CSPG SEMINAR 1983

COAL PROJECT EVALUATION

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A contribution towards a realistic balance between exploration geology, engineering and economics.

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I - INTRODUCTION

A successful coal project begins with identification of a prospect and culminates in a viable, efficient, safe mining operation. The arduous path that this process takes is unique for each project but experience shows that it can be made less traumatic.

Not all prospects become mines but those that do require specialized professional input (Figure 1-1). The professional team identified in Figure 1-1 requires a variety of information which includes:

- basic data
    - field observations/testing
    - laboratory tests
- design
    - mine
    - support services
- environmental protection
- economic analyses

The evaluation process has no room for extreme optimists or pessimists as a realistic approach is needed. Table 1-1 gives a partial flow chart of basic information input, its uses and bench mark decisions. The sequencing of information flow is such that geologists generate and interpret the early data assembled, but the geologist's enthusiasm for data gathering should be guided in part by the needs of others, such as the mine and coal preparation plant designers. Similarly engineering design in the later stages of a project should be vetted by other disciplines such as economists and accountants as to overall viability.

The risks in coal mine development are high. A producing mine will employ hundreds of people, with capital investment in the order of $100 to $200 per annual tonne of saleable coal. The elapsed time from commencement of prospect evaluation stage to full production will seldom be less than 5 years and can be longer than 10 years. It is, therefore, essential that the data collection and interpretation be thoroughly planned, documented and reported in the 'language' of the professional team members who will use their information.

PROSPECT TO PRODUCTION

WHAT INFORMATION DO WE NEED AND USE?

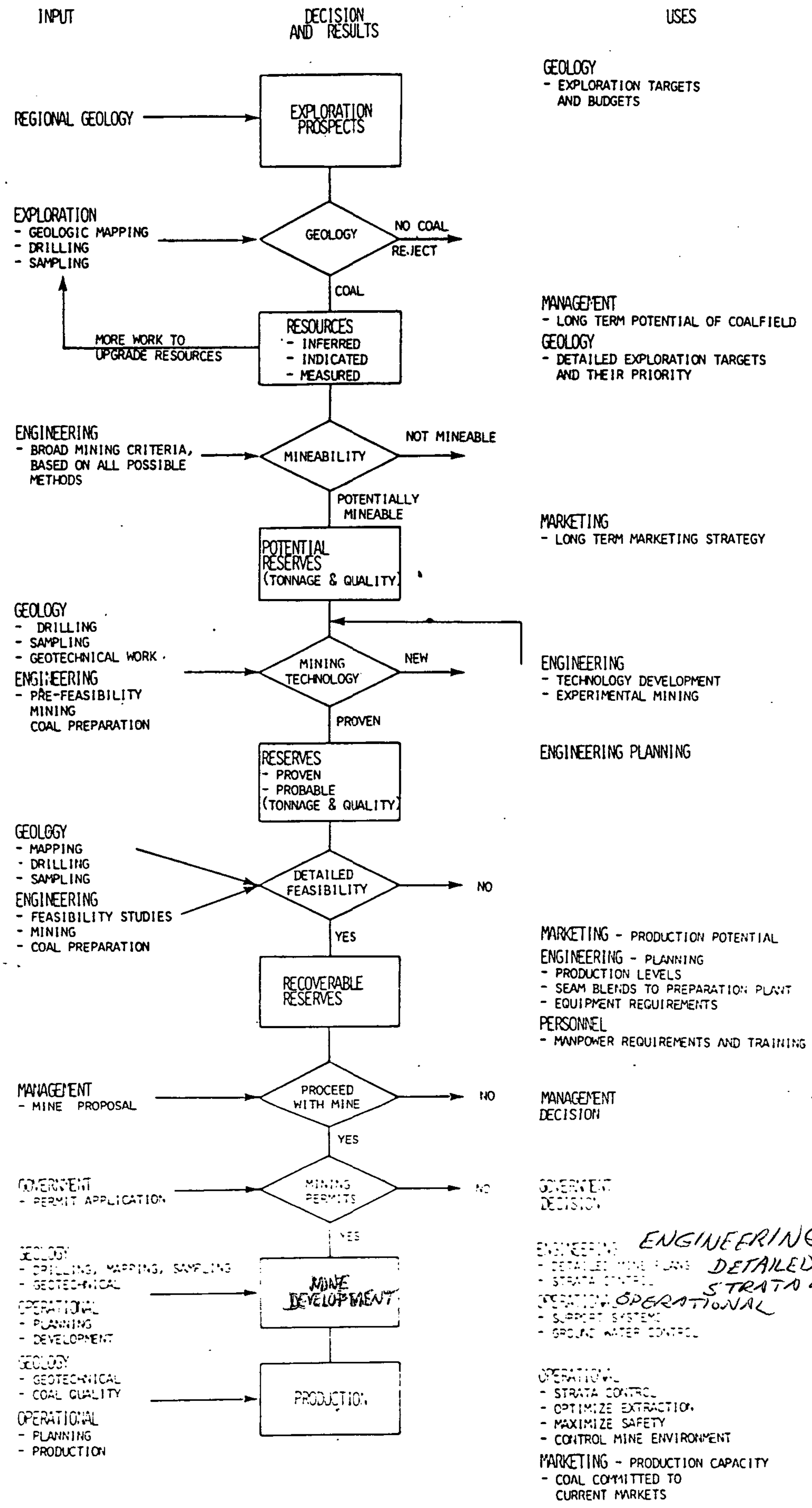


TABLE 1-1
PROSPECT TO PRODUCTION

AMCL

- Geologists
    - structure
    - stratigraphy
    - sedimentology
    - coal petrology
- Mining Engineers
- Geotechnical Engineers
- Mechanical Engineers
- Electrical Engineers
- Civil Engineers
    - roads
    - plants
    - buildings
- Coal Preparation Engineers
- Transportation Experts
- Economists
    - marketing
    - risk analysis
- Accountants
    - cash flow
    - taxes
    - royalties
- Managers
- Bankers
- Biologists
    - wildlife
    - fisheries
    - forestry
- Architects
- Archaeologists

FIGURE 1-1: Coal Project Evaluation - Specialized Professional Input

2 - GEOLOGIC DATA BASE

The primary responsibility of the geologist who is usually in charge of the initial phases of a coal project is to establish the presence of coal on the property. An understanding of the depositional environments of coal formation can be extremely valuable in planning an exploration program.

2.1 COAL DEPOSITION

Coal is derived from plant material such as algae, wood, bark, resin, pollen, etc. which accumulates under water in a stagnant, low energy environment. The plant material may grow in situ (eg: swamps) or may be transported to the site of deposition.

A critical balance between basin subsidence and accumulation of organic debris must be maintained over long periods of time to produce deposits of appreciable thickness. This process may be interupted or stopped by a change to a higher energy environment depositing mud or sand over the organic material.

The process of coalification (Figure 2-1) begins with dewatering of the plant material to form peat with a volume reduction of about 10:1. Under ever increasing pressure and temperature the peat is altered to form coal with a further volume reduction of about 10:1. This process involves a chemical change from cellulose to carbon. Initially carbon dioxide, hydrogen and water and some methane are released to form lignite and sub-bituminous coals. Eventually mostly methane is released to form bituminous and anthracitic coals (Figure 2-2 Rank Classification).

Conclusions

The degree of metamorphism (rank) has a direct impact on the end use of the coal (Figure 2-3) and free methane in the coal increases significantly with increasing rank.

2.2 DEPOSITION OF COAL BEARING STRATA

Most large coal deposits form in a deltaic environment which, by its very nature, implies a highly variable local stratigraphy. Figure 2-4 illustrates such a depositional model in which the drastic lithologic facies changes are most evident. Coal seam geometry is influenced by differential compaction in the underlying strata (Figure 2-4 Note 4d) and by erosion due to channel formation (Figure 2-4 Note 4b). The overlying strata is also affected by differential compaction indicated by a slump along the channel/sub-channel boundaries (Figure 2-4 Note 6a).

From a mining view point the effects of this depositional sequence are demonstrated in Figure 2-5.

Conclusion

The rock strata above and below a coal seam has a direct and significant bearing on the mining method and costs. It is essential to collect data relevant to mine design during the exploration phase.

2.3 STRUCTURAL GEOLOGY

Structure may be limited to a cleat or joint fabric in the rock mass or affect seam geometry directly by folding and faulting. It is, therefore, essential to resolve the seam geometry in the exploration phase to make accurate coal quantity determination and assess the effect of the same structures on the eventual mining operations (Figure 2-6).

Major structures, both folds and faults, usually define mine boundaries. While massive thickening of coal in the hinge areas of folds has attracted many open pit operators into production decisions, the same thickened coal seam encountered below stripping depth in an underground mine is almost impossible to mine efficiently.

There are always smaller scale structures that do not materially affect the coal seam geometry and are, therefore, not noticed or described during the exploration phase, such as:

- faults with stratigraphic throws of less than seam thickness
- minor rolls and folds
- degree of fracturing, eg: joints, cleats, etc.

In both surface and underground mines these small-scale structures can have serious impact (Figures 2-7 and 2-8) on:

- highwall stability
- roof control
- caving characteristics
- fluid reservoirs and feeders

Conclusion

Any evidence of the smaller scale structures that may affect mining needs to be documented and brought to the attention of the mine designers. This could include water and gas make in boreholes, stratigraphic repetitions or missing sections, core fracturing, etc.

2.4 COAL QUALITY

Coal is a complex material with a variety of uses (Figure 2-3). The three current principal end uses are:

- thermal coal for power generation
- coke for the steel industry
- chemical feedstock for pharmaceutical, liquefaction and gasification, etc.

Coal testing is an integral part of coal evaluation for determination of:

- rank
- potential mining section
- coal washability

The handling, sampling and splitting of coal core is probably the most important aspect of early data gathering and it is essential to divide a coal section into sufficiently small sample intervals (200 mm) to allow quality variations to be established.

Determination of the 'mining interval' requires that coal samples be kept quite separate from shale splits, and that roof and floor material be analyzed (Figure 2-9).

Coal washability data should be acquired for 'mineable seam sections' and where possible the effect of roof or floor dilution should be determined (Section 5).

Specific gravity (unit density) or bulk density determinations are required to assist in converting coal volume to tonnage.

2.5 RESOURCES AND RESERVES

The coal industry needs a set of 'labels' for two distinct concepts that the 'hard rock' community distinguish as:

- "**mineral deposit** - a mass of naturally occurring mineral material, usually of economic interest . . .
- "**ore** - the naturally occurring material from which a mineral . . . of economic value can be extracted at a reasonable profit."

(Glossary of Geology, Bates & Jackson, 1980)

Concerning coal, while no commonly accepted definitions exist, the terms **resources** and **reserves** label these concepts.

a. Coal Resources

Coal in the ground of determined quality is a resource. The assurance of existence of this resource should be defined and ultimately levels of confidence could be assigned to all resource figures. The density of data points required to achieve the same level of confidence could be quite different for individual coal seams. However, until an acceptable system is evolved, the Federal Department of Energy, Mines and Resources definition of measured, indicated and inferred resources is probably as good a system as any, as long as coal quality is included (Figure 2-10).

b. Coal Reserves

Reserves represent coal which can be produced at a profit and thus a real asset for planning purposes. Since a sequential process is required to determine costs and potential profits, various levels of reserves could be defined (Table 1-1).

- potential reserves which are technically mineable
- recoverable reserves, the run-of-mine product
- saleable reserves or prepared coal

Recoverable and saleable coal must be defined in terms of quality and price.

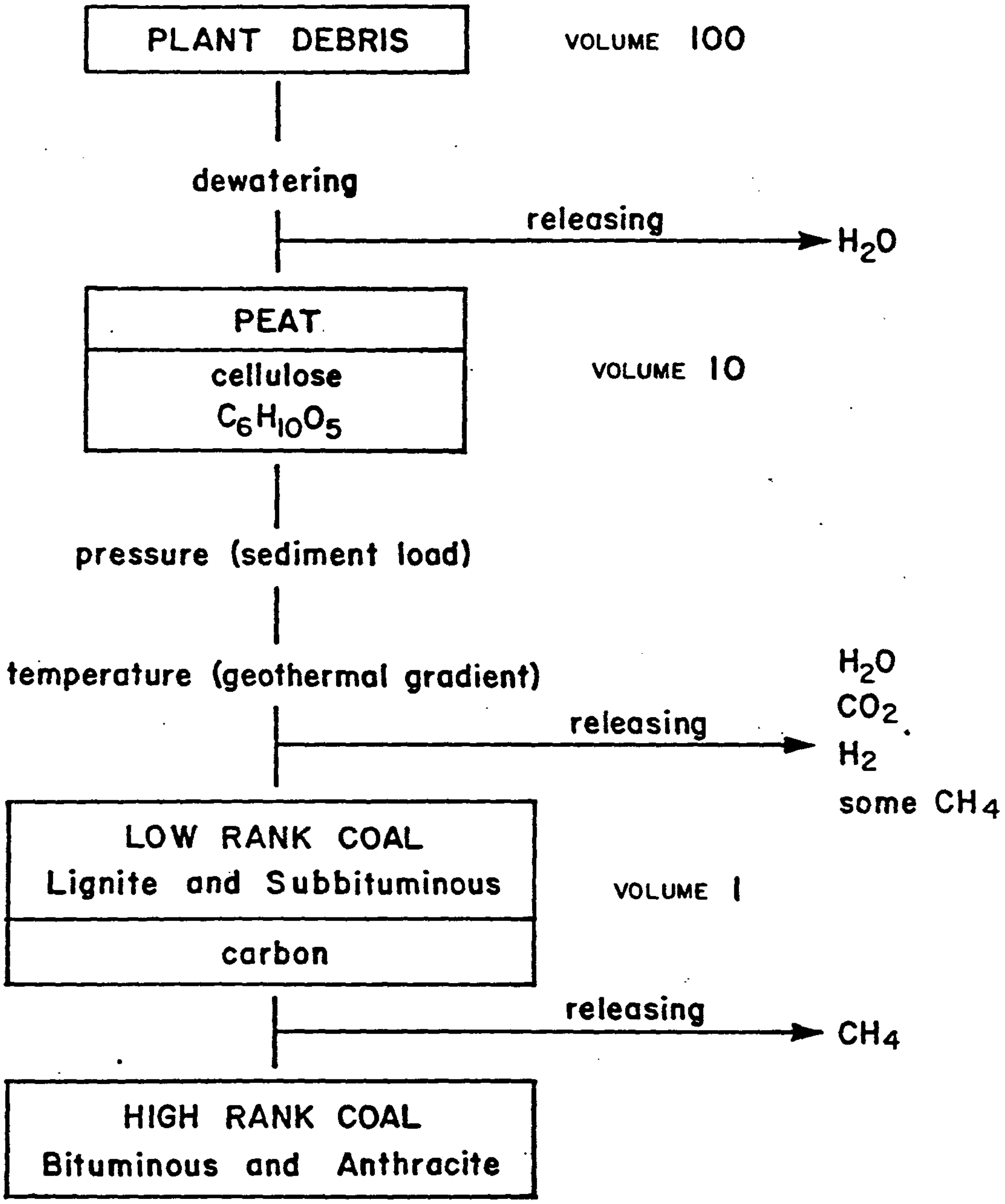


FIGURE 2-1: The Process of Coalification

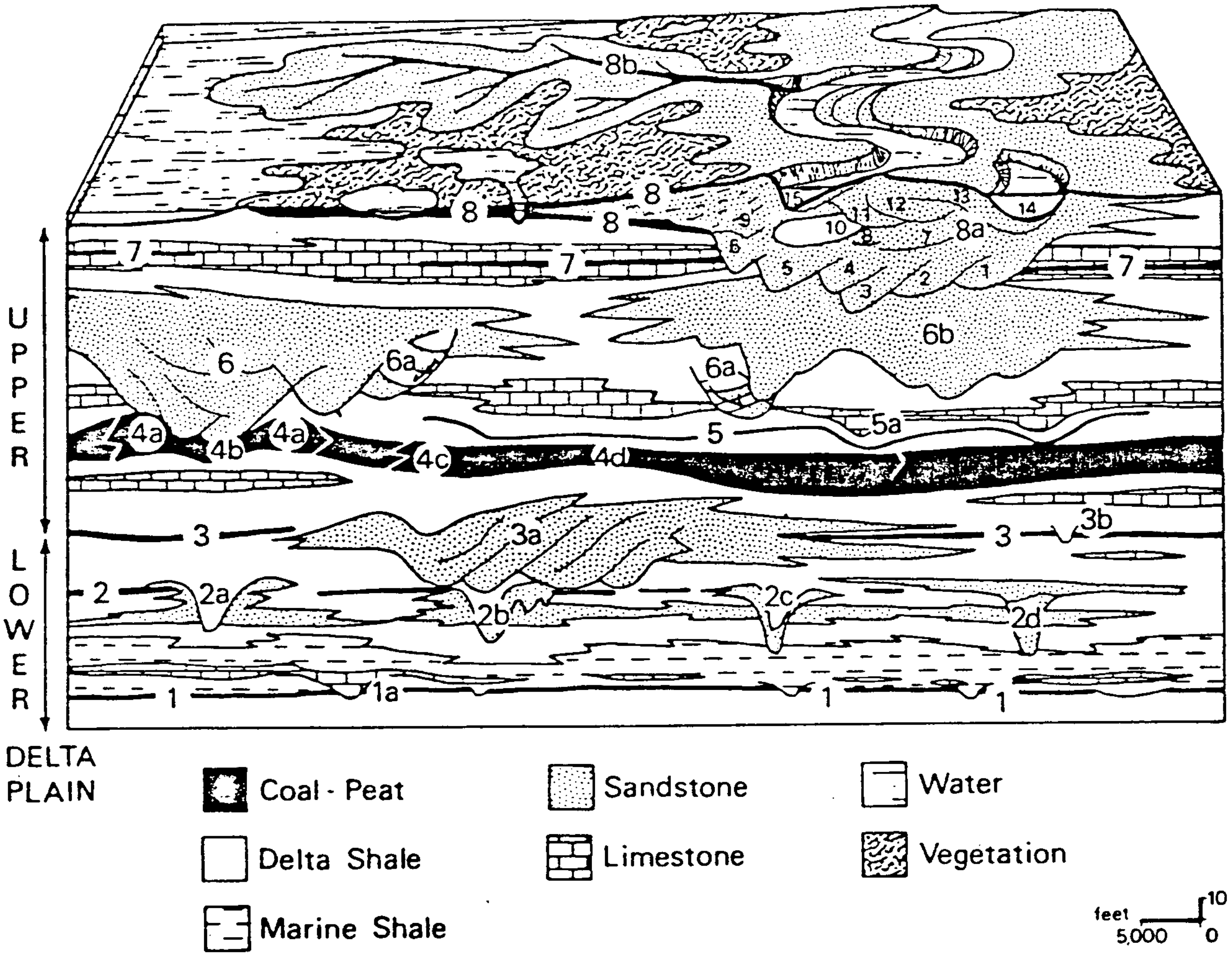
VM%*	FC%*	CLASS	GROUP	CALORIFIC VALUE ** Btu per lb	CALORIFIC VALUE ** MJ/kg
		ANTHRACITIC (1)	META — ANTHRACITE		
2	98				
			ANTHRACITE		
8	92				
			SEMIANTHRACITE		
14	86				
		BITUMINOUS (2)	LOW VOLATILE BITUMINOUS		
22	78				
			MEDIUM VOLATILE BITUMINOUS		
31	69				
			HIGH VOLATILE A BITUMINOUS		
				14 000	32.6
			HIGH VOLATILE B BITUMINOUS		
				13 000	30.2
			HIGH VOLATILE C BITUMINOUS		
				11 500	26.7
		SUBBITUMINOUS (4)	SUBBITUMINOUS A (3)		
				10 500	24.4
			SUBBITUMINOUS B		
				9 500	22.1
			SUBBITUMINOUS C		
				8 300	19.3
		LIGNITIC (4)	LIGNITE A		
				6 300	14.7
			LIGNITE B		

* Dry, mineral-matter-free basis.
** Moist, mineral-matter-free basis.
(1) Non-agglomerating; if agglomerating classified as low volatile bituminous.
(2) Commonly agglomerating.
(3) If agglomerating classified as high volatile C bituminous.
(4) Non-agglomerating.
VM : Volatile matter
FC : Fixed carbon

FIGURE 2-2: Classification of Coal by Rank

Coal of this rank		Generally has these qualities	and has these potential uses or these characteristics	Depending on qualities such as:
Class	Group			
Anthracitic	All groups	Relatively high calorific value	As a thermal coal	Quantity of ash, sulphur and other deleterious constituent and the extent to which they can be removed or suitably reduced by beneficiation processes; ash fusibility
		Non-agglomerating	Does not coke	
		Low moisture content	Stores and transports well	
		High fixed carbon content	Source of carbon	
Bituminous	All groups	Variably agglomerating	As a blend or directly for making metallurgical coke	Sulphur content and extent to which it can be removed or reduced by beneficiation processes; coal type
		Relatively high calorific value	As a thermal coal	Comments at top of column apply here as well
		Low moisture content	Stores and transports well	
	Hv A, B and C	Fairly high volatile matter content	For gasification or liquefaction	
Sub-bituminous	All groups	Non-agglomerating	Does not coke	
		Moderately high calorific value	As a mine-site thermal coal	Comments at top of column apply here as well
		High moisture content	Does not store or transport well; subject to spontaneous combustion	
		High volatile matter content	For gasification or liquefaction	
Lignitic	All groups	Non-agglomerating	Does not coke	
		Relatively low calorific value	As a mine-site thermal coal	Comments at top of column apply here as well
		High moisture content	Does not store or transport well; subject to spontaneous combustion; may necessitate drying before use	

FIGURE 2-3: Inter-relations of Rank, Quality and Use



Notes:

1. Tidal delta plain coal seam
1a. Shale-limestone filled tidal channels
2. Lower delta plain coal seam
2a. Coal to shale-filled abandoned distributary channel
2b. Sandstone-filled active distributary channel with alternate bars
2c. Sandstone- and shale-filled distributary channel (active then abandoned)
2d. Sandstone-filled distributary channel reworked as overlying transgressive sandstone
3. Upper lower delta plain coal seam
3a. Sandstone-filled meandering channel with point bars
3b. Drainage channel with shale fill
4. Upper delta plain coal seam
4a. Thick coal due to differential compaction by overlying channel sandstone
4b. Thin coal resulting from erosion and/or lateral squeezing by overlying channel sandstone
4c. Clay vein (dike) of prelithification origin
4d. Thin coal resulting from position over underlying channel sandstone (differential compaction)
5. Rider coal
5a. Drainage channel
6. Channel sandstone, meandering channel with point bars
6a. Channel bank to subchannel slump structures
6b. Channel sandstone position following avulsion ("jumps") from position at 6
7. Transgressive coal with facies into limestone
8. Peat coal of swamp in upper delta plain to alluvial plain. Discontinuities include lateral facies change to lake clays and flint clays, clay-filled washout by drainage channel, and coal split by sandstone (8b, 9) of crevasse splay
8a. Meandering channel with point bars numbered one (oldest) to 15 (youngest), with fossil oxbow clay plug deposits (10, 14)
8b. Crevasse splay

FIGURE 2-4: A Depositional Model
Fluvial Dominant Deltaic Environment (after Donaldson, 1978)

Surface Mining

- blast hole drilling costs can be high in sandstone
- uniform fragmentation in blasting will only be achieved by judicious changes in hole spacing or powder factor
- abrasive material will increase equipment maintenance costs
- water may be a problem
- weathering characteristics influence the angle of repose in waste dumps

Underground

- varying seam thickness difficult to accommodate with some equipment
- roof support very difficult near facies changes - safety hazard
- sandstone may be a methane reservoir
- incendiary sparking of cutter-picks against sandstone may explosively ignite a methane/air mixture.
- floor material may not bear traffic or may heave and cause problems
- water

FIGURE 2-5: Rock Mass Effects on Mining

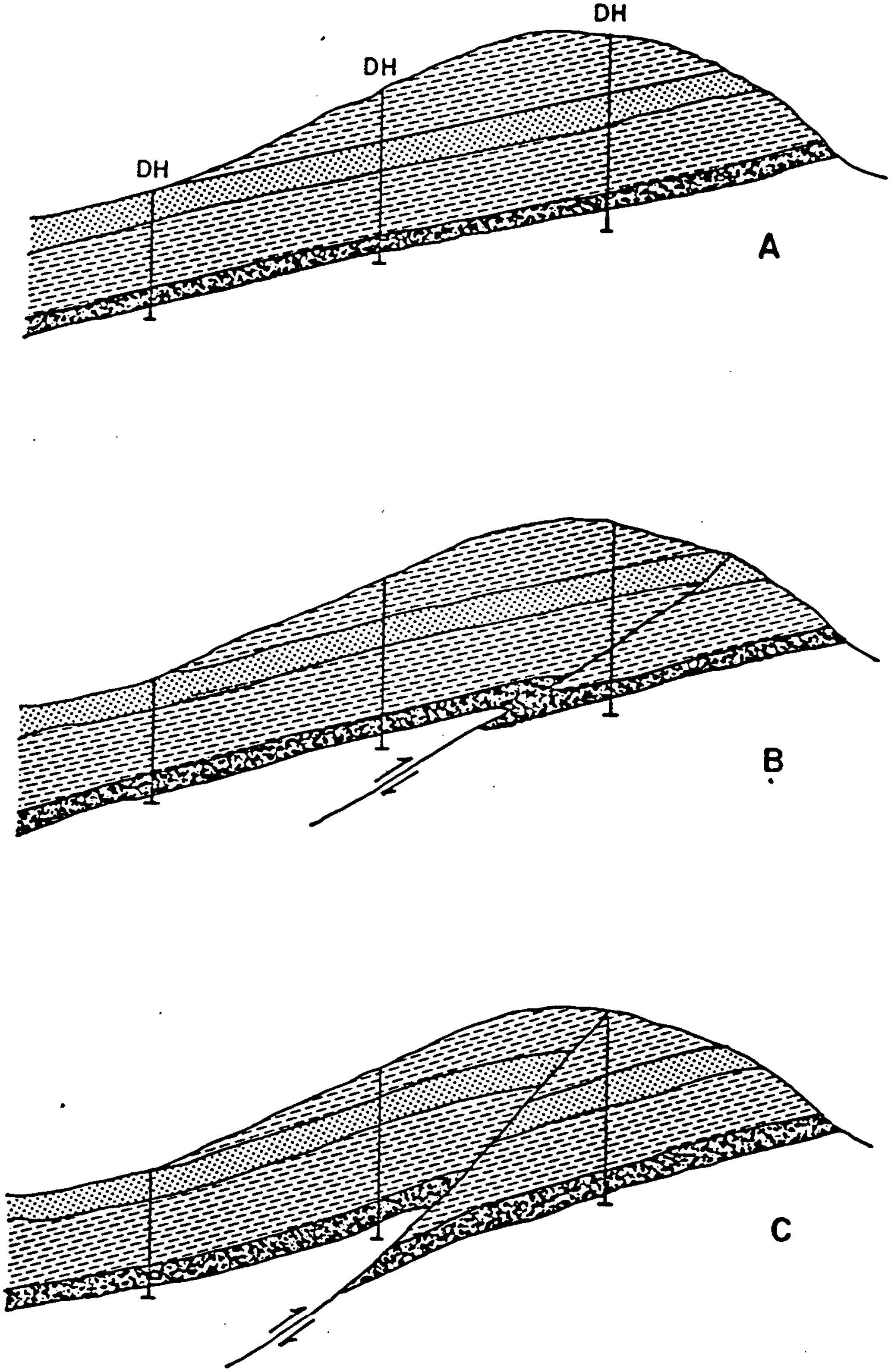


FIGURE 2-6: Alternative Structural Interpretations

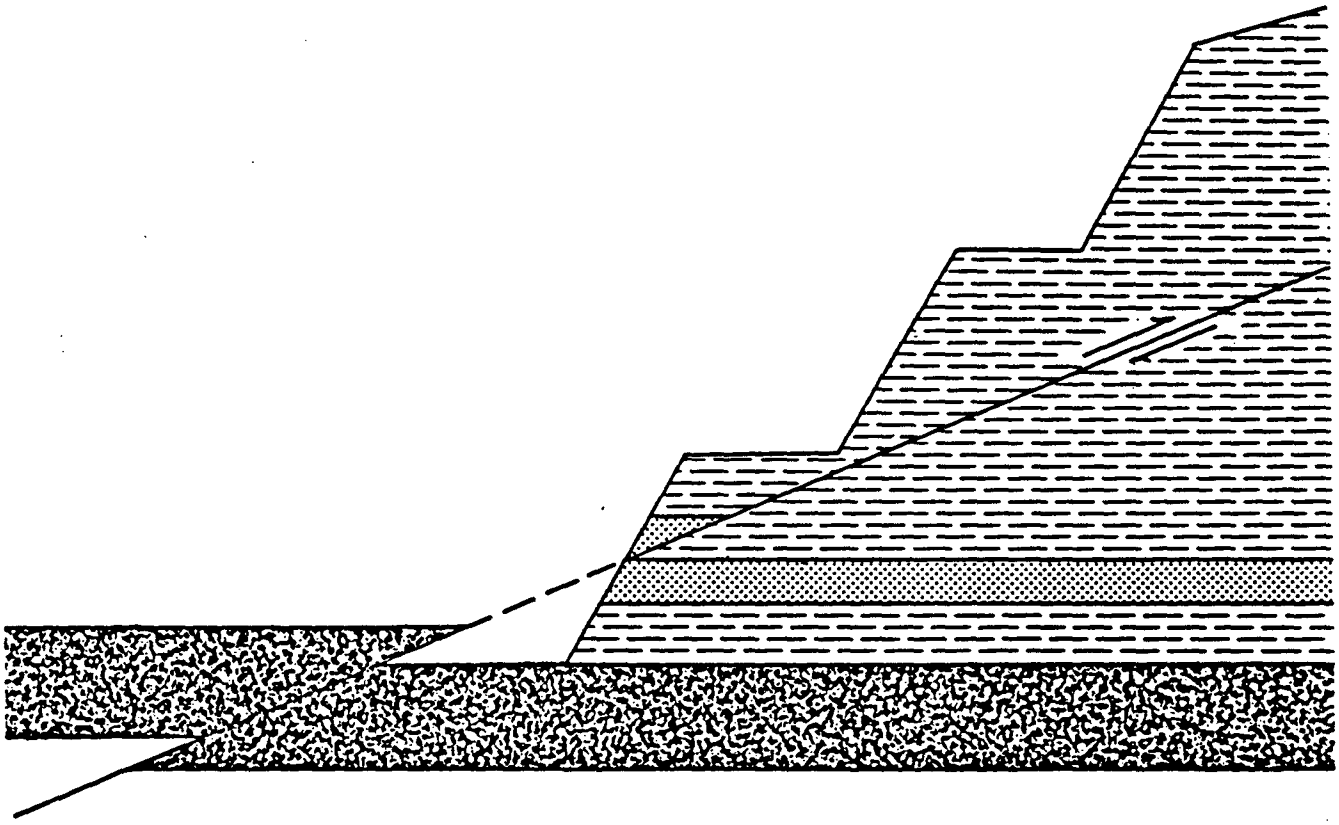


FIGURE 2-7: Thrust Fault as a Potential Slip Plane in a Highwall

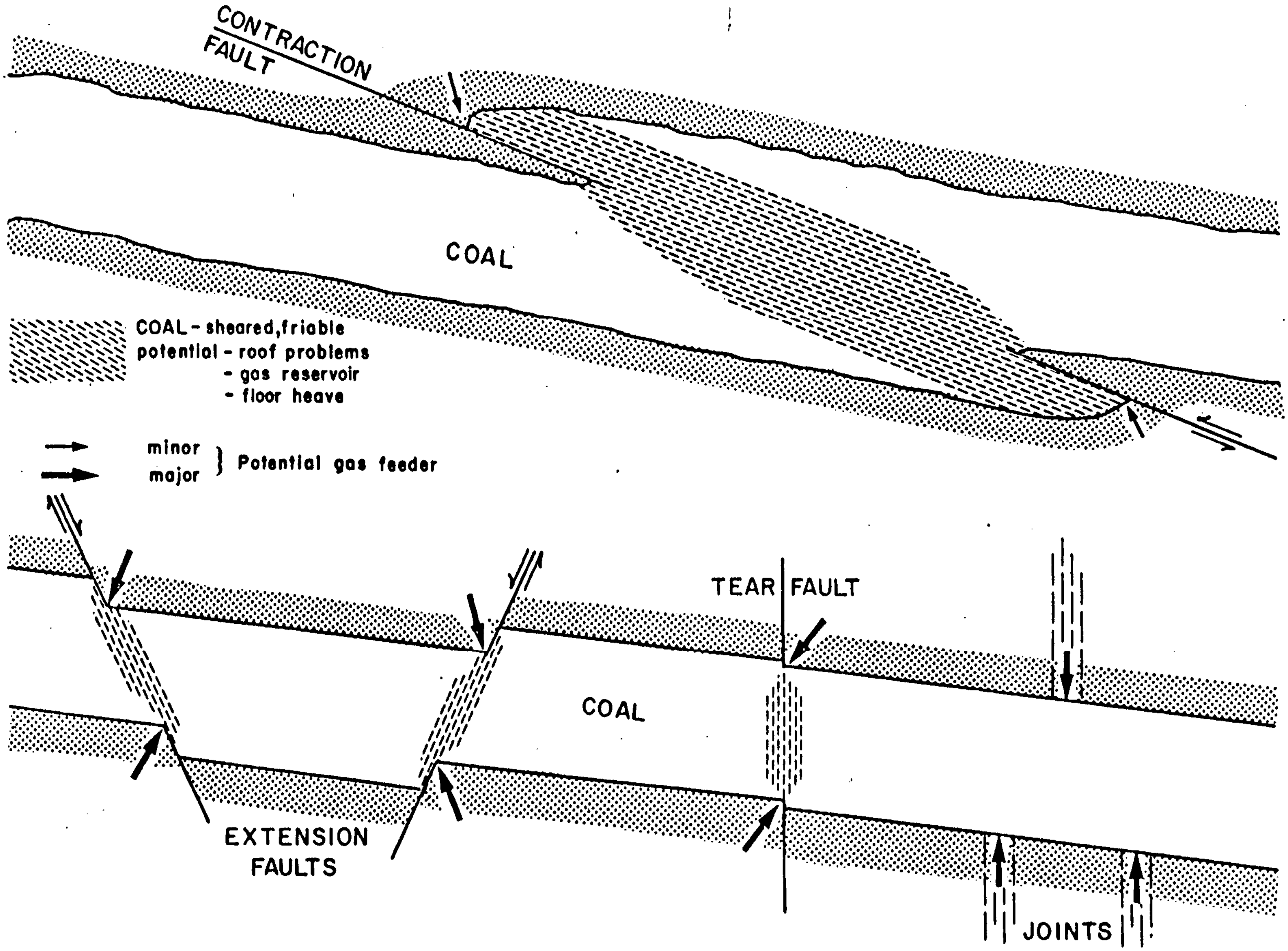


FIGURE 2-8: Schematic Sections Illustrating Structural Features in Relation to Underground Mining

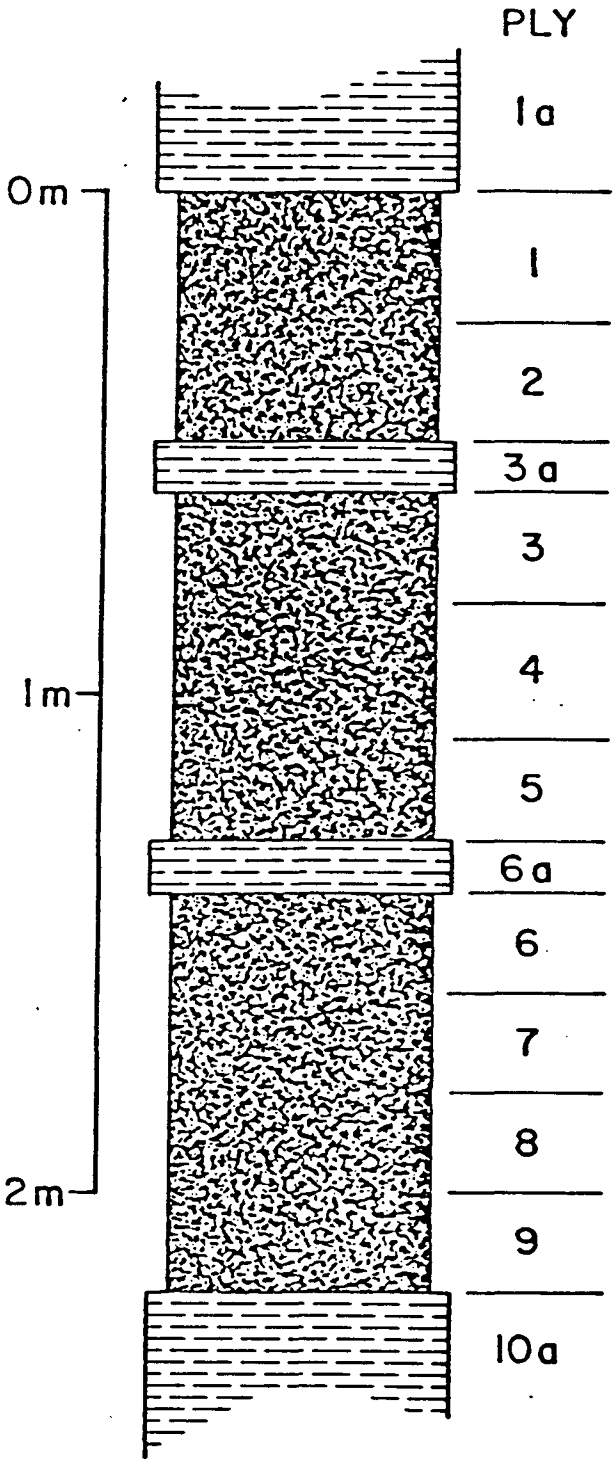


FIGURE 2-9: Coal Seam Sampling

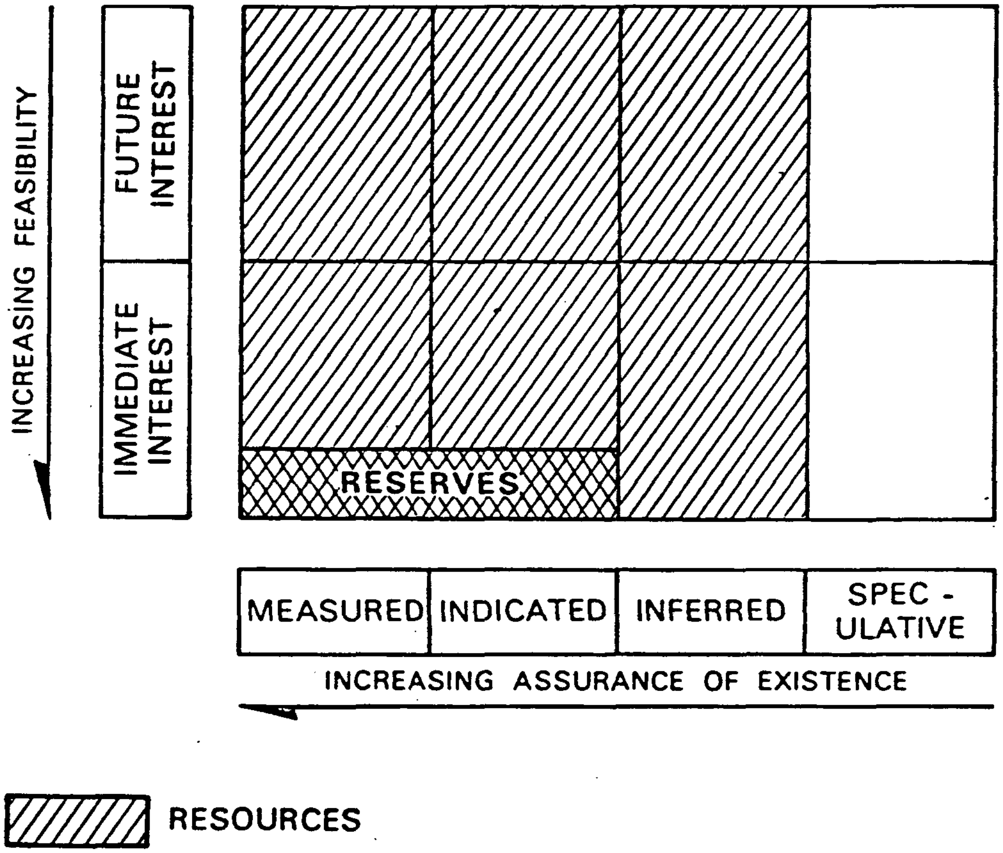


FIGURE 2-10: Coal Resources and Reserves

4.2.3 Longwall Mining

The longwall system is used in Canada only in Cape Breton Island. In Europe almost all of the underground production comes from longwall faces.

The longwall mining system requires a mine layout with coal panels 100 m to 250 m wide by 750 m to 2000 m long. These panels can be developed by driving gate roadways before panel extraction (Figure 4-7 Retreat Longwall), or by advancing the gate roadways along with panel extraction (Figure 4-8 Longwall Advance). Roof support at the coal face is provided by hydraulic chocks or shields (Figure 4-9) which provide a steel canopy over the entire face length. Coal is cut by a shearer travelling on the armoored face conveyor used to clear the coal from the face. The incremental advance of the face supports after each pass of the shearer is shown in Figure 4-10, and the advance of the shearer into the coal face at the gate roads is shown in Figure 4-11.

The roof strata is allowed to cave behind the face supports leaving behind a caved area (gob) in the retreating longwall system. Where the advancing longwall system is used, a 'pack' has to be built, to stabilize the advancing gate roads and contain the ventilation to the face (Figure 4-12). The roadside pack can be built out of wood, waste rock and more recently special cement slurries pumped into plastic bags.

A longwall face 175 m - 200 m long costs in the order of $15 000 000. The installation cost underground is at least $500 000. This face should produce about 1 Mt/a in a 2 m coal seam. An annual production of 3 Mt can be guaranteed from 4 such faces. Manpower requirements at the face and in the gate roads near the face is approximately 70 manshifts/d (3 shift operation) for an expected face productivity of 4500 t/d. Total mine manpower will depend on the mine services required to maintain face operations (coal clearance, men and materials transport, etc.) .

The longwall system is a non-selective mining system and, therefore, is relatively sensitive to seam thickness variation. Longwalls in dipping strata normally advance along the strike with the maingate on the downdip side. Longwalls have been operated on faces dipping over 40°, but the face productivity drops off sharply on dips greater than 20°.

The high rate of cutting coal on a longwall requires a ventilation system adequate to cope with the methane gas released and a dust suppression system to minimize workman exposure. Roof and floor strata must be analysed for quartz content to determine the potential for incendive sparking.

Conclusions

- longwall mining requires a known, fairly constant seam geometry because of the high cost of face installation
- modern face supports can deal with almost any roof conditions as long as the floor strata is sufficiently competent
- roof caving characteristics will determine, to a large extent, the type of face support required

4.2.4 Shortwall Mining

The shortwall mining system was developed as a method to extract narrow pillars (about 30 m) in a room-and-pillar system. A longwall-type face support is used in this system, but the coal cutting is carried out by a continuous miner.

The wide face-cut (at least 2 m) requires longer canopies on the supports. Since the face supports cannot be advanced until the continuous miner has backed out of the face-line, the roof along the face remains unsupported for a large part of the cutting cycle.

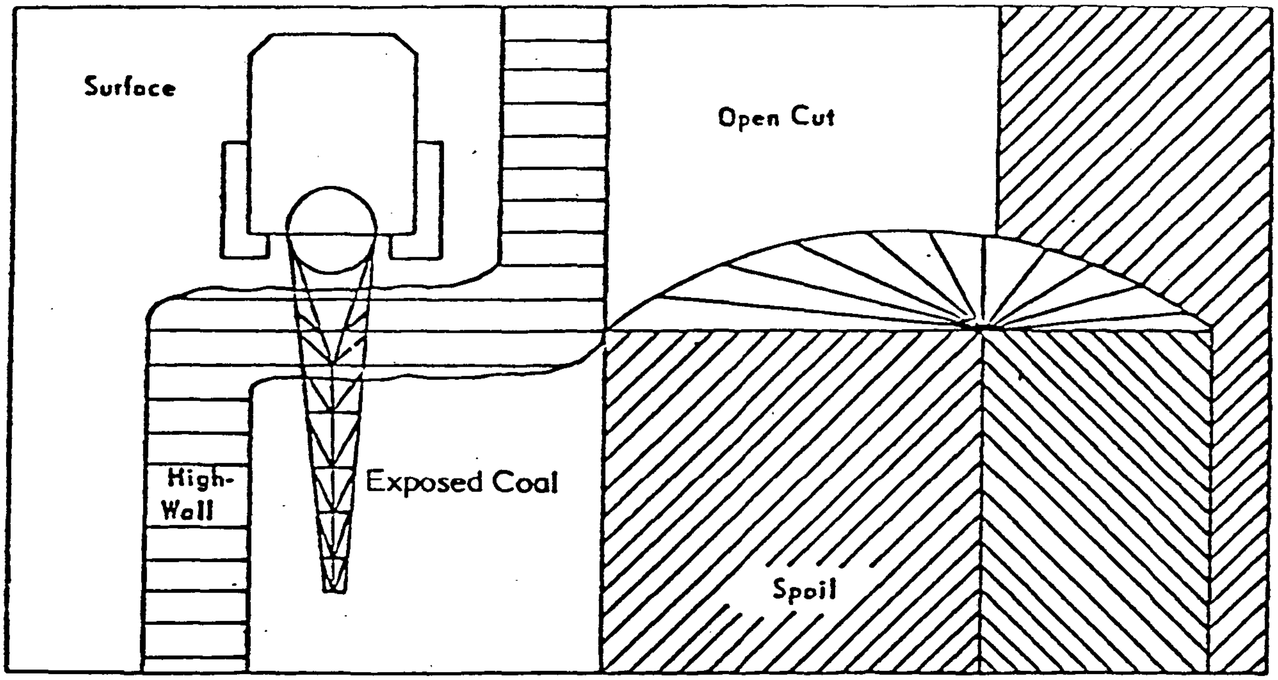
It has been found both in Australia and the US that the shortwall system will only be productive under excellent roof conditions.

4.2.5 Hydraulic Mining

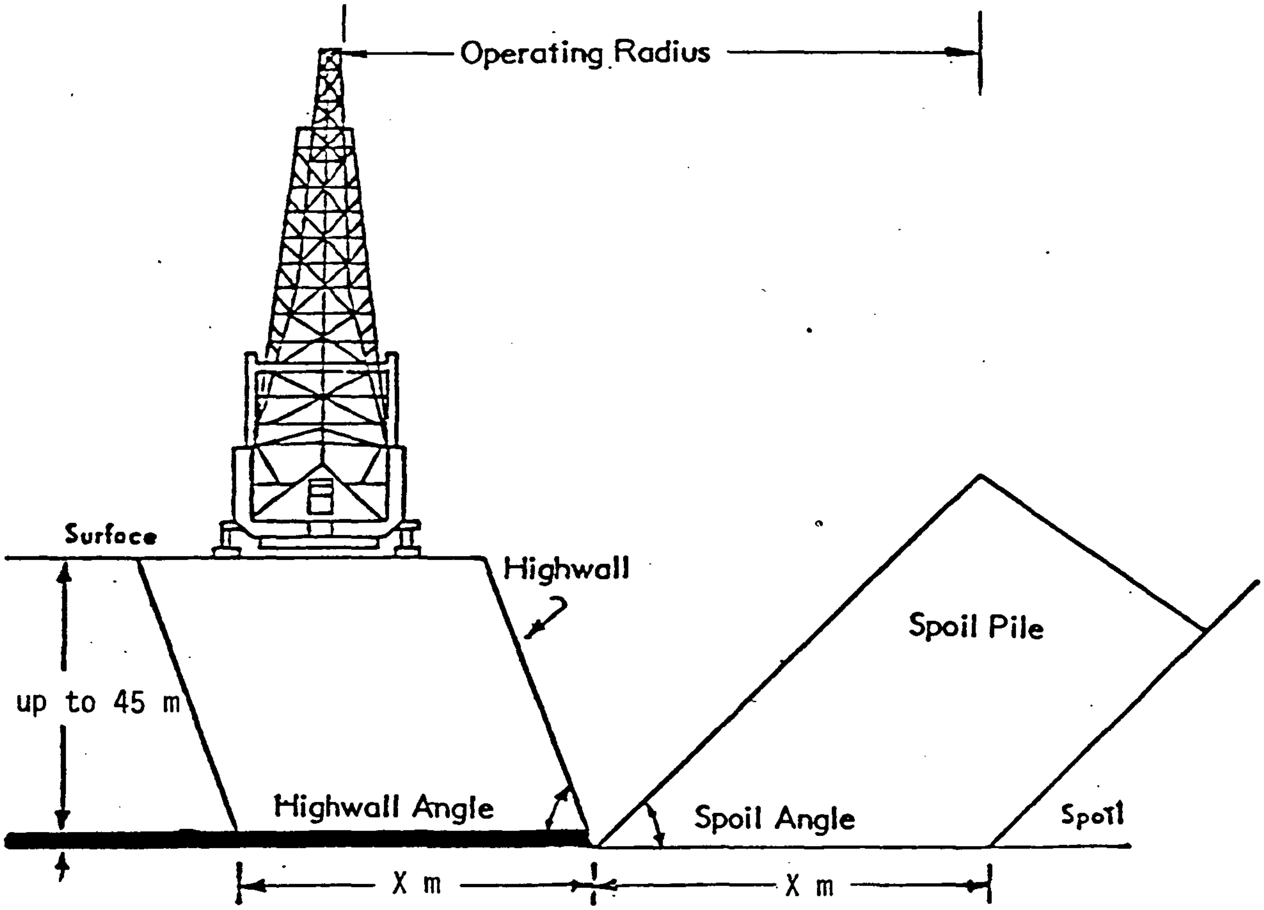
The technology of hydraulic mining was brought to Canada by Kaiser Coal (now BC Coal), to solve the thick and steep seam mining problems encountered in the Sparwood area. The system involves the development of roadways near the base of the coal seam at a constant gradient (apparent dip) of 4° to 7° where coal is transported as a slurry in open flumes. Roadway development is done with continuous miners, but pillar extraction is done with hydraulic monitors (high pressure water jets). During pillar extraction there are no men at the coal cutting face.

To date Balmer South Mine at Sparwood is the only operation using this system. Although Cardinal River Coal, south of Hinton, is developing an hydraulic mine.

This mining system demands a seam inclination of over 20° and has worked successfully in dips up to 60°. The success or failure of the system depends on the roof strata. If the roof caves too readily, only a small part of the pillar can be extracted. If the roof strata is too competent to cave soon after extracting a pillar slice, the mining crews are exposed to the risk of an airblast when the cave finally takes place over a large area.



Plan View



Section View

FIGURE 4-1: Range Diagram for Single Seam Strip Mine

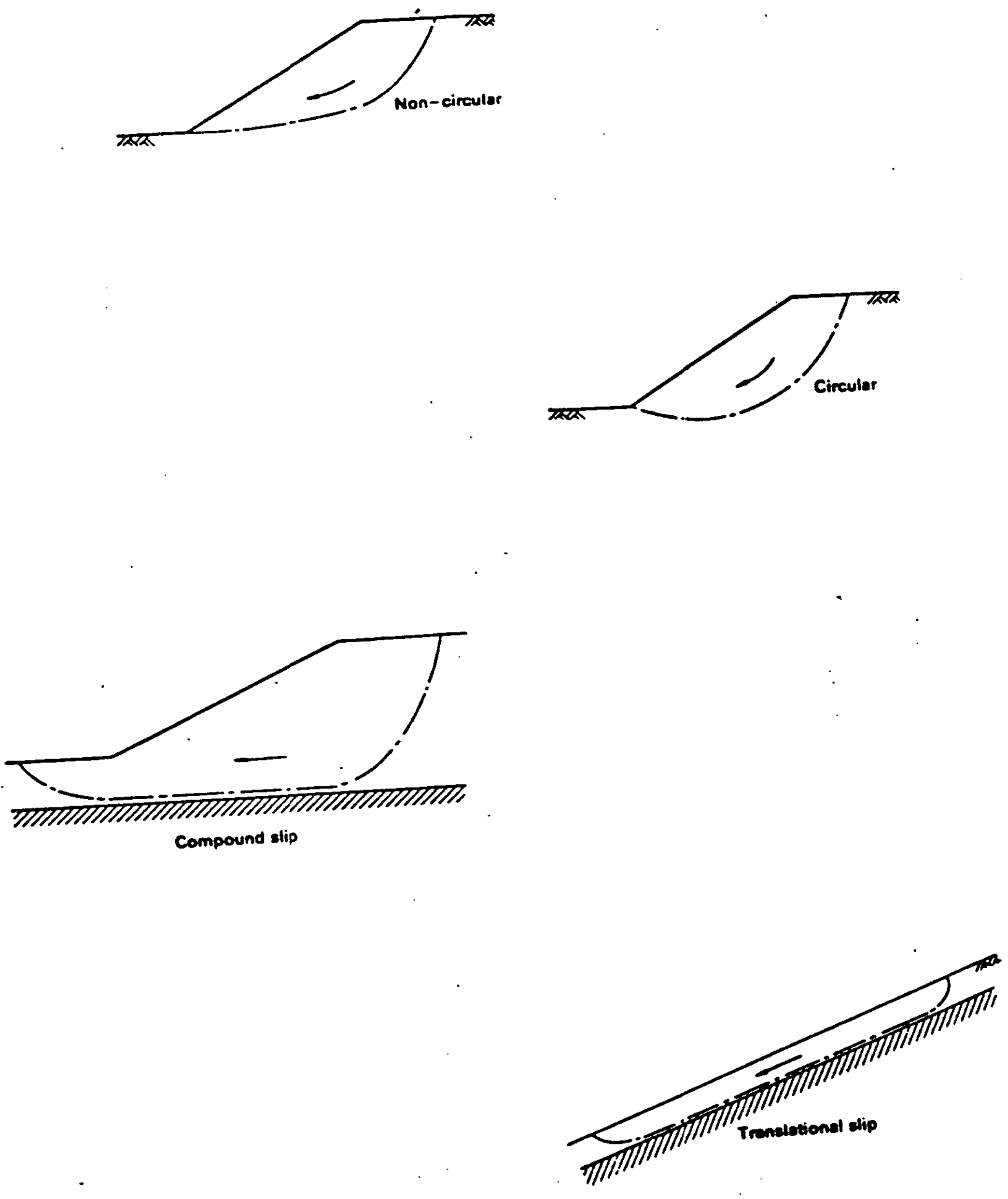
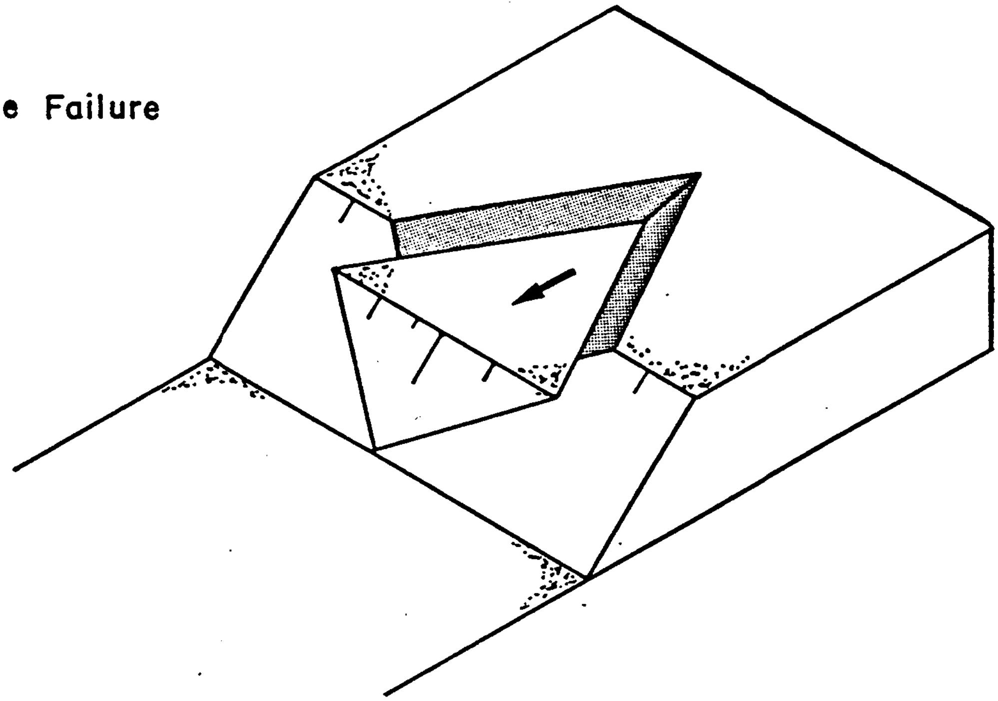


FIGURE 4-2: Modes of Slope Failure, Soil Conditions
(Craig, R.F., 1974, Soil Mechanics)

Wedge Failure



Block Failure

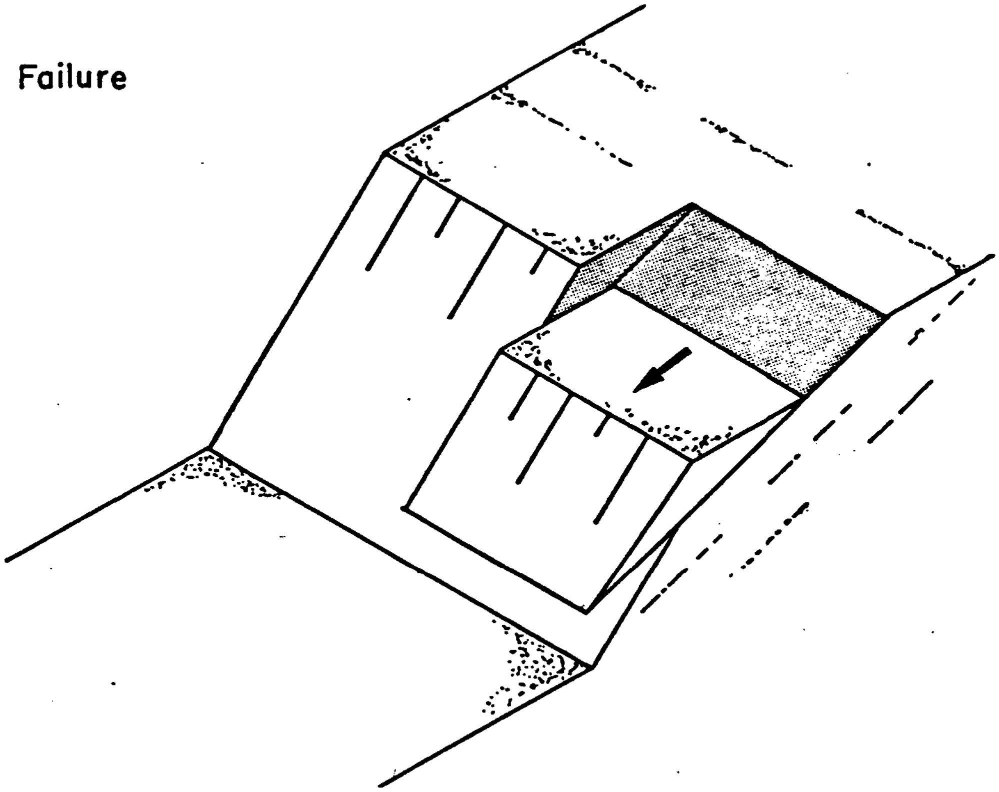


FIGURE 4-3: Modes of Slope Failure, Rock Conditions

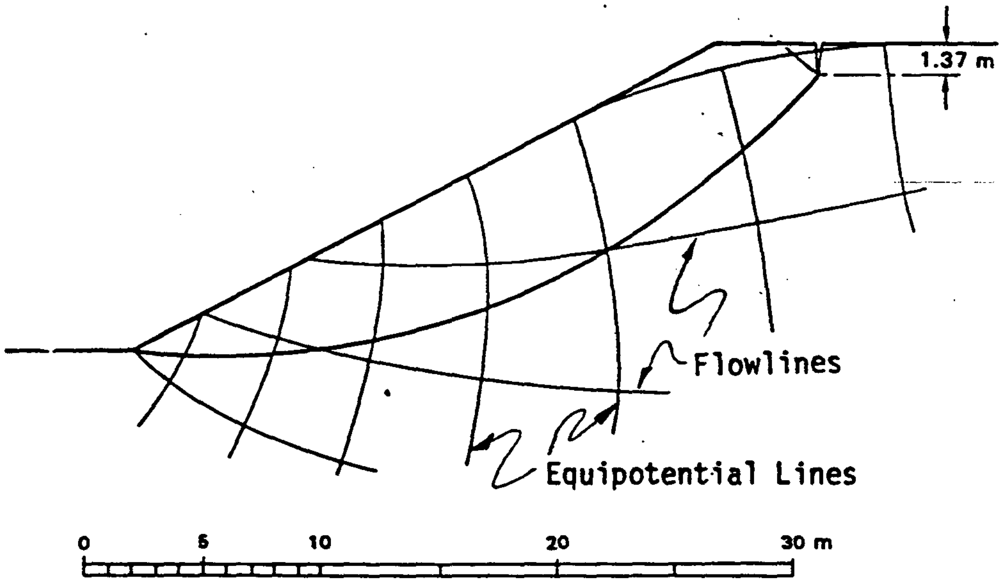


FIGURE 4-4: Groundwater Flownet in Soil Slope
(Craig, R.F., 1974, Soil Mechanics)

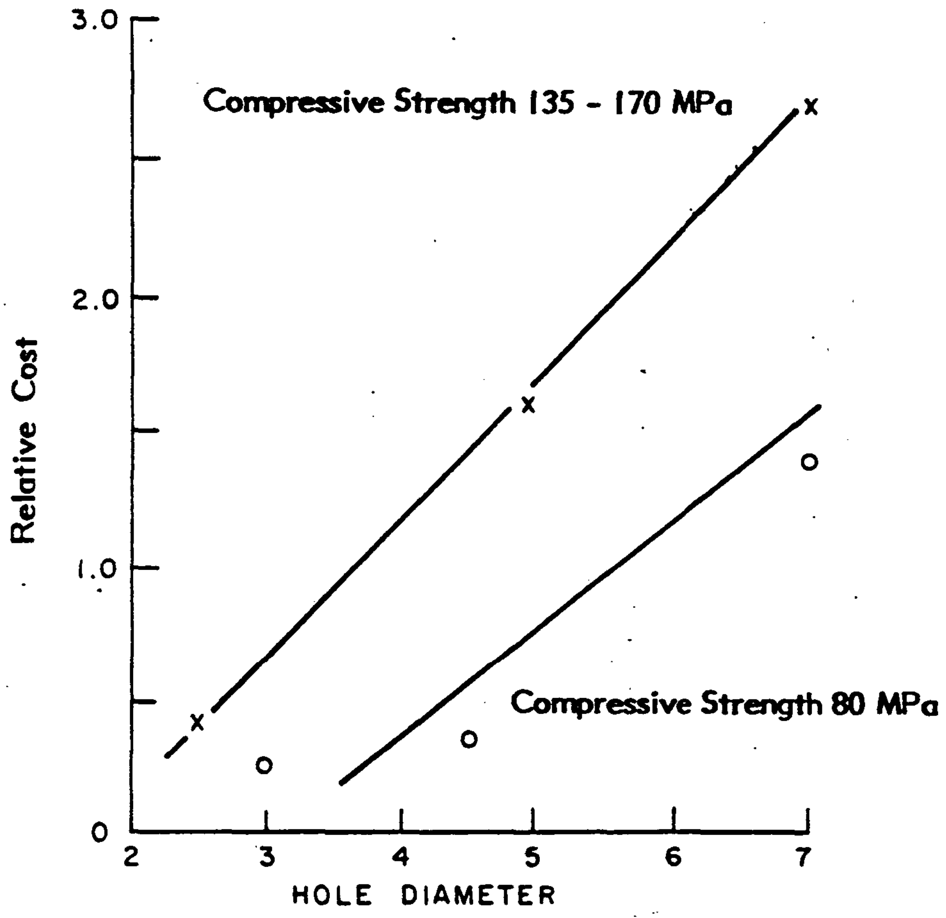


FIGURE 4-5: Relative Effect of Overburden Compressive Strength on Drilling Costs (after Bauer, A., 1974, Open Pit Explosives, Drilling, Blasting)

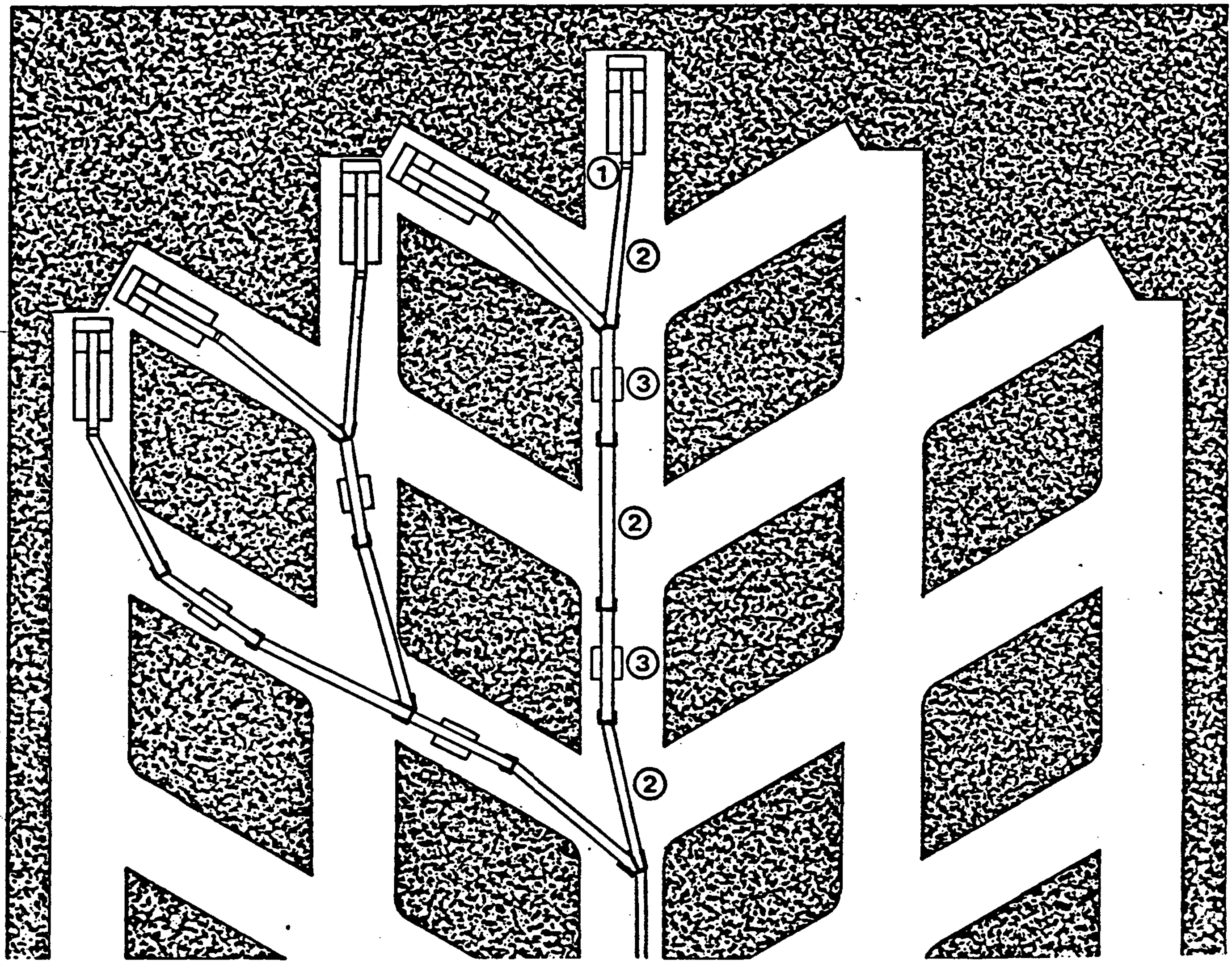


FIGURE 4-6: Room-and-Pillar Five Entry Development

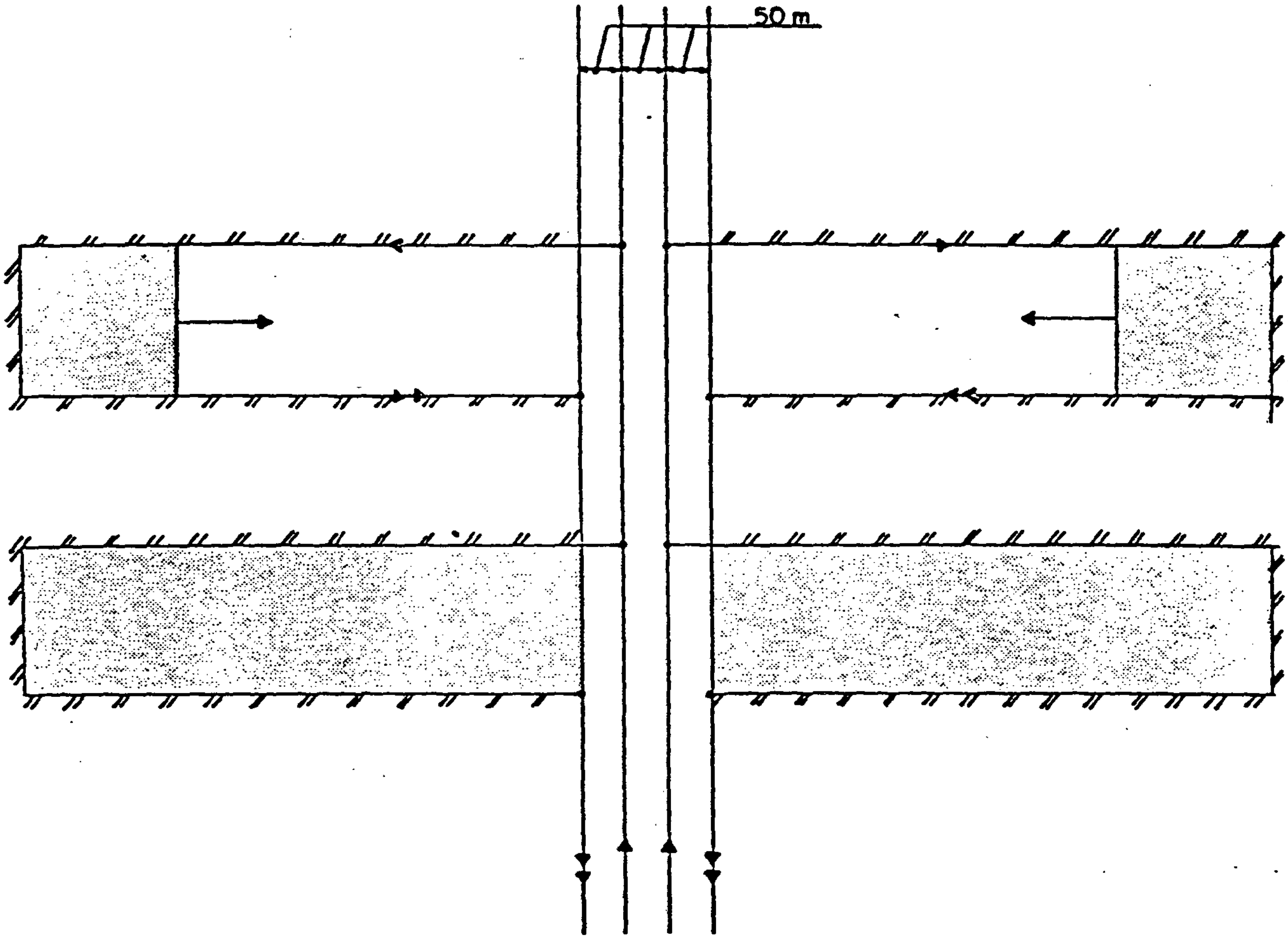


FIGURE 4-7: Longwall Retreat Mining - Schematic

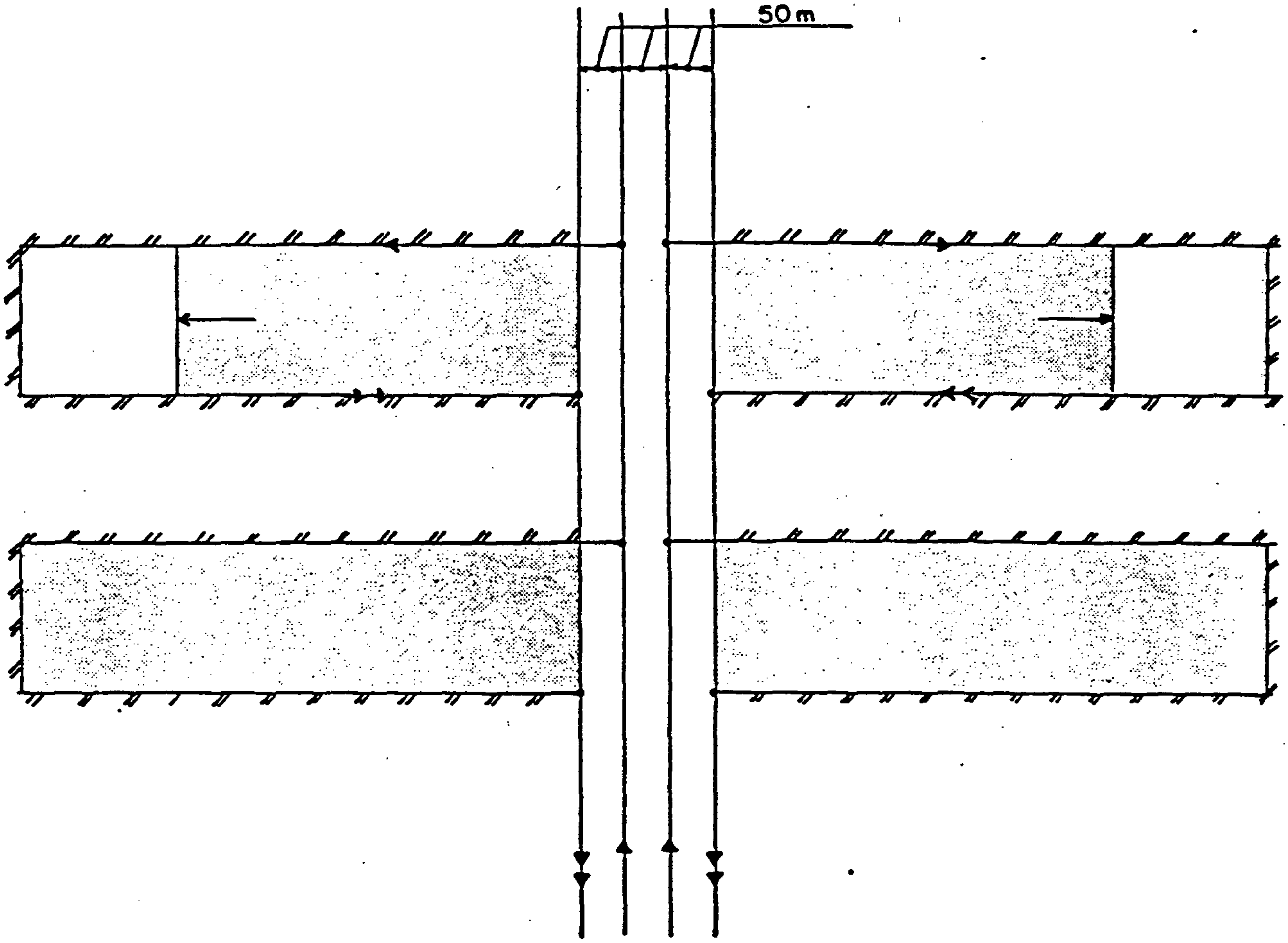


FIGURE 4-8: Longwall Advance Mining - Schematic

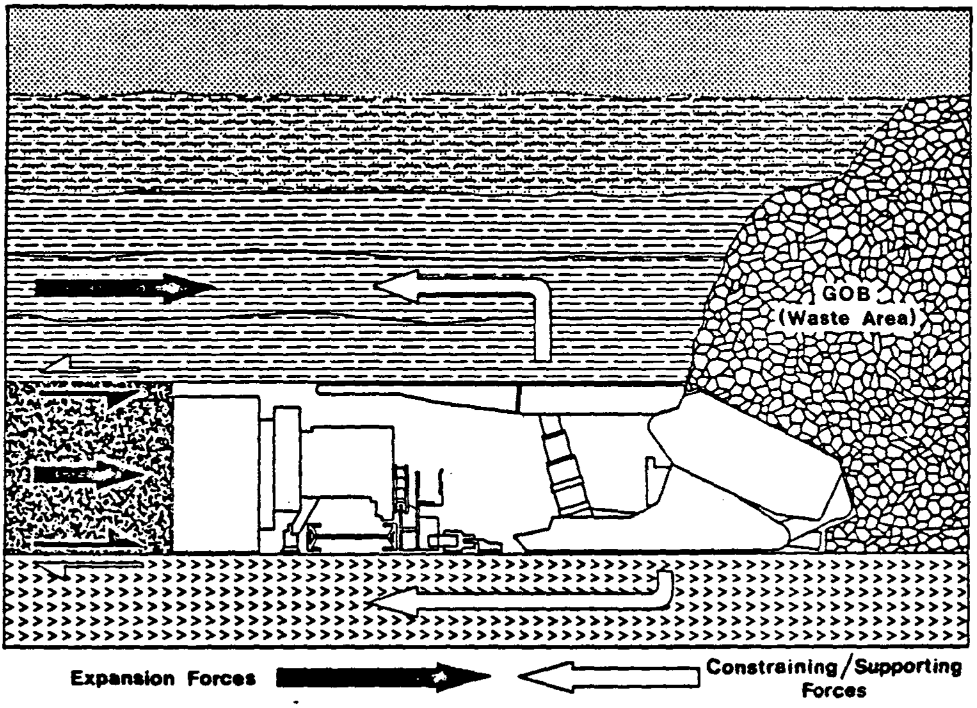


FIGURE 4-9: Longwall Face Support Systems

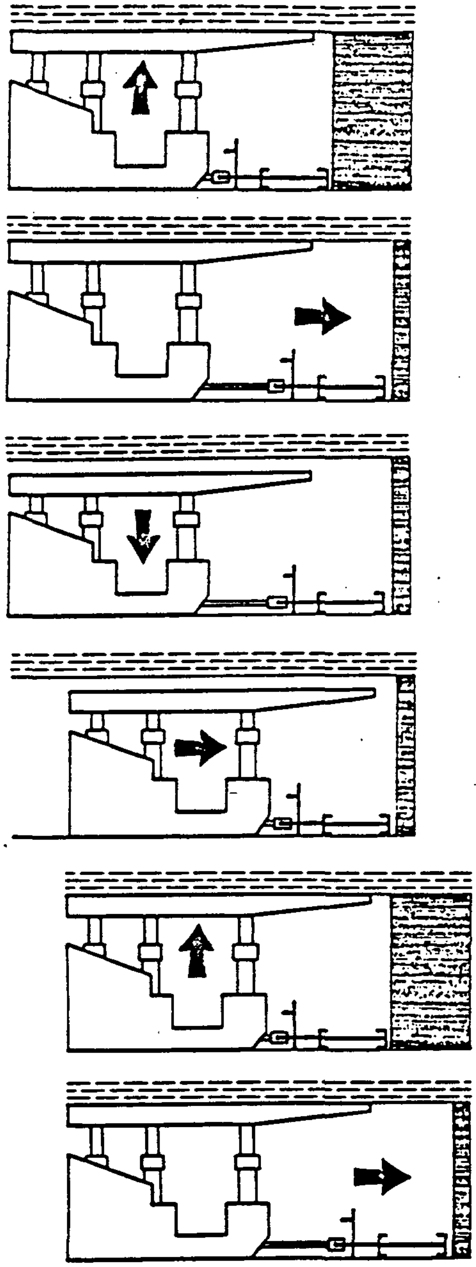
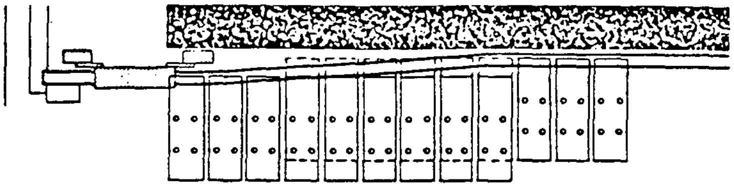
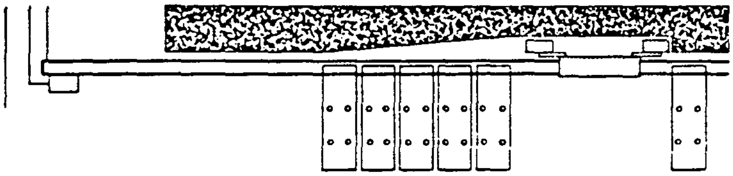


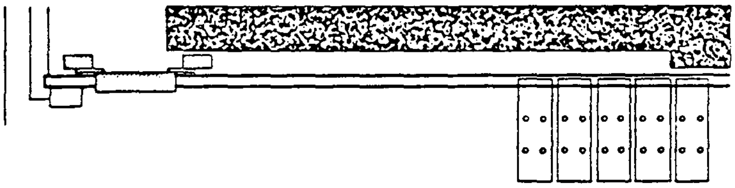
FIGURE 4-10: Face Support Advance



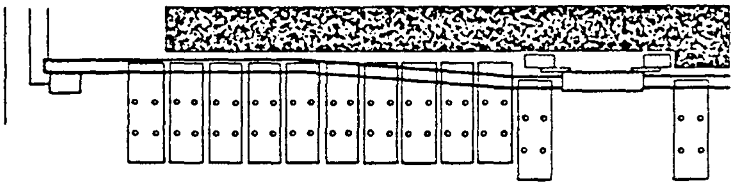
STAGE I Machine cuts into Gateside



STAGE II Machine flits back - cuts around snake to form buttock supports -conveyor advanced



STAGE III Machine cuts back into Gateside



STAGE IV Machine flits back into buttock supports - conveyor advanced

FIGURE 4-11: Initiating a Face Cut

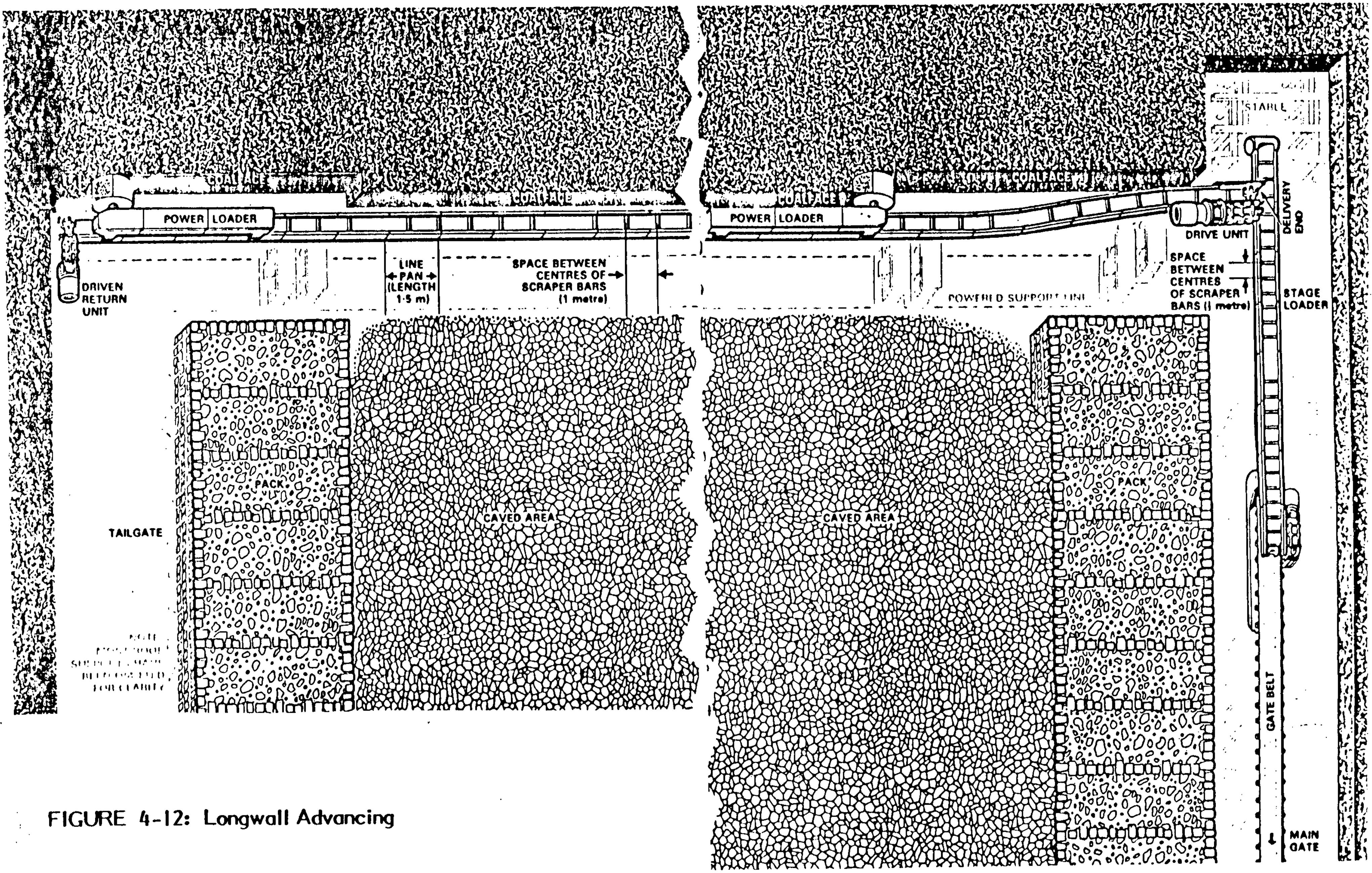


FIGURE 4-12: Longwall Advancing

5 - DATA FOR COAL PREPARATION

120
140
40
260

From a coal preparation engineer's point of view, the exploration and assessment of coal properties is of utmost importance in

- determining the potential uses of the coal
- determining the economic justification for mining the coal
- preparation plant design

To make a realistic assessment of the coal's potential, work must begin at the initial exploration stage, with a thorough and comprehensive test program. The type and extent of exploration, as well as the nature of the analyses required, are site specific.

Accurate assessment of the coal is necessary if a reliable determination of the amount of reserves, the nature of mining conditions and the quality of coal is to be achieved.

5.1 INITIAL EXPLORATION

During the initial exploration phase of a coal prospect, the primary objectives are:

- to determine initial yield projections for different mining sections, and use these for broad economic analyses
- to identify any potential difficulties in preparing a saleable coal product
- to develop preliminary concepts of preparation plant design
- to determine the range of product that can be achieved from the coal resource - the utilization of a particular coal

Local conditions will determine the type of sample required. Samples are procured from sources such as drill cores, adits, outcrops, trenches and from any adjacent mine. The possibility of acquiring data from oil and gas holes should not be overlooked.

It is essential that samples from whatever source are representative of a known intersection.

The analytical flowsheet for the samples depends on known local conditions, but should always err on the side of too much information rather than too little. However, there is no point, for example, determining coking characteristics, if the coal in surrounding mines is undoubtedly suitable for thermal use only. A typical analytical flowsheet for cores is shown in Figure 5-1.

The following factors should be considered when designing an analytical flowsheet:

- The samples should be representative of the proposed mining sections. It is essential that material above and below this section also be sampled so that the analyses can be adjusted for changes in mining section.
- Roof and floor material that could possibly dilute the run-of-mine coal should be tested.
- If clays are suspected to be present near the seam, then the mineralogical composition of the non-coal samples should be determined. The presence of clays, particularly of the free-swelling variety, can have a significant impact on preparation plant design.
- It is important to know the mineral analysis of ash to determine slagging characteristics and, therefore, the market limits.
- The analysis of the coal for trace elements is important, as excess of certain elements could mean the coal is unacceptable in the marketplace. Example would be phosphorus, sodium and chlorine in addition to the well-known sulphur.

The importance of designing a comprehensive sampling and analytical procedure for the initial phase of exploration is that it can save substantial costs in subsequent phases. It is not prudent to prove the existence of millions of tonnes of coal resources, if the coal is unmarketable due to some quality deficiency. Additionally, sufficient data should be gathered to allow broad economics of mining and marketing the coal to be undertaken. The operation may not be viable even if a huge coal resource is proven.

5.2 SUBSEQUENT DATA ACQUISITION

Data gathering for coal preparation plant design, coal quality and yield predictions in subsequent exploration phases should be modified by the information gained during the initial phase.

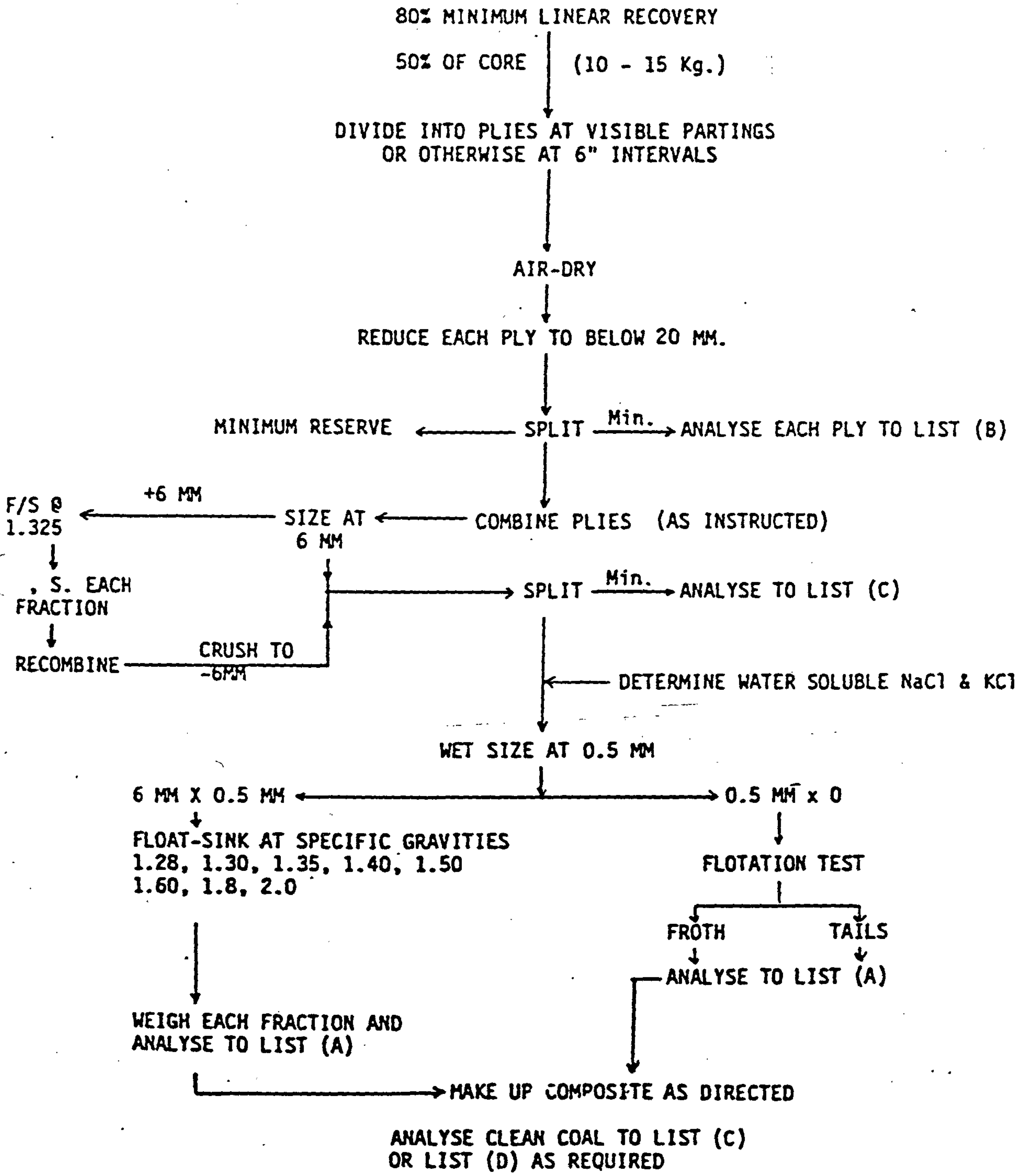
Bulk samples give information over and above that provided by drill cores, by carrying out tests such as:

- full-scale washability tests
- test washing in a pilot plant, or nearby full scale plant
- flocculant tests
- filtration tests
- flotation tests (if appropriate)
- drying tests
- indication of size distribution of run-of-mine coal through degradation tests

The quantity of material available allows replication of test runs under varying test conditions.

The aim of this phase of exploration is to expand the previous data base, resolve or define problem areas, and to predict preparation plant design parameters. The design of the preparation plant will be developed so that run-of-mine coal is washed to give products acceptable to the market while maximizing the return to the mine owner.

Unless data obtained in exploration programs are meaningful, the wrong conclusions can be drawn in respect to project design and profitability.


80% MINIMUM LINEAR RECOVERY
50% OF CORE
(10 - 15 Kg.)
DIVIDE INTO PLIES AT VISIBLE PARTINGS OR OTHERWISE AT 6" INTERVALS
AIR-DRY
REDUCE EACH PLY TO BELOW 20 MM.
MINIMUM RESERVE
SPLIT
Min.
ANALYSE EACH PLY TO LIST (B)
F/S @ 1.325
+6 MM
SIZE AT 6 MM
COMBINE PLIES (AS INSTRUCTED)
, S. EACH FRACTION
SPLIT
Min.
ANALYSE TO LIST (C)
RECOMBINE
CRUSH TO -6MM
DETERMINE WATER SOLUBLE NaCl & KCl
WET SIZE AT 0.5 MM
6 MM X 0.5 MM
0.5 MM x 0
FLOAT-SINK AT SPECIFIC GRAVITIES 1.28, 1.30, 1.35, 1.40, 1.50 1.60, 1.8, 2.0
FLOTATION TEST
FROTH
TAILS
ANALYSE TO LIST (A)
WEIGH EACH FRACTION AND ANALYSE TO LIST (A)
MAKE UP COMPOSITE AS DIRECTED
ANALYSE CLEAN COAL TO LIST (C) OR LIST (D) AS REQUIRED

A.S.T.M. STANDARD

LIST (A)	PROXIMATE ANALYSIS	D3172
	TOTAL SULPHUR	D271
	CALORIFIC VALUE	D271
	F.S.I.	D720
LIST (B)	LIST (A) PLUS SPECIFIC GRAVITY	
LIST (C)	LIST (B) PLUS	
	CHLORINE	D2361
	PHOSPHORUS	D271
	ULTIMATE (MOISTURE, C,H,N,S,ASH, O_2)	D271
	HARDGROVE GRINDABILITY INDEX	D409
	ASH FUSIBILITY TEMPERATURES	D1857
	ASH ANALYSES	D2795
	SULPHUR FORMS	D2492
LIST (D)	LIST (C) PLUS	
	GIESELER FLUIDITY	D2639
	RUHR DILATATION	DIN Standard
	GRAY-KING COKE TYPE	B.S.S. "
	PETROGRAPHIC ANALYSES	
	MEAN MAXIMUM REFLECTIVE OF VITRINITE	D2798
	- MACERAL ANALYSIS	
	- COMPOSITION BALANCE INDEX	
	- STRENGTH INDEX	

FLOTATION TESTS

REAGENT - 4 parts Kerosene + 1 part M.I.B.C.
REAGENT DOSAGE - 0.5 lbs. reagent/ton dry solids
PULP DENSITY - 10% weight/weight
CONDITIONING TIME - 1 minute
FROTH TAKEN OFF AT - 1 minute and 2 minutes

ALL ANALYSES TO BE TO ASTM STANDARDS WHERE AVAILABLE, OTHERWISE TO APPROPRIATE STANDARD.

FIGURE 5-2: List of Analyses for Borehole Cores

6 - INFRASTRUCTURE AND ENVIRONMENTAL CONSIDERATIONS

Every phase in the evolution of a coal project is faced with providing the necessary infrastructure and keeping any adverse environmental impact to a minimum. Both of these factors can have a tremendous impact on any coal project, but they are very much site specific.

Anyone who has been involved in the BC Stage 1 and Stage 2 submissions, or the Alberta mine permit applications is well aware of the detailed government requirements. It cannot be stressed enough that data collection for these submissions should be accumulated, starting in the erarliest exploration stages. A partial check list is given in Figures 6-1 and 6-2.

Surficial Geology

- unconsolidated overburden description
- landslides - a hazard to construction
- sand and gravel - building materials
- drainage basins - flood predictions
- flood plains
- groundwater
- soil profiles

Construction Site Potential

- bridges
- overland conveyors
- main and secondary access roads
- railway spurs and loadout loops
- shop and office complex
- coal preparation plant
- tailings ponds
- settling ponds
- townsites
- air strips

FIGURE 6-1: Infrastructure Considerations

Biological Data

Fauna - wildlife habitat
- aquatic habitat
- rare species

Flora - commercial timber
- revegetation potential
- soil profiles
- rare species

Archaeological Sites

Air and Water Pollution

Dust Sources
- roads
- mining operations
- coal preparation plant

Noxious Fumes

Water Pollution
- settling ponds
- garbage dumps
- tailings ponds

FIGURE 6-2: Environmental Considerations

7 - PROJECT ECONOMICS

A coal mining operation is an expensive industrial complex. Like any other industry within an economic system, the bottom line has to be an acceptable, positive cash flow. The investment and risks are high but the return on investment should be the deciding factor for each project.

7.1 CAPITAL AND OPERATING COSTS

Cost estimates are usually broken down into capital and operating costs. These are unique to each coal project. A few recent summary examples of cost estimates are given in Figures 7-1 to 7-5.

Capital costs for a coal project can be divided into general costs related to the project and specific costs because of location (Figure 7-6).

The Northeast BC coal developments presently under construction for example, will involve the following expenditures by governments:

Mine and local infrastructure	$ 209 000 000
Port facilities	51 000 000
Railway (Anzac route)	745 000 000
Total	$ 1 005 000 000

Operating costs should be allocated to various aspects of the project (Figure 7-7). If this is done during the evaluation, cost sensitivities can be developed more readily for changing conditions such as market specification, labour, technology changes. The readily identifiable cost levels are:

- run-of-mine coal cost
- FOR cost which includes run-of-mine costs plus coal preparation and other mine site costs
- FOB cost which includes FOR costs plus transportation and port handling charges

Certain operating costs such as royalties and head office costs are allocated by individual companies to different cost levels.

In the project cost examples (Figures 7-1 to 7-5) operating costs are limited to mining costs, coal preparation and minesite overhead costs.

7.2 ECONOMIC EVALUATION

The accuracy of an economic analysis is very much a function of the amount and quality of information available concerning the coal prospect. If the only information available consists of a few exploratory borehole logs, the economic valuation of the property can only be based upon an estimate of the mineable reserve multiplied by a current unit market price paid for reserves of similar coal in a comparable location. At the other end of the spectrum, if a detailed feasibility study of the prospect has been prepared setting out estimated capital and operating costs consistent with a detailed mine plan, a discounted cash flow analysis of estimated future costs and revenues can be compiled to arrive at the present worth of the property. Obviously a far greater degree of confidence can be placed on this latter type of analysis, since likely costs and timing as well as estimated revenues are reflected in the calculation.

It is widely accepted that the Internal Rate of Return method is the preferred method of analysing project profitability since, unlike any other method, the time effects of expenditures and revenues are taken into account. The IRR method is known by a variety of names, including Net Present Value Method, Discounted Cash Flow Analysis, and others.

A detailed discussion of a financial analysis is beyond the scope of this seminar.

Mining Method	Open Pit - truck/shovel
Mine Life	20 years
Annual Product	2.4 Mt run-of-mine
	2.0 Mt clean
Coal Preparation Plant Yield	85%
Workforce	600
Capital Cost	$300 000 000
Operating Cost	$20/t run-of-mine
	$28/t clean

FIGURE 7-1: Surface Mine 'A' - Project Cost

Mining Method	Strip Mine - dragline
Mine Life	20 years
Annual Product	3 Mt
	2.0 Mt clean
Workforce	400
Capital Cost	$300 000 000
Operating Cost	$9/t run-of-mine
	$20/t clean

FIGURE 7-2: Surface Mine 'B' - Project Cost

Mining Method	Strip Mine - draglines
Mine Life	30 years
Annual Product	3 Mt
Workforce	125
Capital Cost including CPP and replacement costs	$140 000 000
Operating Cost	$5/t run-of-mine
Stripping ratio	4.5 m^3/t coal

FIGURE 7-3: Surface Mine 'C' - Project Cost

Mining Method	Longwall
Mine Life	20 years
Annual Product	4.5 Mt run-of-mine 3.0 Mt clean
Coal Preparation Plant Yield	68%
Workforce	1200
Capital Cost	$400 000 000
Operating Cost	$18/t run-of-mine $28/t clean

FIGURE 7-4: Underground Mine 'A' - Project Cost

Mining Method	Longwall
Mine Life	20 years
Annual Product	0.7 Mt run-of-mine 0.5 Mt clean
Coal Preparation Plant Yield	75%
Workforce	500
Capital Cost	$140 000 000
Operating Cost	$32/t run-of-mine $43/t clean

FIGURE 7-5: Underground Mine 'B' - Project Cost

- **General Costs**

These include the following for all coal projects:

- mining equipment
- coal preparation plant
- feasibility and engineering studies
- construction management
- surface facilities, shops, offices, coal handling
- mine access
  - haul roads for surface mines
  - shafts and slopes for underground mines
- capital development
  - pre-stripping in surface mines
  - development of first production face underground
- replacement capital over life of project
- capital spares

- **Specific Location Costs**

This is particularly significant for project development in remote locations and could include:

- community development
- railway spur
- additional spares inventory

FIGURE 7-6: Capital Costs

- Mining Costs
  - for surface mines equipment operation and maintenance is the largest single item, dragline operating costs can be as high as 60% of mining costs
  - for underground mines labour costs are often 50% of mining costs

- **Depreciation and Amortization**
- **Royalties**
- **Coal Preparation and Coal Handling**
- **Transportation**
- **Port Handling and Analysis**
- **Overhead Costs**
  - minesite
  - corporate
  - housing
- **Financing Costs**
- **Taxation**

FIGURE 7-7: Operating Costs

8 - PROJECT ASSESSMENT

The assessment of the viability of a coal project is made as part of an evaluation process which embraces assessments of engineering feasibility, market prospects, social and environmental impacts, and economic analysis. Figure 8-1 illustrates the normal sequence of assessment and how the validity of the engineering and financial evaluations depend upon preceding parameters such as geology, coal quality, site conditions and market specifications. The accuracy of the engineering feasibility and economic analysis are thus a function of the amount and degree of detail available from the basic data and its interpretation.

A project evaluation, therefore, is sensitive to the manner in which all contributing parameters are identfied, evaluated and assessed within the overall context. However, all coal projects must be evaluated in some form at an early stage in order to determine whether or not it is an attractive project, or whether investigation and evaluation should continue.

Coal projects tend to proceed through several stages of assessment before major expenditures are made, the assessments becoming progressively more detailed as overall feasibility is established. No matter what stage the project evaluation has reached, however, in our experience it is important that each project parameter is given due consideration so that a balanced view of the project is obtained. Thus, consideration of mining methods or coal preparation should be included before a detailed exploration program is pursued. At the same time, the economics of the project are just as important as the engineering feasibility.

The two principal activities required in coal project evaluation are:

- Mine Feasibility
  - geology - resources
  - mining methods - reserves
  - coal quality - saleable coal
  - surface facilities
  - infrastructure
- Marketing and Economic Analyses

Mine feasibility and design is an iterative process whereby preliminary judgements on mine design, production, marketing and economics are tested by subsequent analyses, which are supplemented as necessary by additional data derived from confirmatory studies of specific aspects, the procedure being repeated in progressively greater detail with an increasing level of accuracy as the degree of project definition increases. Identifiable phases are shown in Figure 8-2.

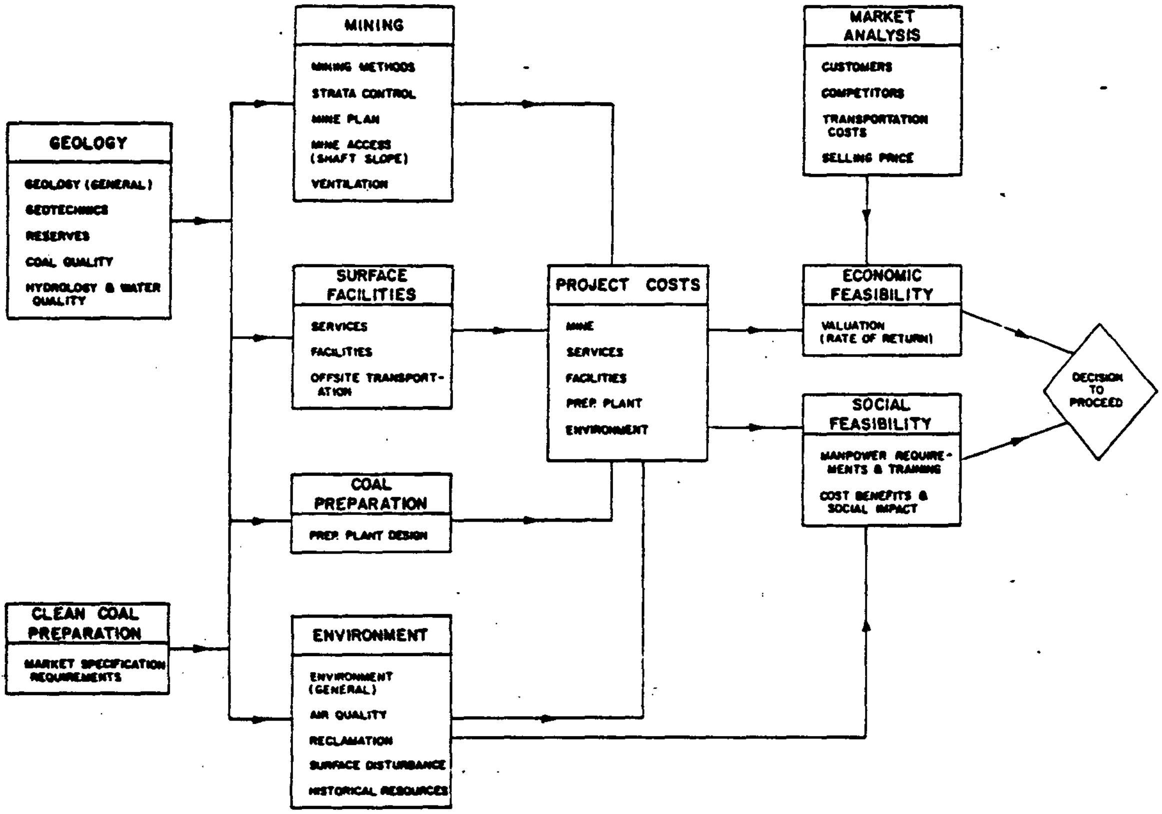


FIGURE 8-1: Project Assessment

PHASE I - PROSPECT ASSESSMENT

- **Prospect Identification**
- **Lease Acquisition**
- **Initial Exploration**
  - surface mapping (where applicable)
  - limited number of boreholes
  - extensive geologic interpretation
  - detailed coal quality
  - qualitative geotechnical assessment
- **Prefeasibility Study**
  - geology
  - conceptual mine plan
  - limits to coal preparation
  - approximate quality of saleable product
  - costs within 30%
- **Marketability of Product**

FIGURE 8-2a: Evaluation Phases

PHASE 2 - PROJECT FEASIBILITY

- **Exploration Boreholes for Specific Purposes Only**
    - coal quality
    - stratigraphic or structural discontinuities

- **Bulk Samples (if practical)**
    - coal washability tests
    - burn tests
    - coking tests

- **Environmental Baseline and Impact Studies**
    - soils
    - groundwater
    - atmosphere
    - wildlife, etc.

- **Geotechnical Parameters of Significance to Conceptual Mine Plan in Roof, Seam and Floor Strata**
    - composition, eg: bentonitic clays
    - strength
    - hydrology - pressure and flow rates

- **Feasibility Study**
    - geology
    - mine design
    - flowsheet of coal preparation plant
    - environmental impact
    - surface facilities and transportation
    - manpower
    - costs within 20%

- **Marketing**

FIGURE 8-2b: Evaluation Phases

PHASE 3 - SEAM ACCESS AND TEST DRIVAGE

- **Preproduction Drilling**
  - geotechnical data for shaft sinking or tunnelling contracts
  - site specific data for long-term access roadways
- **Detailed Engineering of Shafts and/or Slopes**
- **Shaft Sinking or Tunnel Drivage**
- **Test Drivage in Seam for Support Systems and Dimensions**
- **Detailed Engineering**
  - costs within 10%

PHASE 4 - MINE DEVELOPMENT AND PRODUCTION

FIGURE 8-2c: Evaluation Phases