# SOMA LIGNITE BASIN, TURKEY

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# 13.1 Introduction

# 13.1 Introduction

- **Lignite (갈탄)**

  low pressure, low temperature 에서 생성

  low rank coal

  수분함량이 높음 (max. 66 %)

  Ash 성분도 많음 ➔ 건조시키면 가루로 변함

  낮은 에너지 밀도 ➔ 운송 수단의 연료로는 부적합

  주로 산지와 가까운 화력 발전에서 사용됨

Lignite mine (독일 북서부 노르트라인베스트팔렌 주 쾰른 시)

(emuseum.go.kr)

# 13.1 Introduction

- **SOMA LIGNITE BASIN** 개발 배경

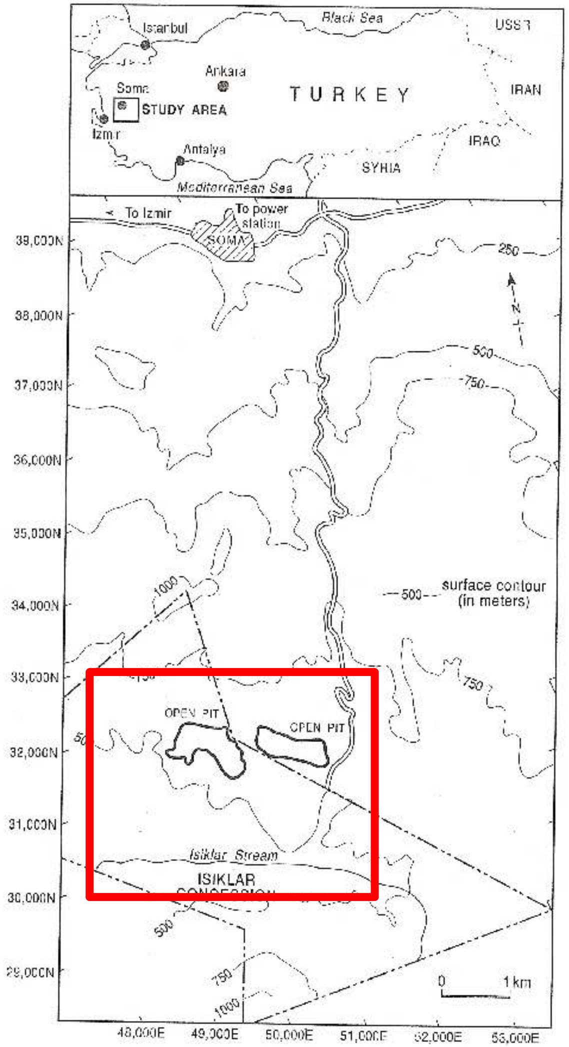
| | | |
|---|---|---|
| **Energy crisis** caused by the OPEC **oil price rises** which started in 1973 | Search for **alternative** fossil fuels | Important for **developing countries** which wish to **reduce** their **reliance** on **imported oil** |

→ **exploitation of Soma Isiklar lignite deposit in western turkey**

→ **feedstock for the Power Station (A, B)**

→ **2 Mt** 를 광산 확장을 통해 증가

# 13.1.1 Location




(fig. 13.1)

- **Soma lignite deposit**
  - In the Manisa Province of western turkey
  - 10 km south of the town of Soma
  - South-facing slope
  - Elevations ranging from 750 m in the north to 310 m in the south

# 13.2 Exploration programs

# 13.2.1 Previous work

- **Database : four drilling programs**

(table 13.1)

| Drilling program | Number of holes | Total meterage | Drilling date |
|---|---|---|---|
| 200 | 34 | 8790 | 1960 |
| 100 | 50 | 10,825 | 1976 |
| 300 | 9 | 1547 | 1981 |
| 400 | 29 | 8631 | 1982 |
| Total | 122 | 29,793 | |

- Analyzed for ash & moisture content, calorific value, sulfur & volatile content
- Produced Isopach, structure contour, isoquality, reserve map
- Geotechnical study, specific gravity

# 13.2.2 Core recovery

- 코어 회수율이 **95%**를 넘지 못하면 재시추
- 회수율을 증진시키기 위한 방법
  - Use of large diameter wireline
  - Use of air flush core barrels
  - Use of triple tube core barrels

# 13.2.3 Geophysical logging

- **Typical DTH(Down-the-hole) geophysical logs**
  - natural gamma, density, neutron, caliper, resistivity, etc
  - Shale, mudstone, marl ➔ high γ, density
  - Coal ➔ low γ, density
  - Neutron ➔ estimating porosity
  - Resistivity ➔ indicate bed boundaries

# 13.2.4 Sampling

- **Whole lignite sequence was sampled, Including all parting material**

- **All lithological layers in the seam greater than 30 cm thick were sampled**

- **Minimum thickness of parting that could be mined as waste in the open pit**

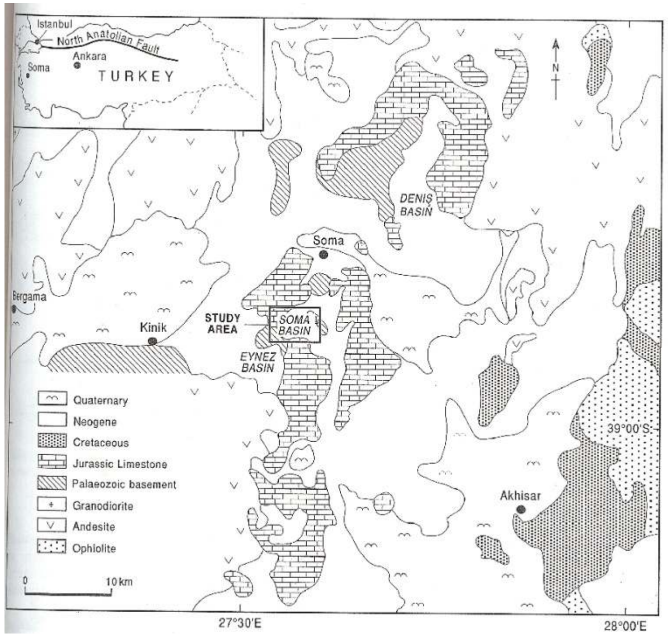
# 13.2.5 Grouting

- **All holes where deep coal is likely to be mined by underground methods drilled prior to mining should be sealed using pressure grouting**

**➔ reduce potential water Inrush hazard**

# 13.3 Geology

# 13.3.1 Geological setting

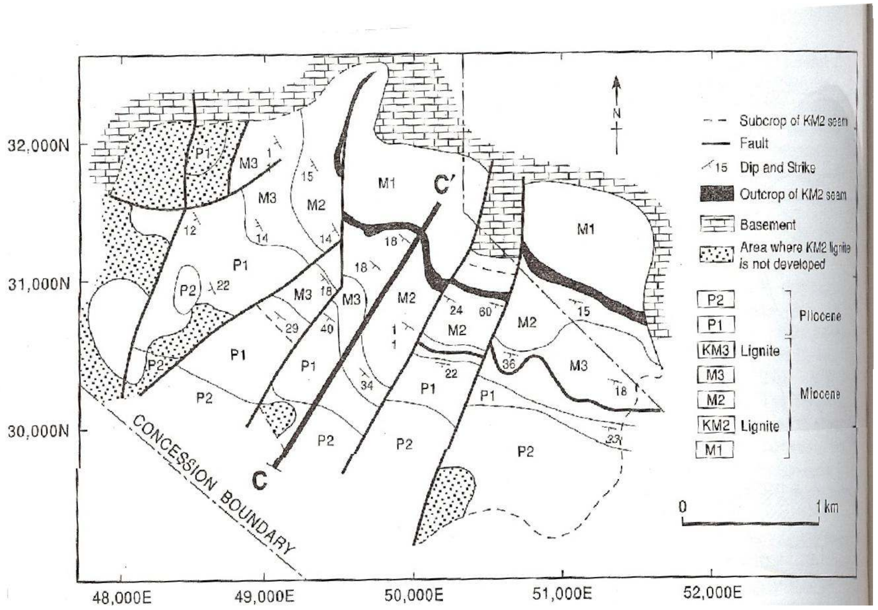



(fig. 13.2)

- Precambrian, Palaeozoic and Mesozoic Sedimentary and igneous rock
- North Anatolian Fault (NAF) :
  late Serravallian (mid. miocene)
- Series of NE-trending graben*s

* Graben : 단층에 수반하여 상반이 하강하여 생긴 좁고 긴 열극

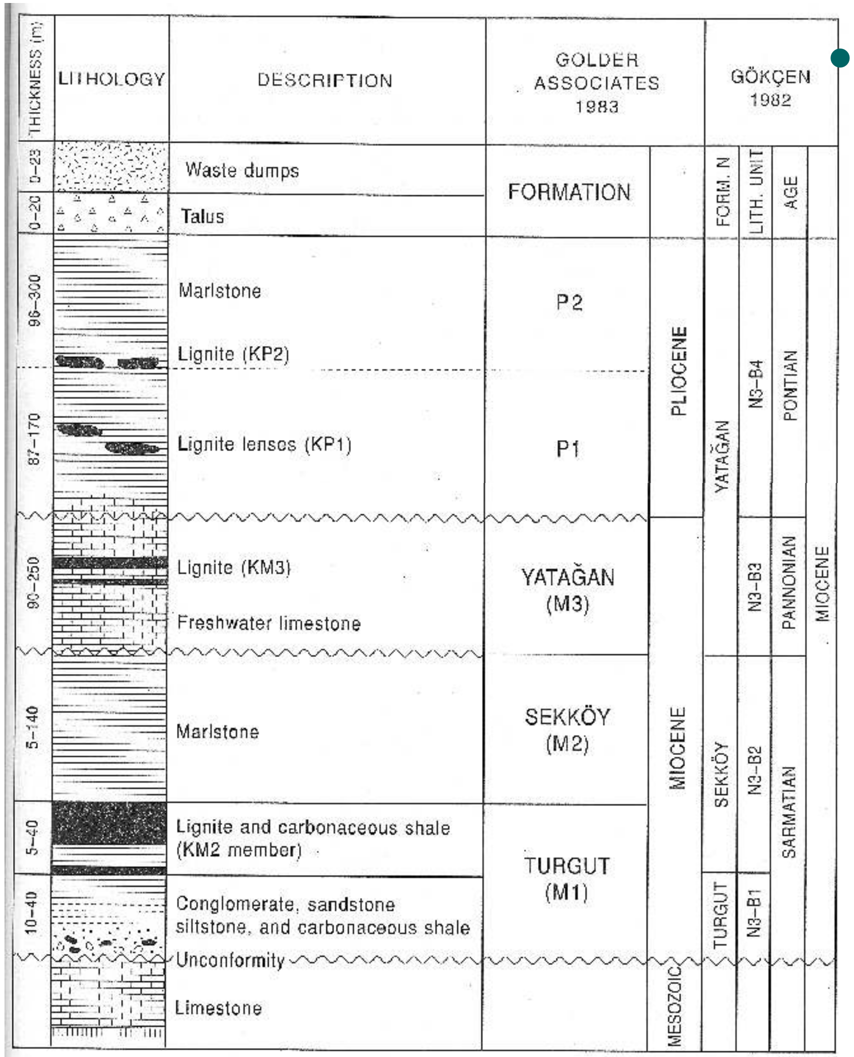
# 13.3.2 Geology of the Soma Basin




(fig. 13.3)

- Miocene and Pliocene sediment
- NE : high / SW : low
- Not contain volcanic Rx.
- KM2 and KM3 : lignite
- NE – SW faults

# 13.3.2 Geology of the Soma Basin



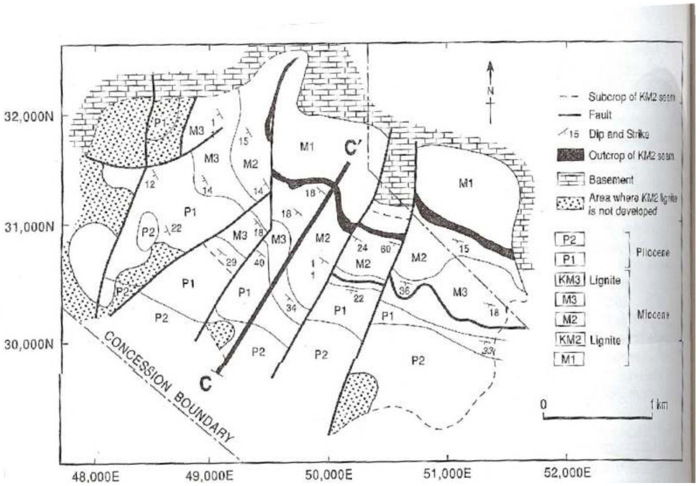

(fig. 13.4)

- Stratigraphy of the basin
  - Top of basement :
    consist of debris flow
  - KM2 : hard, black, bright,
    cleats, concoidal fracture
  - Sharp contact :
    KM2 – SEKKOY(marlstone*)

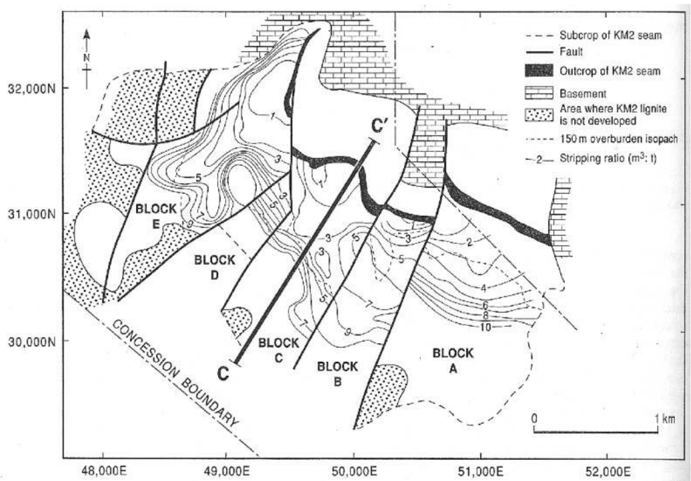
Difference Gamma value
∵ change to an arid climate

*Marlstone : 이회암

# 13.3.3 Structure of the Soma Basin



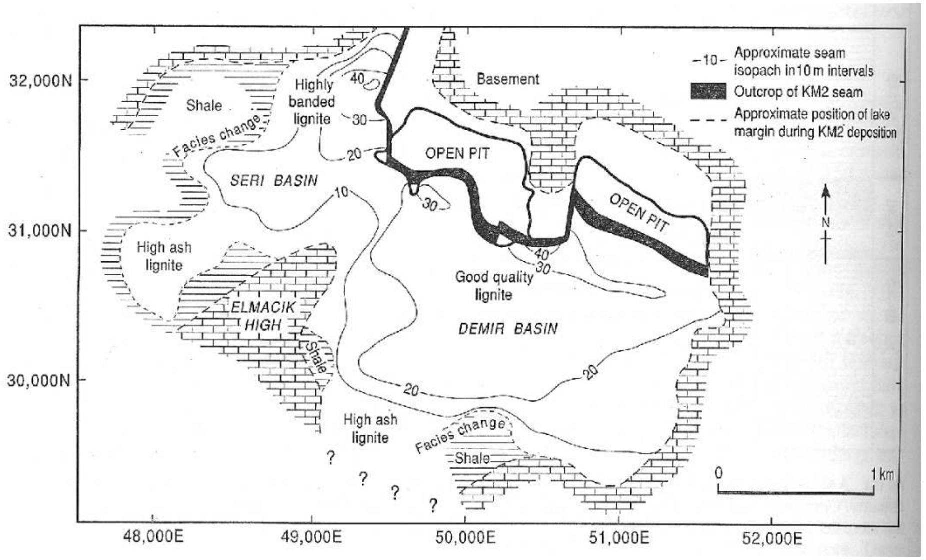
(fig. 13.3)



(fig. 13.8)

- **Tilting to the southwest**
- **Faulting trends NE-SW**
- **Define mining blocks :**
  **A,B,C,D, and E**
- **Dip to the southwest at an average of 20 degree**
  north rim ➔ steeper

# 13.3.4 Depositional model for the Soma Basin



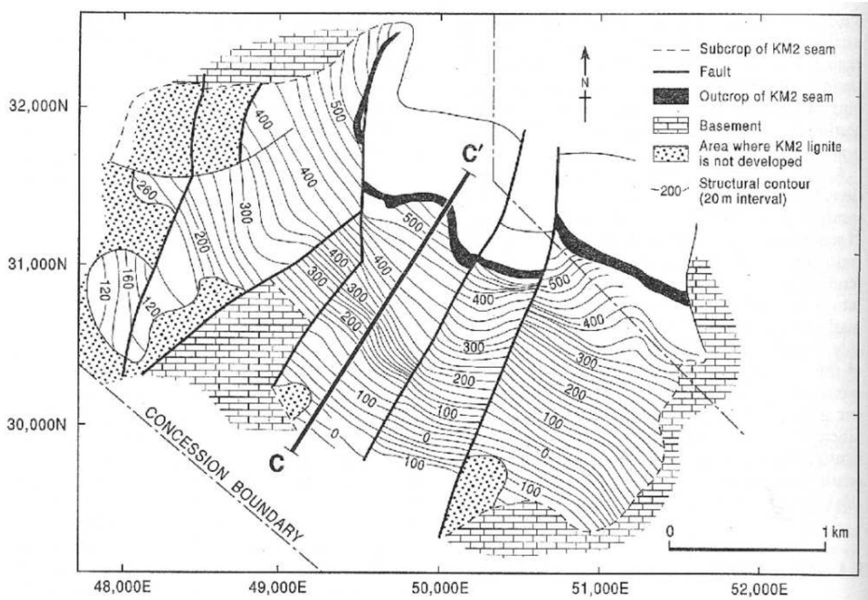
(fig. 13.5)

- 북쪽의 가파른 **basin**
- ➔ **run-off 발생 (모래, 자갈)**
- ➔ 중앙으로 유입되어 퇴적
- ➔ **gravelly sandstone at the base to siltstone and mudstone at the top (fig.13.4)**

- ➔ **Temporal variation**
- ➔ **Repetition of fining-upward sequences and rapid lateral variation (filled basin)**
- ➔ **Plant growth**
- ➔ **Form KM2**
- ➔ **Climatic change**
  (warm humid ➔ arid)
- ➔ Sedimentation of marl deposition
- ➔ **The fine grain size and the calcareous nature of the material suggests deposition by low energy input into a low energy water body**
- ➔ **unconformity**

# 13.4 Data Assessment

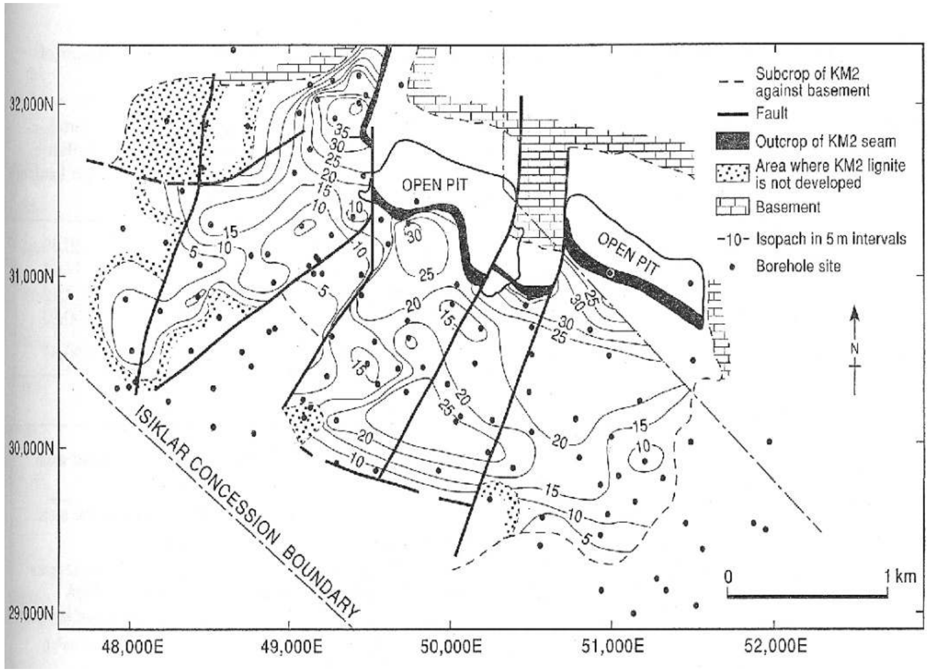
# 13.4.1 Structure contour maps




(fig. 13.6)

- **Top of KM2 seam**
  - 지하구조의 형상을 알 수 있음
  - 단면도와 함께 이용
    ➔Basin의 단층 패턴 분석
    ➔작업의 안정성 도모
  - Mine design 시 이용
    ➔Identify potential slope failure

# 13.4.2 Isopach maps




(fig. 13.7)

**I : for the KM2 seam** (fig.13.7)

**II : for the overburden material**

**III : for the basement**

- **Thickness from 2 to 57 m**
- **Average 17 m**

- **(지표의 고도) - (top of KM2)**

**= (thickness of over burden)**

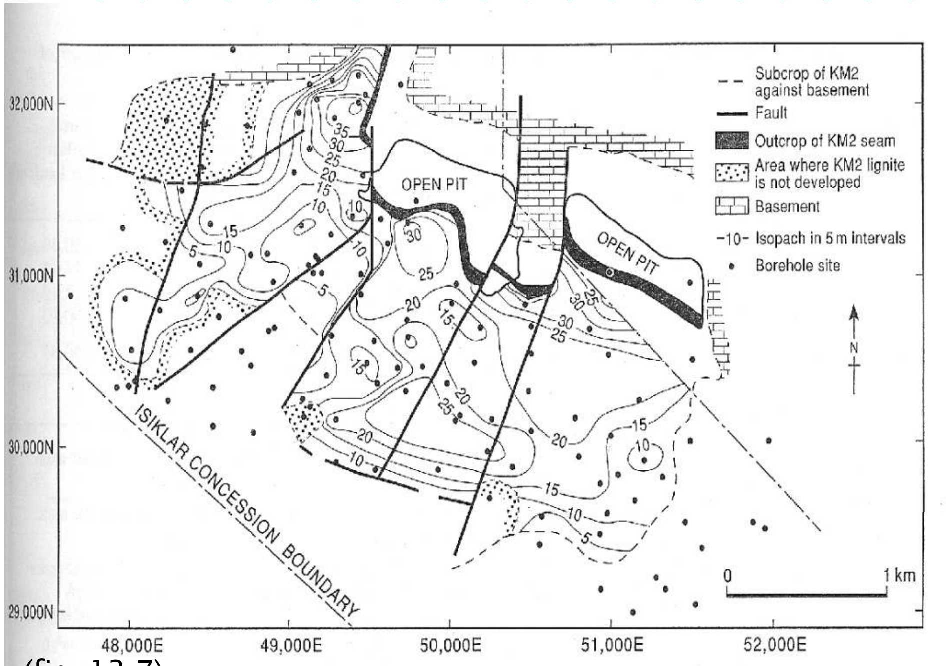
- **(top of KM2) - (top of base)**

**= (thickness of KM2)**

- **(top of base) – (bottom of base) = (thickness of base)**

**➔ Estimate overburden volume (table 13.2)**

# 13.4.2 Isopach maps

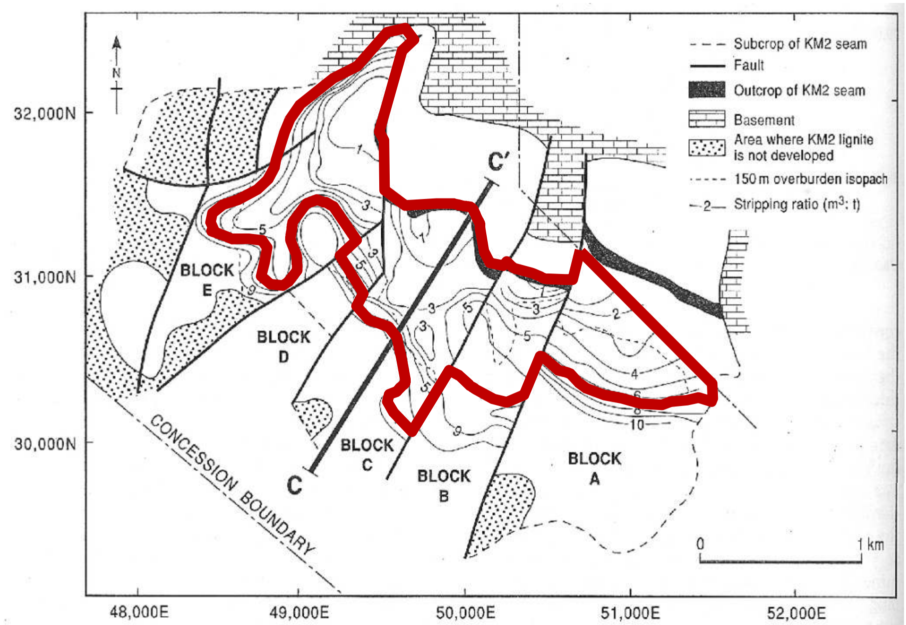



(fig. 13.7)

(table. 13.2)

| Block | Pit area | | | Slopes | | | Total volume (M bank m³) |
|---|---|---|---|---|---|---|---|
| | Area (km²) | Thickness (m) | Volume (M bank m³) | Area (km²) | Thickness (m) | Volume (M bank m³) | |
| A | 0.146 | 78.9 | 11.52 | 0.148 | 62.7 | 9.28 | 20.80 |
| B | 0.412 | 90.1 | 37.12 | 0.189 | 54.6 | 10.32 | 47.44 |
| D | 0.072 | 87.6 | 6.31 | 0.096 | 60.3 | 5.79 | 12.10 |
| E | 0.882 | 84.8 | 74.79 | 0.357 | 70.1 | 25.24 | 100.03 |
| Totals (mean) | 1.512 | (85.8) | 129.74 | 0.790 | (64.1) | 50.63 | 180.37 |

# 13.4.3 Stripping ratio map




(fig. 13.8)

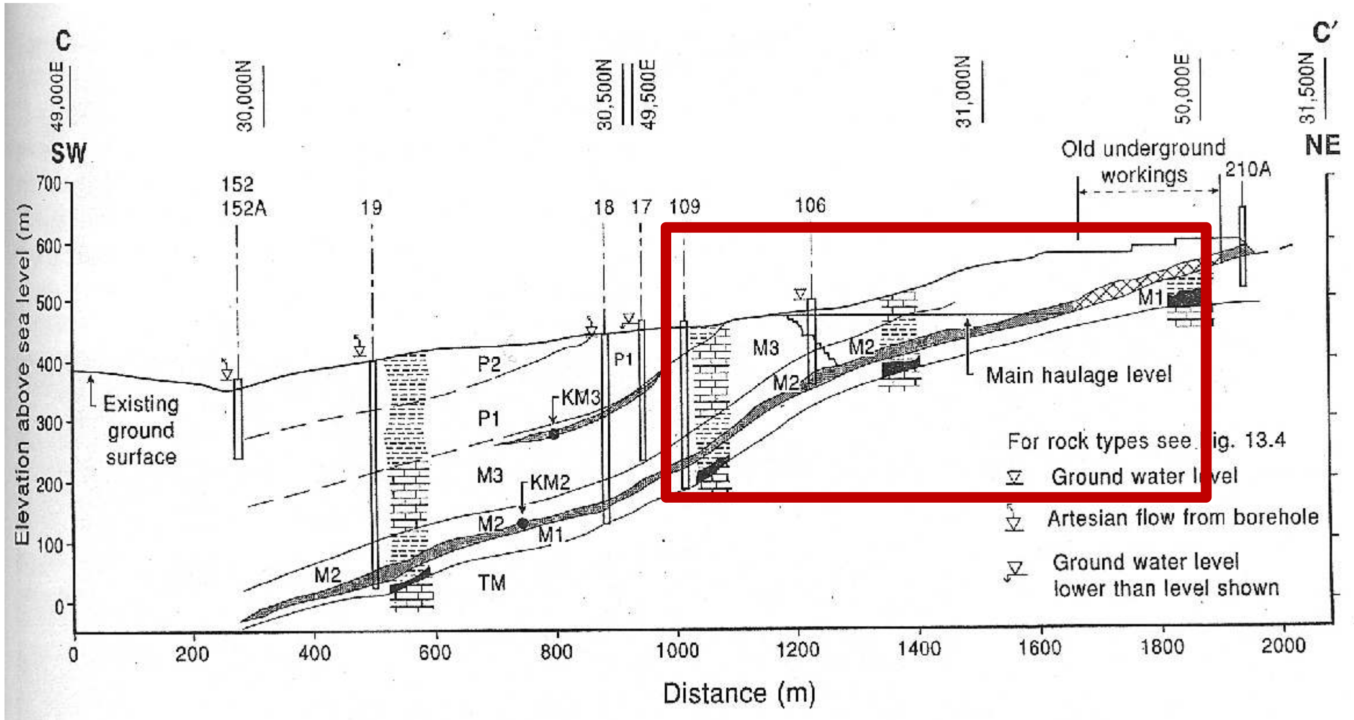
- **Stripping ratio (or overburden ratio)**

**= (overburden material in m^3) : (lignite [ton])**

**= (overburden material in m^3) : (lignite (A * thickness)* 1.73)**

**Generally [1 to 10] :1, <7:1 ➔ economically sound**

# 13.4.4 Cross-section




(fig. 13.9)

- **To verify the structural information and the seam correlation**

# 13.5 Geotechnical Investigation

# 13.5.1 Investigation program

- To avoid expensive duplicate drilling of boreholes

1. Geotechnical logging

   ➔ RQD, point load strength, UCS
2. Geotechnical testing
3. Structural mapping
4. Measurement of water levels
5. Sensitivity analyses

   (e.g. 지하수 조건, 암강도, 전단강도)

# 13.5.2 Geotechnical conditions

- **Overburden**
  - Limestone and marlstone : strong, USC=80 Mpa

    mudstone and siltstone : weak, USC < 30 Mpa
  - Bedded and jointed, parallel to lignite
  - Dips range between 15 and 45 degrees to the SW
- **Lignite**
  - Point load strength = 1 MPa

    But, cleated and friable ➔ < 1 MPa
- **Footwall (highly depends on groundwater conditions)**
  - Mudstone, siltstone, sandstone overlying limestone

    Shear strength = 0-30 kPa

    angle of shear resistance = 14-17 degree

# 13.5.3 Hydro-geological conditions

- By using piezometer
- Water level : close to the surface
- In lower borehole : occurs artesian flow (7 L/sec)
- Flow maintained for long periods

# 13.5.4 Implications for open pit mining

- **Overbuurden rocks are strong**

**➔ Drilling and blasting  prior to excavation**

- 최대사면경사 : 약 **55** 도, 전체경사 : 약 **45**도
  **Haul road** 폭 : 약 **20 m,**
  **advancing face**의 최대각 : **40** 도 **(fig.13.15)**

- **Dewatering would be required**

# 13.6 Lignite quality

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- **Multiple layer, interbedded sediments**

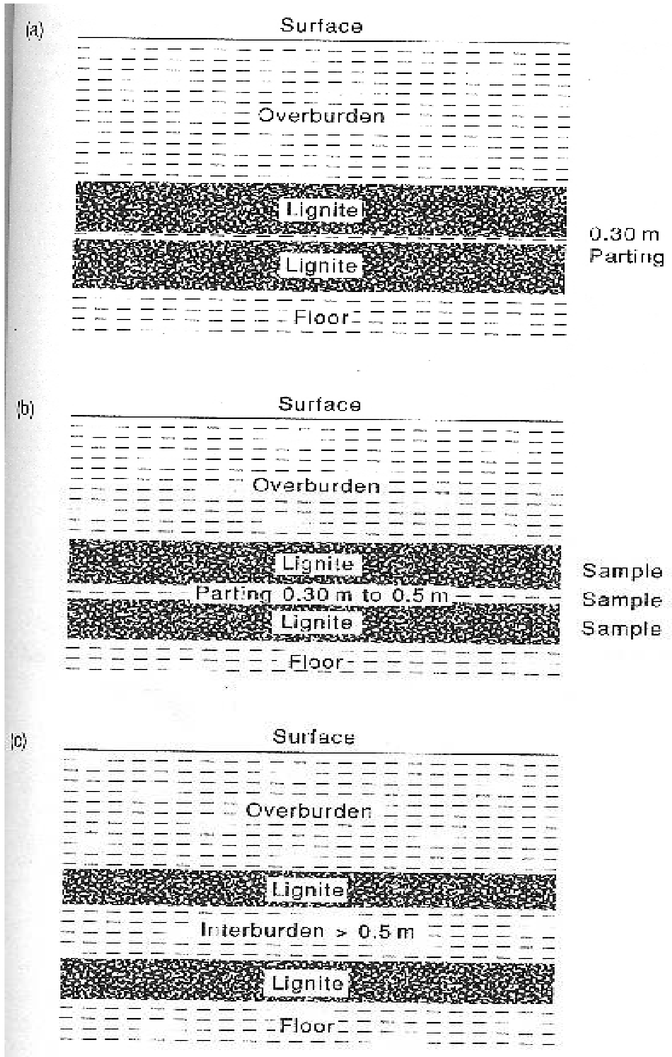
  **➔ difficulties when seam quality is considered**

- **Alternatives**
  - Nonselective mining : zone within lignite layer is mined in total without any attempt at selectively mining waste parting
  - Selective mining : to consider mining the lignite layers selectively, aiming to produce a run-of-mine product which is of acceptable quality.

**➔ Selective mining**

**∵ lignite quality is low, further quality losses caused by bulk mining would be unacceptable**

# 13.6 Lignite quality




(fig. 13.11)

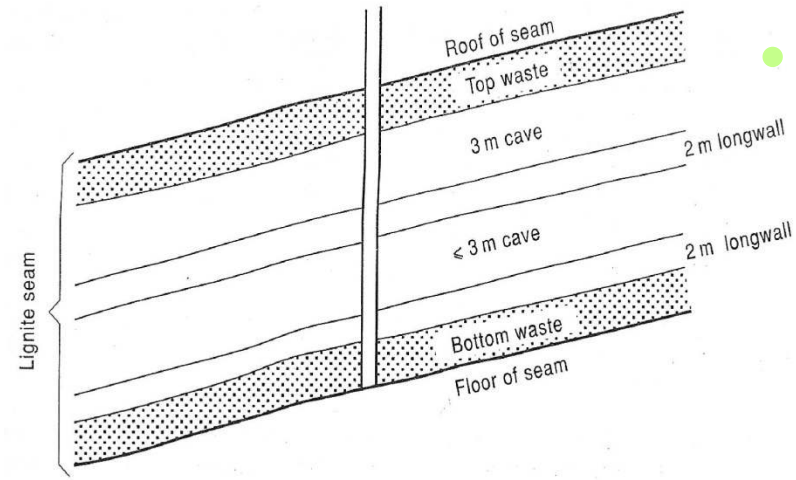
- **Selection criteria – surface mining option**

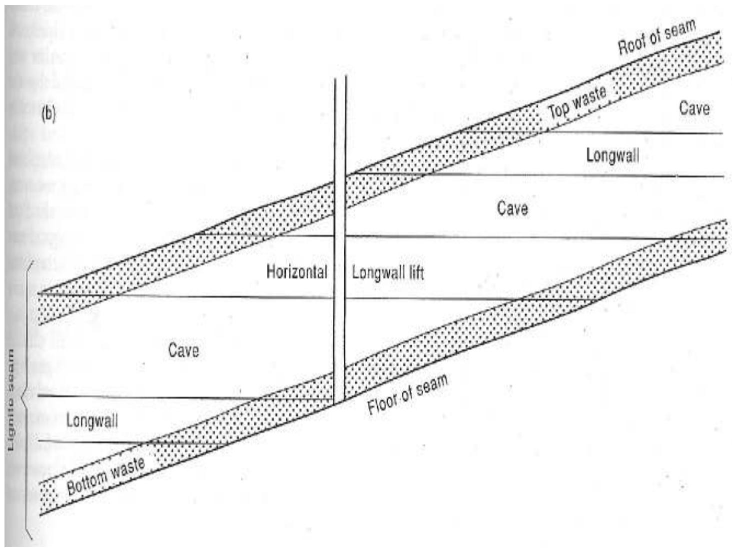
**Except :**

- **Waste parting > 50 cm**
- **Lignite pile < 30 cm with partings on either side**

**➔ (total lignite thickness)+ (partings above and below) > 50 cm**

# 13.6 Lignite quality




(fig. 13.12)

- **Selection criteria – underground mining option**
  - **In-seam mining**
    **Rejected : (parting)>1.5m**
    **thin lignite & thick waste**
  - **Cross-seam mining**
    **Less selective**

# 13.6 Lignite quality

(table. 13.4)

| | Borehole number 210 | 320 |
|---|---|---|
| Lignite, vertical thickness (m) | 18.40 | 11.80 |
| Waste rejected from seam | 0.00 | 3.00 |
| Mineable vertical thickness (m) | 18.40 | 8.80 |
| Number of waste partings | 0 | 3 |
| Number of interface | 2 | 8 |
| Dilution (m) | 0.2 | 0.8 |
| *In situ* CV (kcal $kg^{-1}$) | *3524* | *2071* |
| Undiluted CV (kcal $kg^{-1}$) | *3524* | *2679* |
| *Mineable CV (kcal $kg^{-1}$)* | *3485* | *2435* |
| *In situ* ash content (%) | 27.6 | 39.9 |
| Undiluted ash content (%) | 27.6 | 29.7 |
| Mineable ash content (%) | 28.1 | 33.8 |
| *In situ* SG | 1.55 | 1.90 |
| Undiluted SG | 1.55 | 1.70 |
| Mineable SG | 1.56 | 1.78 |
| Recovery by thickness (%) | 100 | 75 |

(table. 13.5)

| | Borehole number 218 | 302 |
|---|---|---|
| Lignite vertical thickness (m) | 14.70 | 12.10 |
| Lignite in waste partings (m) | 0.00 | 0.75 |
| Waste rejected from seam (m) | 0.00 | 2.35 |
| Mineable vertical thickness (m) | 14.70 | 9.00 |
| *In situ* CV (kcal $kg^{-1}$) | 3662 | 2400 |
| Mineable CV (kcal $kg^{-1}$) | 3595 | 2500 |
| *In situ* ash content (%) | 24.5 | 39.5 |
| Mineable ash content (%) | 25.2 | 37.6 |
| *In situ* SG | 1.49 | 1.73 |
| Mineable SG | 1.51 | 1.70 |
| Recovery by thickness (%) | 100 | 74 |

(table. 13.6)

| | SG | CV (kcal $kg^{-1}$) | Ash (%) | Moisture (%) |
|---|---|---|---|---|
| Open pit | | | | |
| *In situ* | 1.70 | 3069 | 32.7 | 13.5 |
| Mineable | 1.73 | 3103 | 33.0 | 13.5 |
| Block A | 1.73 | 4143 | 20.9 | 13.8 |
| Block C | 1.73 | 3104 | 32.5 | 14.4 |
| Block D | 1.73 | 2516 | 39.1 | 14.0 |
| Block E | 1.73 | 2816 | 36.6 | 12.9 |
| Underground | | | | |
| *In situ* | 1.66 | 3337 | 30.0 | 16.2 |
| Mineable | 1.66 | 3467 | 27.5 | 16.2 |

# 13.7 Lignite reserve estimates

# 13.7.1 Comparison of estimation methods

| Method | Tonnage |
|---|---|
| Polygons<br>Manual contouring (linear itp.)<br>Kriging (150*150 m block)<br>Statistical mean<br>(area * average thickness) | 117.8 Mt<br>102.5 Mt<br>109.4 Mt<br>117.5 Mt |

- **Polygon : quick, but overestimated ➔ increase sample density**
- **Manual contouring**
- **Kriging : the best estimation w/ the lowest estimation variance ➔ knows how reliable each block estimate is.**

# 13.7.2 Confidence in the reserve

- **The confidence in the mineable reserve estimate for the open pit area :**

**tS/n**

**S : standard deviation, n : number of borehole**

**t : t-value for n-1 DoF at the 90% confidence lv.**

- **Global confidence in the average expressed as a percentage :**

**G = A^2 + B^2**

**A : % of the mean for thickness**

**B : % of the mean for SG**

**A=15.9%, B=5.9% ➔ G=17.0%**

# 13.8 Surface mine evaluation

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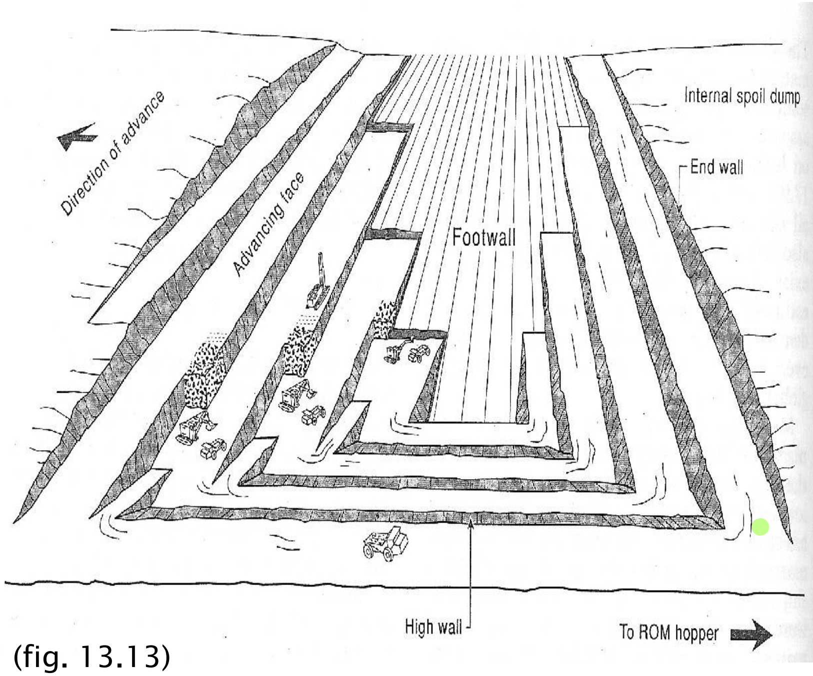
- This evaluation project called for a production rate of 2.13 Mt ROM(run-of-mine) lignite each year

- After rejection of some waste dilution
  → 2 Mt per year

- Exploit the mineable reserves over a mine life of 21 years.

- Block B is not advisable
  ∵ Lignite has been partly extracted

# 13.8.1 Selection of mining method



(fig. 13.13)

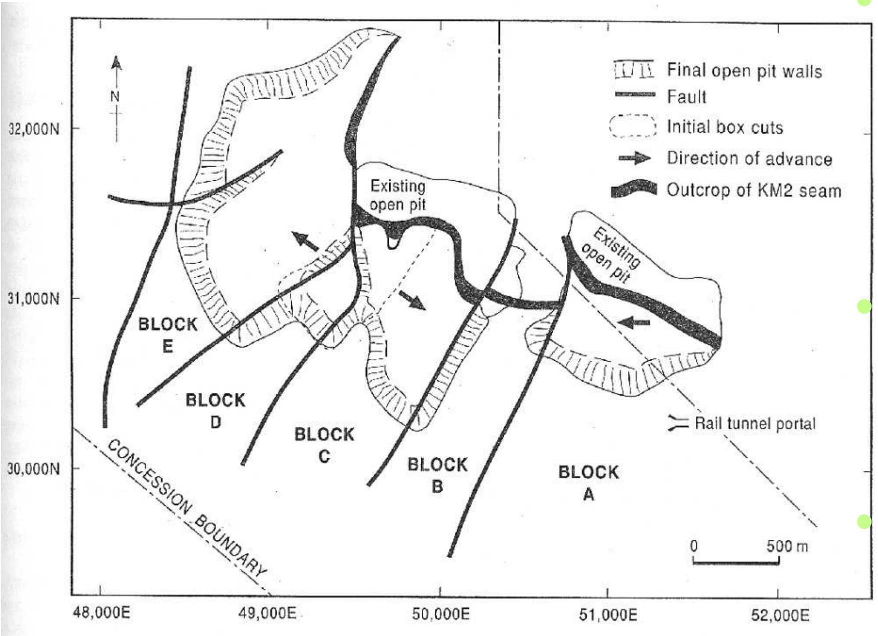
- **Three alternative**
  1. **Advance down the dip**
  2. **Advance up the dip**
  3. **Advance along the strike (terrace mining)**

  ➔ **3rd is the suitable**

- **Until**
  - **Economic stripping limit**
  - **(Practical) mining depth limit**

- **Advantages of 3rd method**
  1. **Minimum area of footwall clay will be uncovered ay any time**
     ➔ **reducing the risk of footwall failure**
  2. Internal dumping of waste reduces transport costs, helps stabilize the footwall, and begins reclamation at an early stage of mining
  3. **The stripping ratio is constant over the life of the mine ➔ mining costs stabilized**

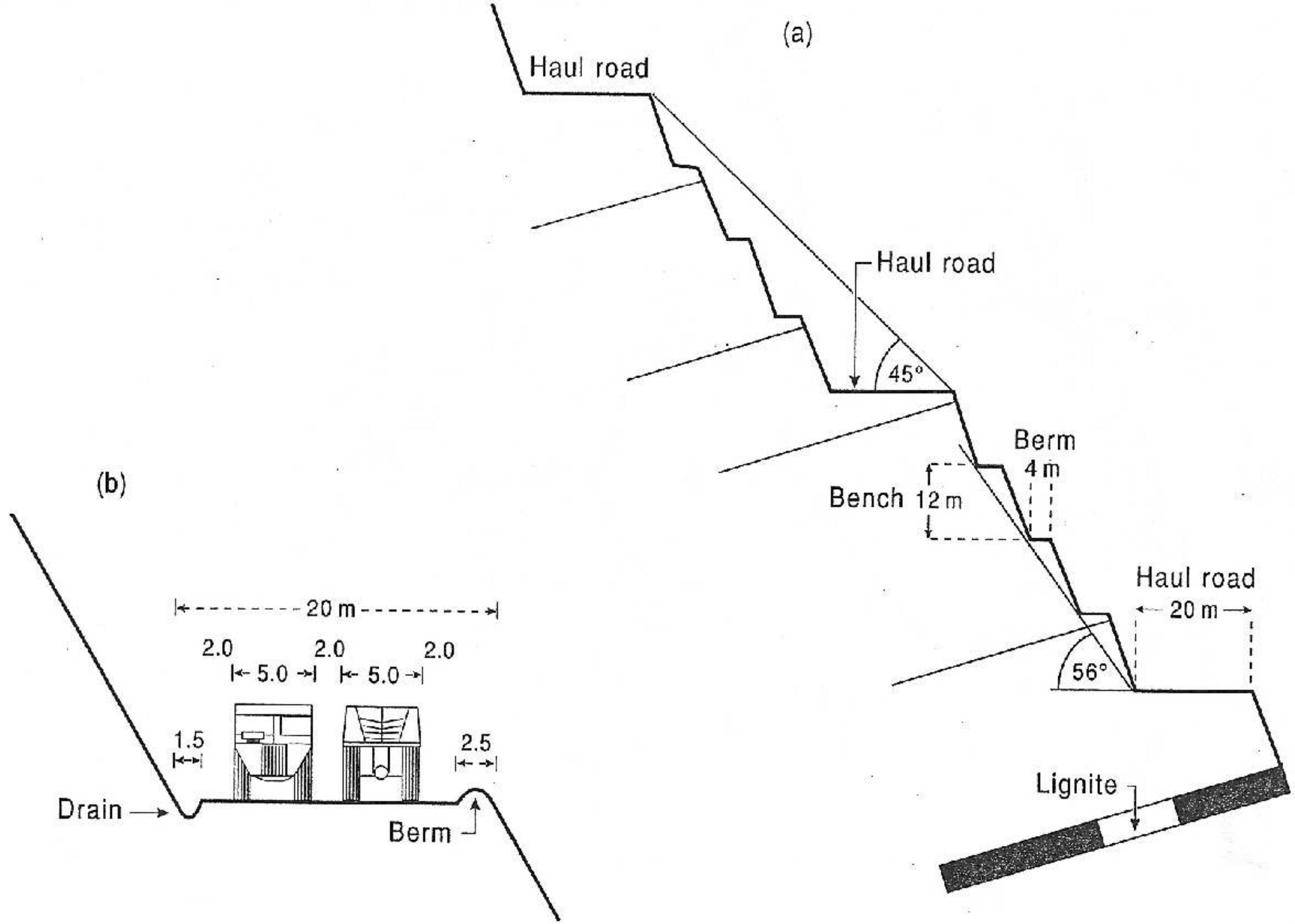
# 13.8.2 Mine design




(fig. 13.14)

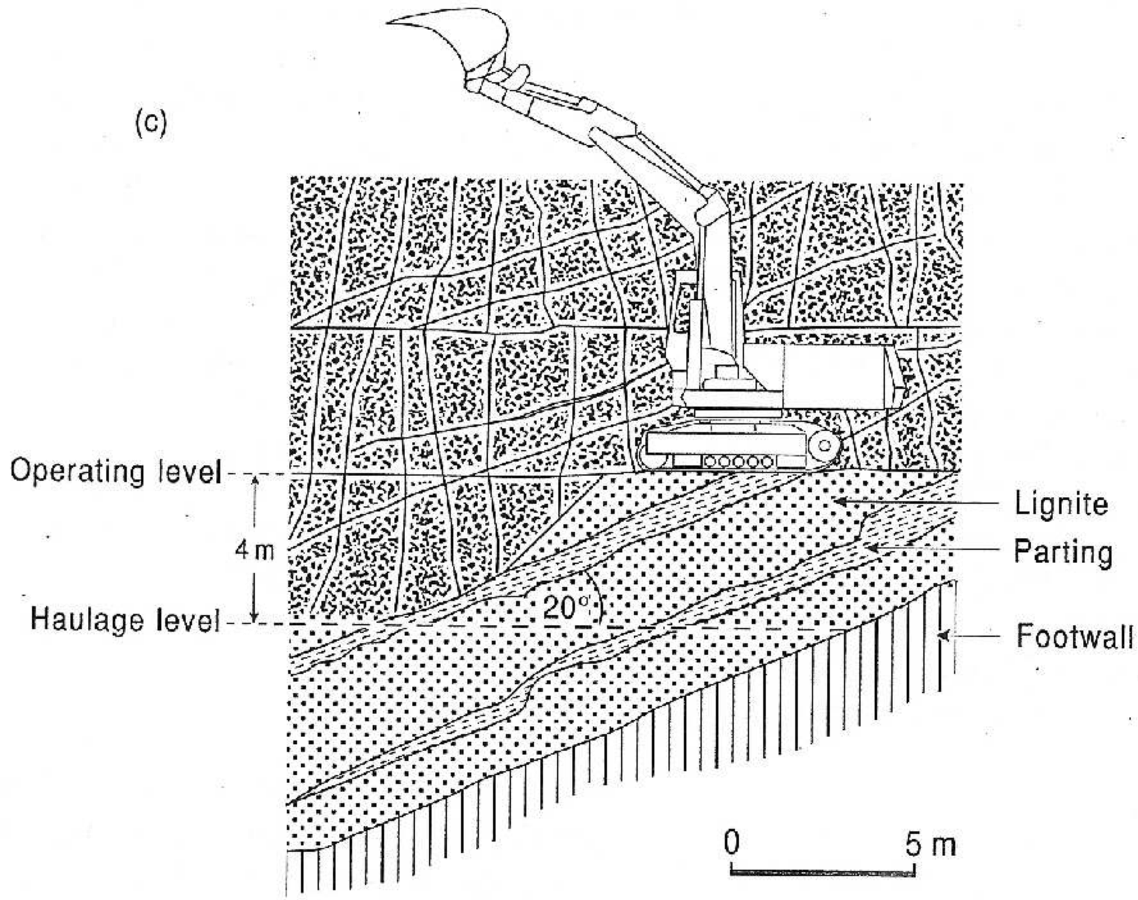
- **Box-cut locations**
  - **First : block C & D**
  - **Close to center of the reserve**
  - **Second : block A**
- **Slopes and access**
  - **Bench height = 12 m**
    **(fig. 13.15)**
- **Haul roads**
  - **Width = 20 m**
- **Spoil disposal**

# 13.8.2 Mine design




(fig. 13.15)

# 13.8.2 Mine design




(fig. 13.15)

# 13.8.3 Mining equipment

- Ratary blasthole rigs  (250-mm-diameter holes)
- Electrically powered rope shovels
  : overburden stripping
- Hydraulic face shovel : lignite loading
- Rear dump trucks : transport
- Bulldozer

# 13.9 Summary

# 13.9 Summary

- Available data on the reserve tonnage and quality of the Soma deposit were adequate for a feasibility evaluation.

→ would support a projected life of 21 years

- Additional data were required on the groundwater regime before forecasts

→ Effects of groundwater pressure and flows on mining

THANK YOU