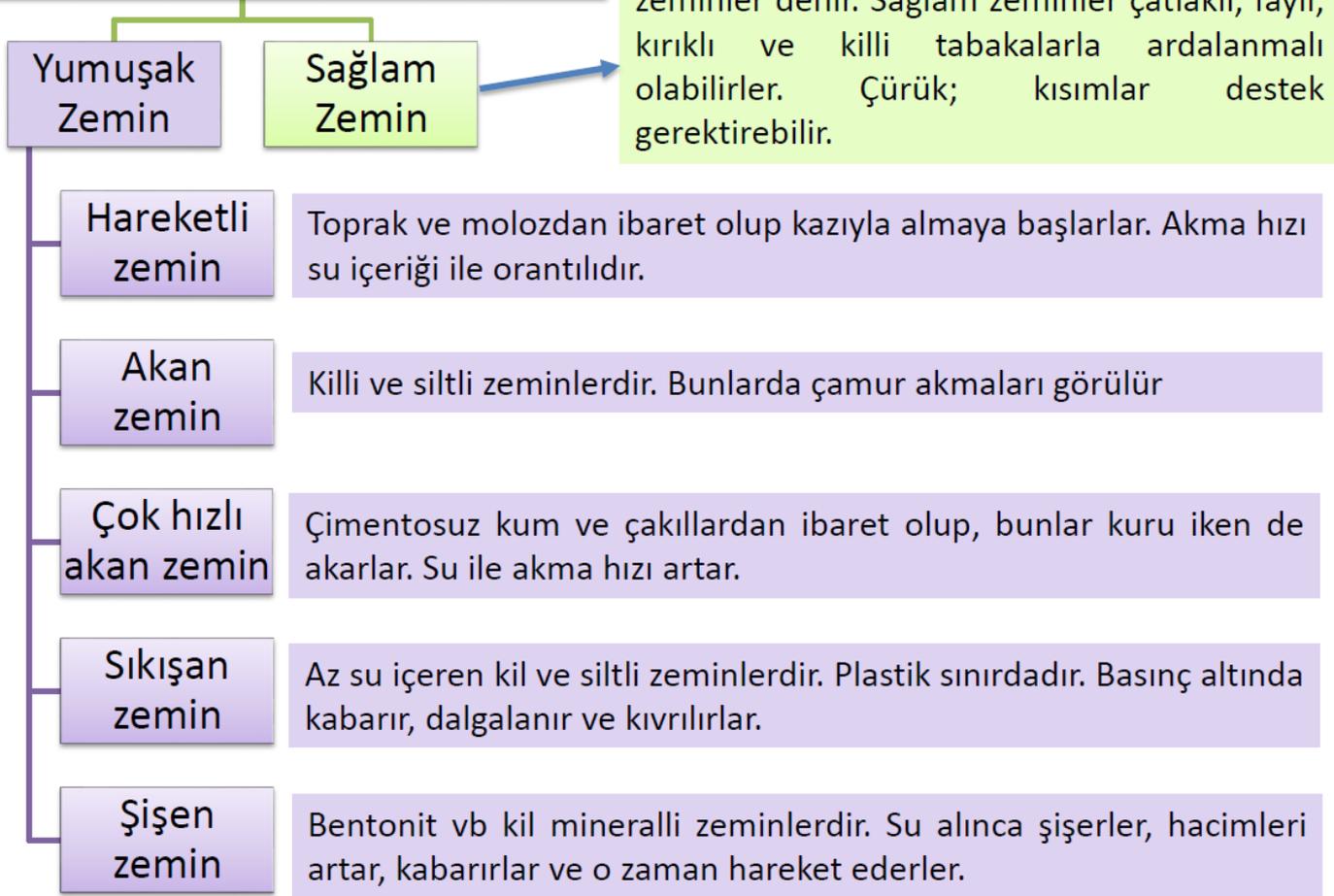
A: SİĞ TÜNEL veya GİRİŞ BÖLGESİ Shallow tunnel or portal area	HOMOJEN BÖLGELER ve FAY ZONLARI
B: YÜZEYE YAKIN TÜNEL ($2D < H < 4D$) Near surface tunnel	$h_1 - h_8, f$: Homogeneous Zones and Fault Zones
C: AZ DERİN, DERİN, ÇOK DERİN TÜNEL ($H >> 4D$) Nearly deep, deep, very deep tunnel	

Underground surveys; Drilling, splitting, well, gallery and geophysical methods are used.

Rocks;

- Lithological and petrographic properties
- Degree of decomposition and depth,
- Hardness and digging properties
- Excavation method and machine selection
- Engineering features of discontinuities
- Groundwater level, sources, effects of concrete and cement of the chemical composition of water, heat and temperature, permeability of the environment
- Sensitivities of rocks to water (melting, swelling, karstification)
- Field experiments in drilling and excavation, laboratory experiments in the samples taken, determination of physical and mechanical properties
- The use of excavated material (pasa) as aggregate in coatings
- Detailed numerical data on tunnel supports and locations are collected.

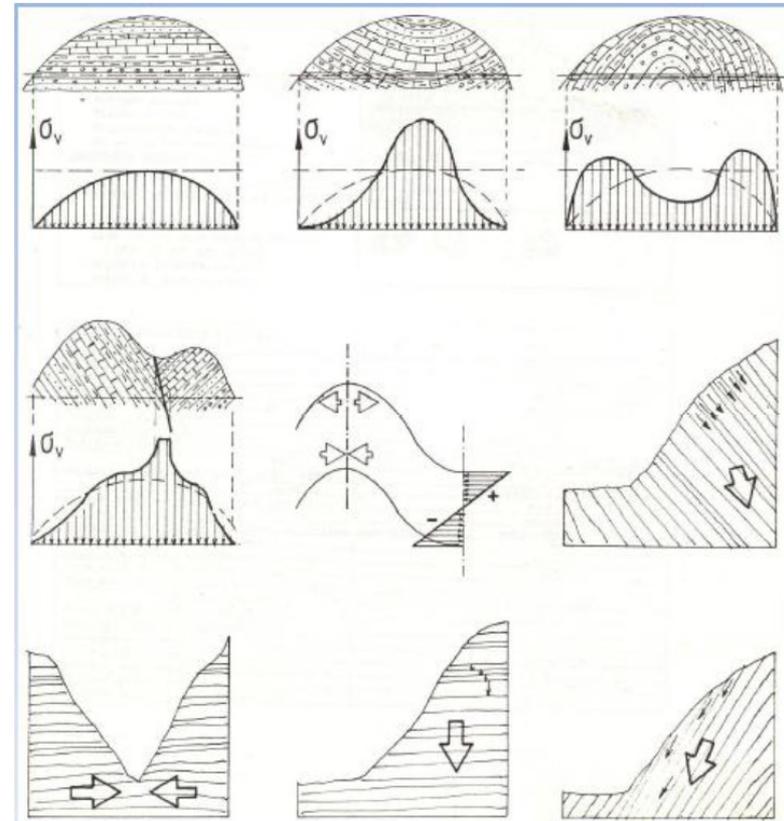
ZEMİNLERİN TÜNEL AÇMA YÖNÜNDEN SINIFLANDIRILMASI



Impact of Stress on Geological Structures

It is necessary to determine the violence and direction of the strains, the tunnel route and its dimensions.

- folds
- syncline
- anticline
- faults
- layers
- It is effective in underground stress distribution.



EXPLORATION & INVESTIGATIONS RELATED of SLOPE STABILITY

- Geomorphologic mapping and preparation of longitudinal & cross sections
- Geological mapping & surveyings (aerial photographs)
- Geophysical surveyings
- Underground explorations, boreholes
- Ground water surveyings
- Laboratory tests
- Model studies

UNDERGROUND EXCAVATIONS

- In Rock
- In Sediment
 - Stability & Arching
 - Water
 - Dry tunnel.....above water table
 - Wet tunnel.....below water table
 - Gases
 - Carbon dioxide (CO₂)
 - Carbon monoxide (CO)
 - Methane (CH₄)
 - Hydrogen sulphide (H₂S)
 - Other gases

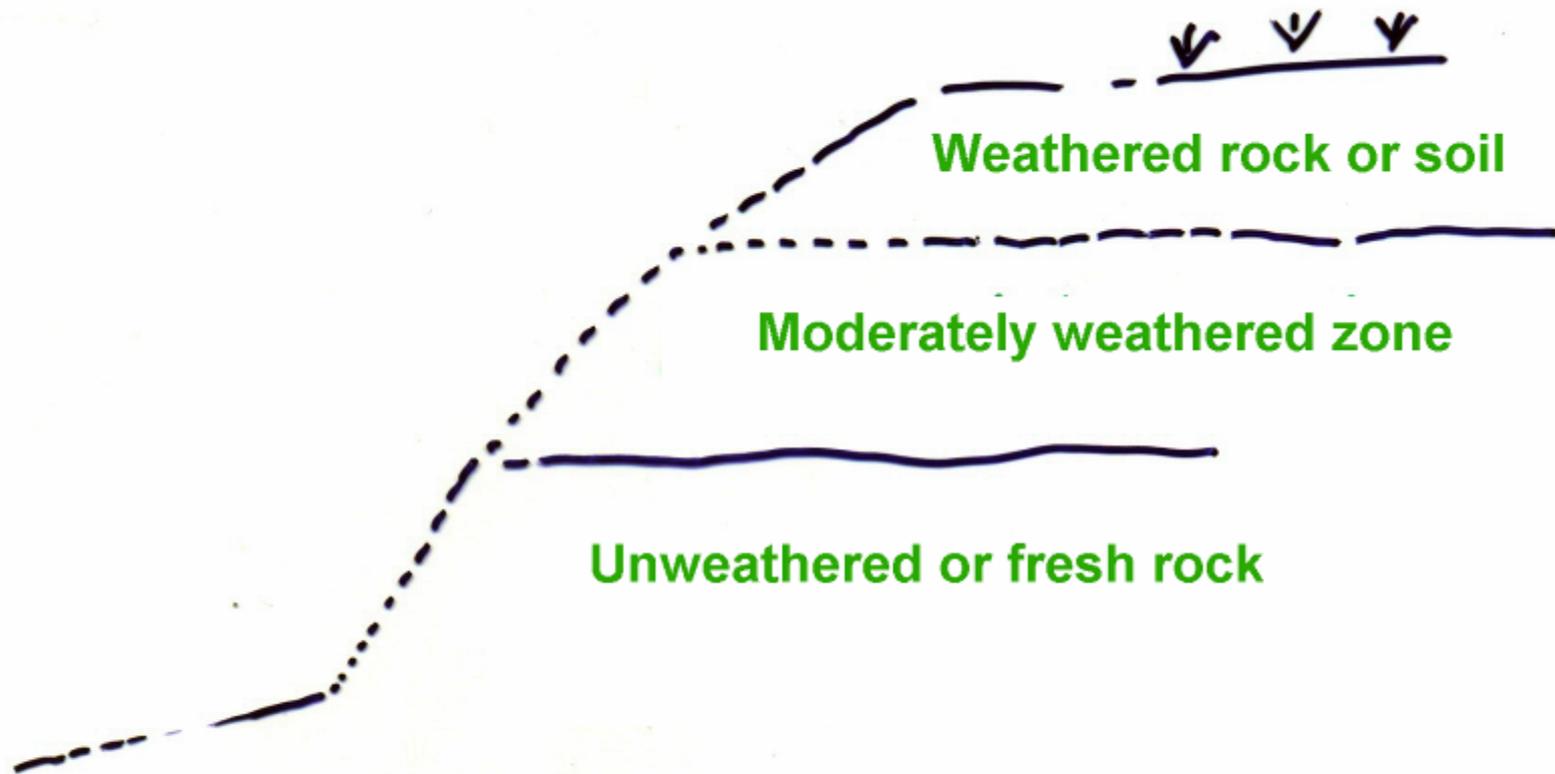
SUBSURFACE EXCAVATIONS

1. GEOLOGY

1. Soil profile or hard rock geology
2. Structure
3. Ground water (hydrogeology)
4. Stability

2. INVESTIGATIONS

1. Mapping (Topographic, geologic, etc...)
2. Geophysical surveying (especially seismic velocity of rocks)
3. Trial pits & boreholes
4. General and local stability analysis
5. Decide to excavation method



VERTICAL GEOLOGICAL SECTION

GASES

(can be lethal or burst)

- Carbon monoxide (CO) 0.97 of air
- Carbon dioxide (CO₂) 1.53 of air
- Methane (CH₄) 0.55 of air

(Highly explosive with air) marsh gas

- Hydrogene sulphide (H₂S) 1.19 of air
(Highly toxic and explosive)
- Sulphur dioxide (SO₂)



- **ROCK FALL**
- **SQUEEZING GROUND (sand, silt, shale, clay)**
- **ROCK BURST**
- **BULKING (Increase in volume, 10-40%)**

FACTORS EFFECTING EXCAVATION of ROCKS

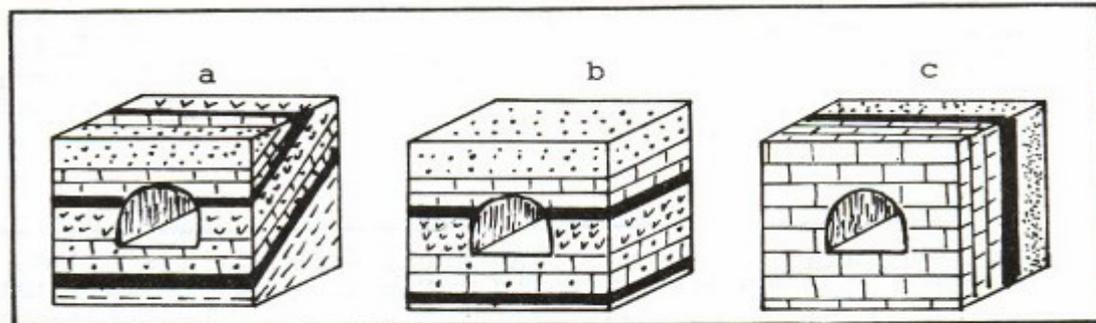
- Mineralogical composition of rocks
- Texture & fabric
- Petrographic features
- Structure
- Rock mass
- Strike & dip of beds in relation to face of excavation
- Intensity of tectonic disturbances
- Degree of weathering

RESISTANCE of ROCKS to EXCAVATION

- Loose soils
- Soil easy to spade (bel ile kazmak)
- Soil easy to dig
- Crumbling weak rocks (ufalamak)
- Rocks easy to blast
- Rocks difficult to blast
- Rocks very difficult to blast

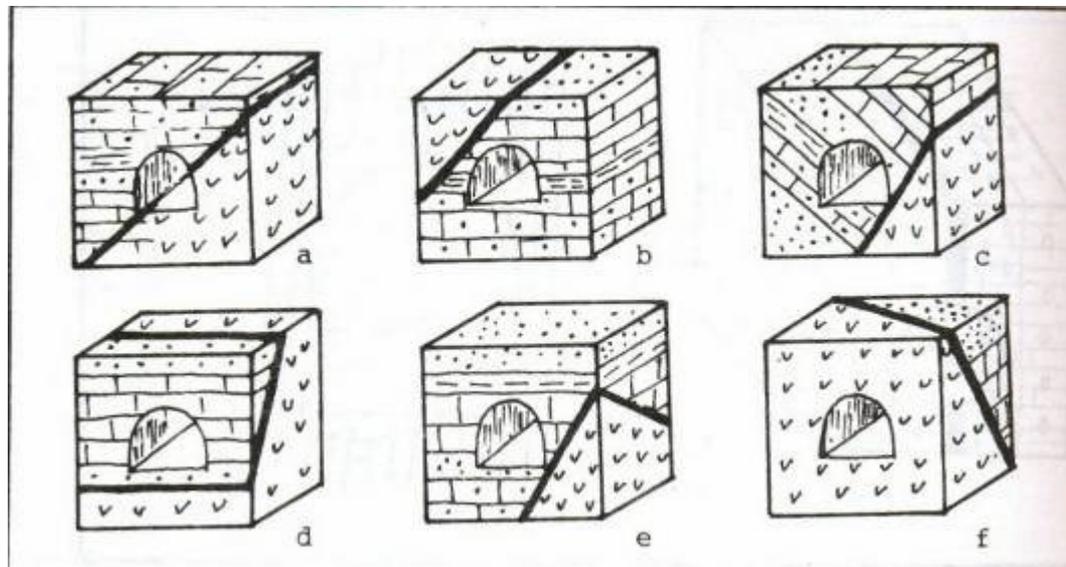
EFFECT of GEOLOGICAL STRUCTURES to TUNNEL EXCAVATION

- **Effect of soil layers:** horizontal, vertical and inclined layers have different kinds of loading conditions for tunnels.



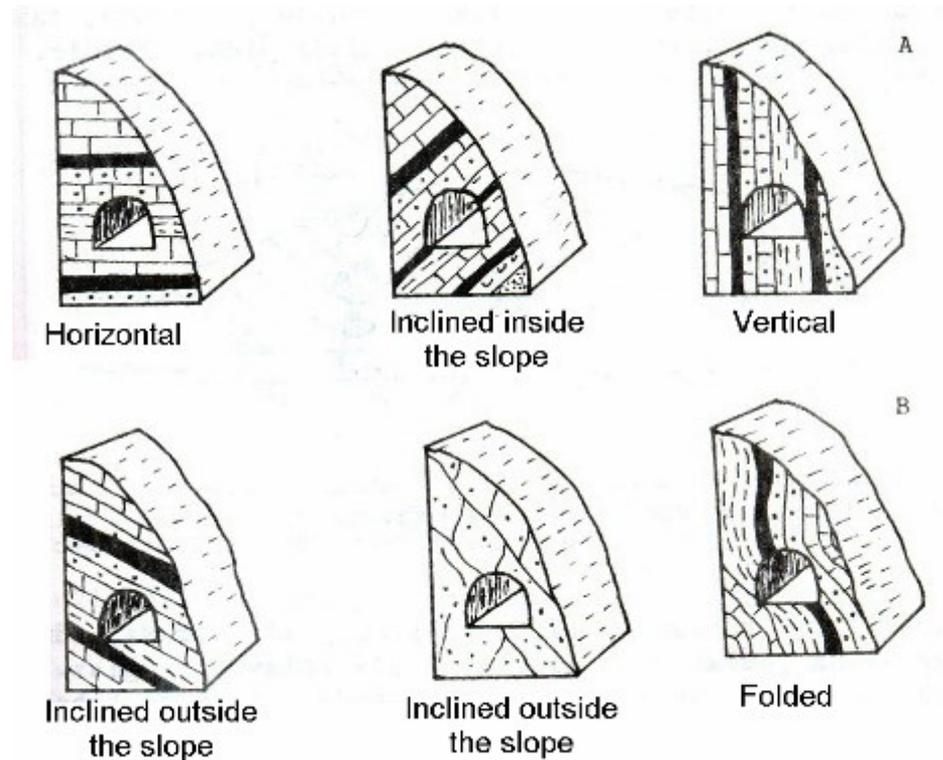
Relation of layers and tunnel direction

- **Effect of faults:** the relation between the fault slope direction and the tunnel direction, width of the fault zone, type and thickness of the fill material and the hydrostatic pressures in both sides of the fault are some problems in the tunnelling.

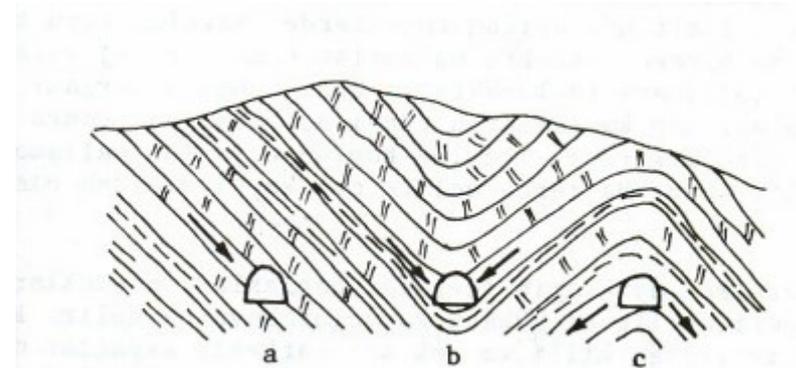
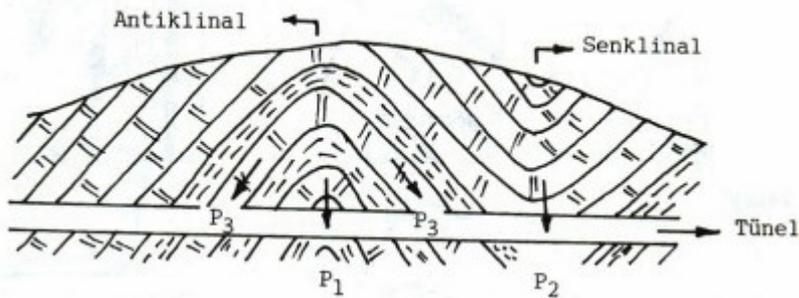


Relation between the fault zone and the tunnel

- **Tunnel excavations in the slopes:** the discontinuities (layers, fissures) inclined inside or outside of the slope are very important regarding the stress and strength of the tunnel.



- **Effect of the folds:** While tunnel is excavated in an area that contains folded rocks, different stresses and conditions may occur depending on the fold type.

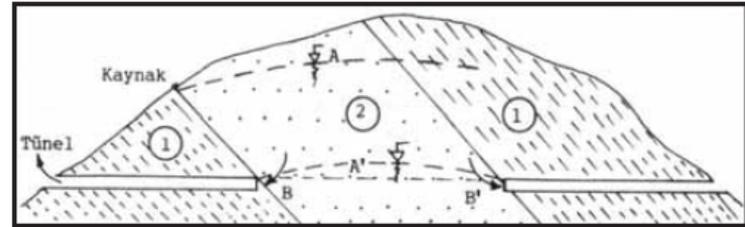


Fold axis and the tunnel direction is parallel

Fold axis and the tunnel direction is vertical

Water Problem

- In the tunnels that open under the groundwater level, the groundwater moves into the tunnel. It works like a tunnel drainage gallery. The permeability of the rocks, discontinuities and karstic cavities (limestones) around the excavation are important. Decrease in strength due to formation of void water pressure.
- Meltable and swollen rocks.
- Working conditions are difficult.
- Risk of loss of goods and life, cost increase.
- Swelling in clayey media and flow to excavation cavity



Şekil 12.9. Her iki yönden geçirimsiz birimlerden geçen tünel kazısında, bir akiferin kesilmesi sonucu yeraltı suyunun tüneli basması ve tünel boyunca boşalması. 1-Geçirimsiz kayaç, 2-Geçirimli kayaç, A: Tünel açılmadan önceki yeraltı su seviyesi, A' : Tünel açıldıktan sonraki yeraltı su seviyesi, B, B' : Tünel açılmasıyla su akımının artması, tünelin drenaj galerisi gibi çalışması (Tarhan, 2002).

HEAT PROBLEM

On the Earth's surface, the temperature increases by 3 ° C every 100 meters towards the deep.

It makes working conditions difficult.

The effective path to solution of the problem is ventilation.

Ventilation;

With air-driven or suction motors (compressor, aspirator)

Provided with tunnel openings.

GAS PROBLEM

Carbon dioxide (CO₂): 15-25% lethal effect. 4- to 6% respiratory distress.

In reaction with water, carbonic acid, tunnel coating and corrosion in metals.

Carbon monoxide (CO): 0.025% excess poisoning, 0.04-0.06% mortality.

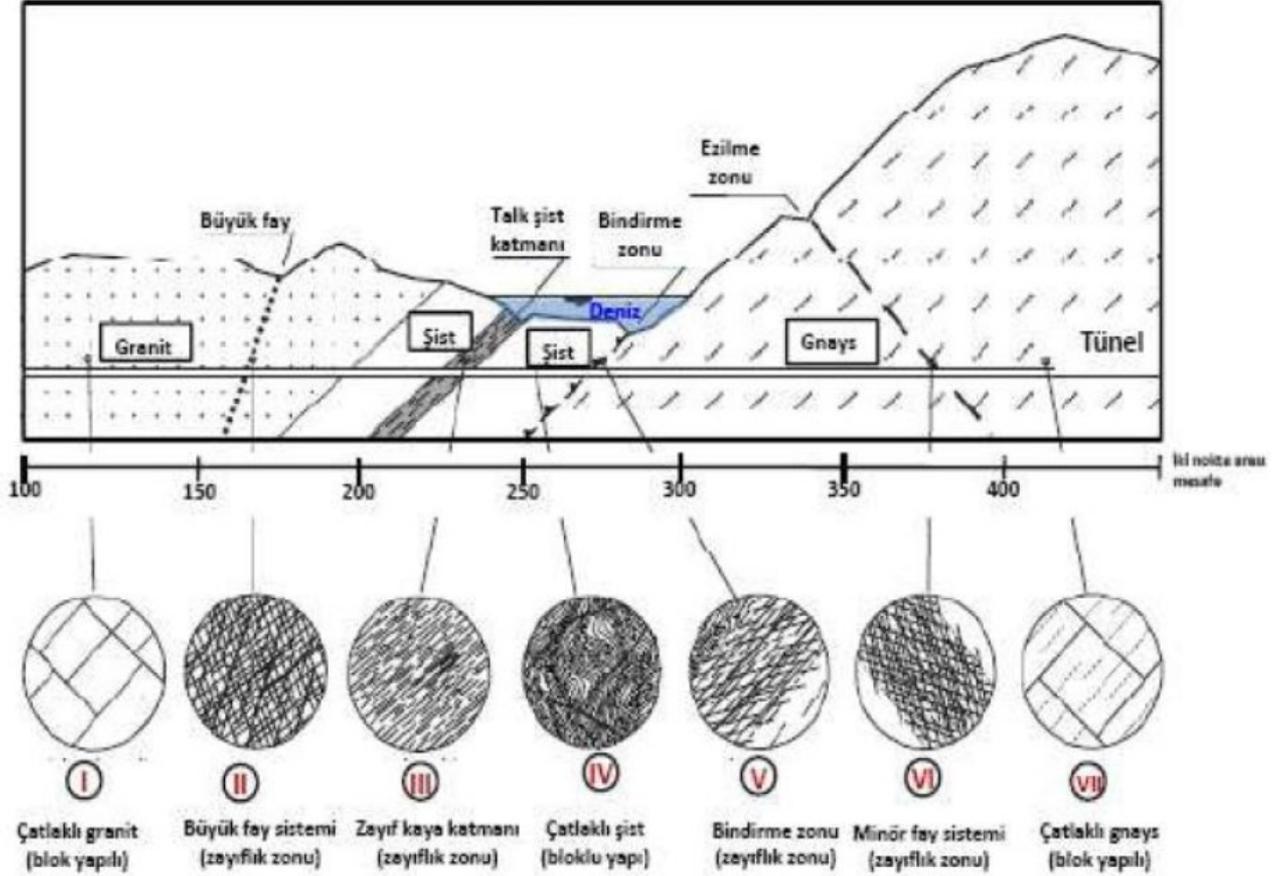
Methane (CH₄): It is explosive (Grizu) if the ratio with air is about 5%.

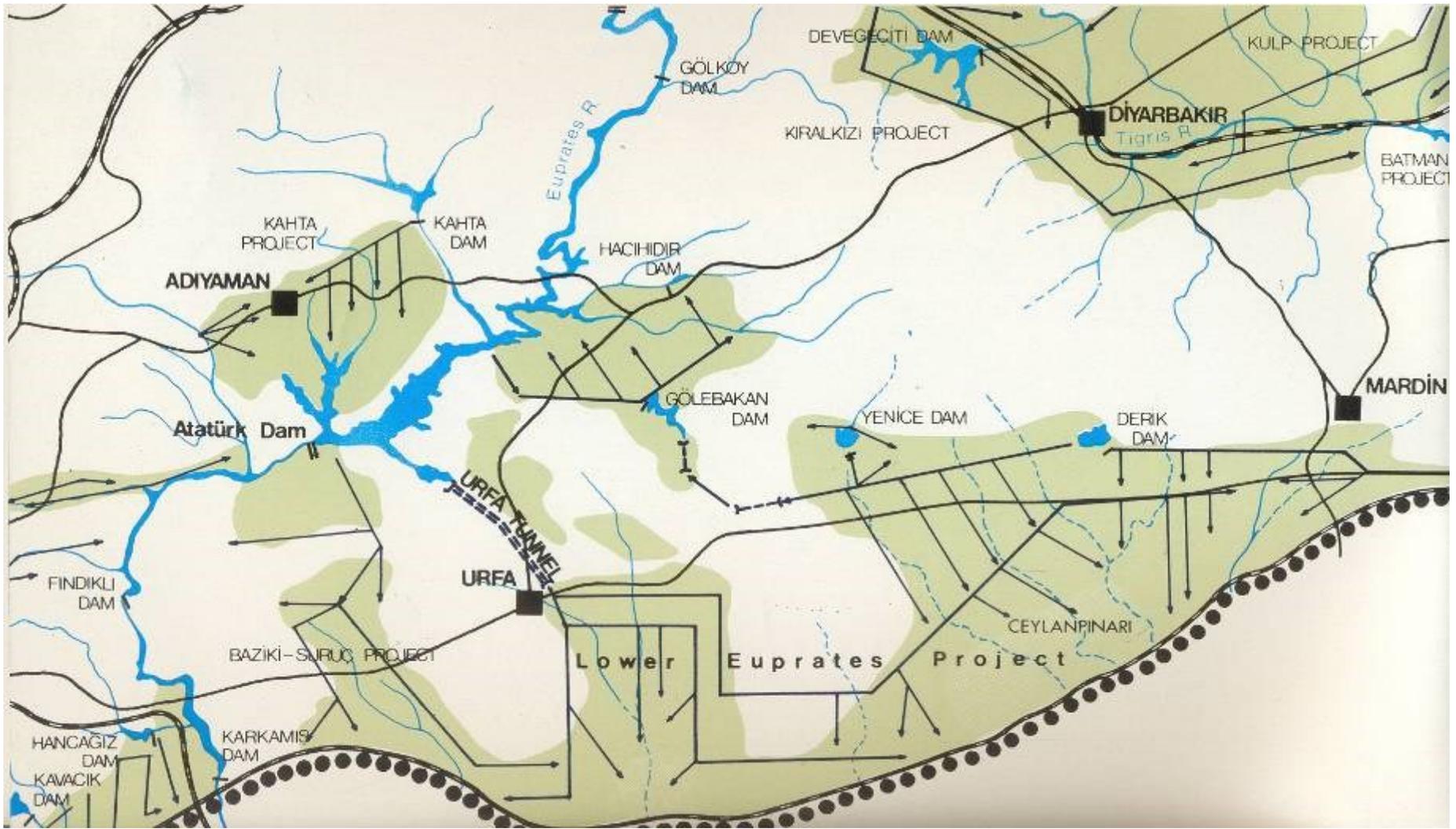
Sulphurdioxide (SO₂): Sulphuroxide coated concrete that reacts to water is formed.

Hydrogen sulphide (H₂S): Less than 1% of the mixture in the air is poisonous. 6% If it is more than that, it is explosive.

The effective way of getting rid of the negative effects of the gases is ventilation.

❖ Uzun bir tünel projesinde karşılaşılabilecek jeolojik ortamlara örnekler





**ONE of the LONGEST IRRIGATION TUNNELS in
the WORLD**



Consist of two concrete lined tunnels each of which is 7.62 m in diameter and 26.4 km in length discharging water from the reservoir of Atatürk Dam.

SITE INVESTIGATIONS

