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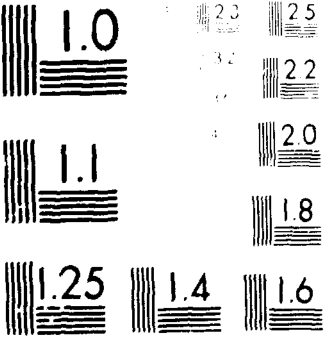

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EXPERT SERVICES AND FELLOWSHIPS

FOR BUILDING MATERIALS AND

NON-METALLIC MINERALS

DP/CPR/79/019

CHINA

Technical report: Assistance to the diamond mining industry - conversion from open pit to underground operation for the No. 701 mine

Prepared for the Government of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of David H. Decon,
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United Nations Industrial Development Organization
Vienna

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ABSTRACT

The project "Expert services and fellowships for building materials and non-metallic minerals" (DP/CPR/79/019) of the United Nations Development Programme (UNDP) in China was carried out by an expert in diamond mining from the United Nations Industrial Development Organization (UNIDO), which was the executing agency.

The main objective of the mission was to provide a feasible method for converting the No. 701 mine from an open pit to an underground operation. The secondary objective was the world-wide dissemination of information on the diamond mining industry. The duration of the mission was only one month, of which two weeks were spent on site at the mine.

It was concluded that from a practical mining viewpoint the conversion was feasible but in the short time available no single mining method could be proposed. Instead two alternatives were selected and an overall mine design proposed that would suit either method.

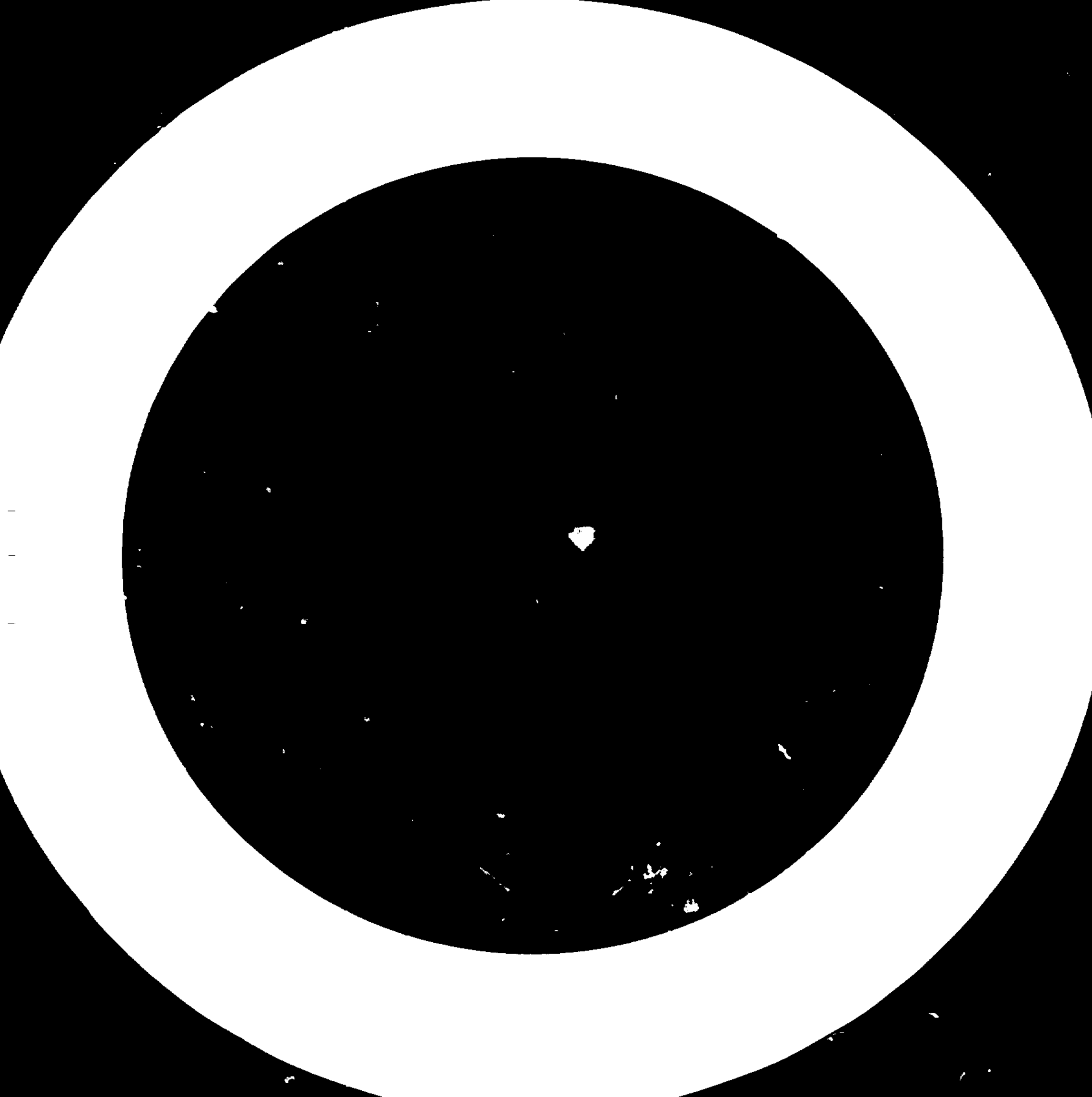
It was recommended that the following work should be done before finalizing the decision on a mining method:

(a) Testing to establish parameters for each mining method;

(b) Comparisons to establish the more favourable economic method;

(c) Rock mechanics investigations on various factors concerning each method.

Further recommendations were that assistance be obtained in running the current operations to improve general management, processing and safety.



CONTENTS

INTRODUCTION

The project "Expert services and fellowships for building materials and non-metallic minerals" (DP/CPR/79/019) of the United Nations Development Programme (UNDP) in China was carried out by an expert in diamond mining from the United Nations Industrial Development Organization (UNIDO), which was the executing agency. The duration of the project was one month.

The No. 701 mine of the Ministry of the Building Materials Industry is a small diamond mine near the town of Meng-yin in the Shantung Province of China. It is apparently the first diamond mine in the country to be approaching the stage where it is necessary to consider its conversion from an open pit to an underground operation. As there is little local experience of this nature available, UNIDO was approached for assistance through the UNDP office in Beijing.

The request was made for a diamond mining expert to assist the Government:

(a) To prepare a draft design for changing from opencast to underground mining;

(b) To recommend the most practical way of converting from opencast to underground mining;

(c) To recommend ways to overcome other problems;

(d) To determine the various techno-economic indexes;

(e) To recommend ways to improve the existing dike mining method;

(f) To lecture on diamond mining techniques and trends of development abroad to local personnel.

The original request for this assistance was made about June 1980 and the expert visited the mine from 29 June 1981 until 14 July 1981, with two two-day periods in Beijing at the beginning and end of this period.

On discussing the project with local personnel it was established that the main emphasis should be placed on the mine design and dissemination of information on diamond mining. With two minor exceptions the objectives were achieved. First, as the dike mine section is now closed, little time was spent on this objective. Second, as the time available for this project was extremely short, it was agreed locally that the techno-economic indexes were of less importance at this early stage in the project and they were therefore given a low priority. It is emphasized that the work was confined to practical design considerations; no attempt was made to establish if the designs would be economically viable. This was mentioned during discussions with local personnel and it was agreed that they would complete such economic justifications.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The conversion from open pit to underground is practically feasible and within the capabilities of the current local personnel.

2. The planning team requires co-ordination and strong leadership to control the various aspects of planning, design and execution of the project by the various sections involved.

3. Testwork will be required to establish certain mining parameters before the final decision on a mining method can be taken. This will include tests:

    (a) To establish the draw characteristics of the ore/waste material;
    (b) To establish the optimum tunnel and level spacing;
    (c) To establish the best fill material;
    (d) To establish pumping and curing characteristics for this material;
    (e) To establish the stability of the pillars in the cut and fill system.

4. An investigation should be conducted into the possible behaviour of the wedge of waste rock between the two sections of the ore body for each mining method. Some rock mechanic expertise may be required to assist local personnel.

5. All equipment proposed is available by local manufacture with the possible exception of the main shaft hoist.

6. To establish the economics of the project in the time available was not possible owing to the differing cost structures and unavailability of data.

7. All economic justifications will be prepared by local personnel for government approval.

Recommendations

1. The expert favours a sub-level cave system, but testwork must be undertaken before the final decision is made.

2. Economic justifications should be carried out by local personnel for this project.

3. Economic exercises will be required to assist in the choice of the mining method and in the final justification to convert the mine from an open pit to an underground operation.

4. All systems used for an underground operation should be kept as simple as possible.

5. The use of an ore stockpile should be introduced immediately as it will be of assistance for both the open pit and the underground operation.

6. The schedule for conversion is tight, and the planning and design work should be expedited to enable early approval to be sought to begin the project on site.

7. Training in managerial and economic systems will greatly assist this operation.

8. Advice on the process could significantly assist the recovery of diamonds, thereby improving the profitability of the operation.

9. Advice on detailed rock mechanic aspects of the underground operation would assist the decision on the mining method.

10. Assistance on safety management is required.

I. UNDERGROUND MINE DRAFT DESIGN

In order to complete the main objective of the project the expert divided this work into two sections. First, consideration was given to the selection of a suitable, practical mining method. Secondly, once a mining method had been selected then the infrastructure of the mine would be designed around it.

A. Selection of mining method

The expert was given an introduction to the mine including descriptions of the current operations with particular reference to information relevant to the project. Thereafter discussions were held with the local design team to establish what work had yet been completed in this direction.

The following alternative mining methods were finally selected by the expert for initial review:

Block caving
Shrinkage stoping
Sub-level caving
Open benching
Cut and fill stoping
Chamber stoping

Block caving and open benching were quickly eliminated as they are best applied to much larger, more regular shaped ore bodies. Some time was taken in considering the advantage and disadvantages of the remaining four possible methods. After comparing the two methods, shrinkage and cut and fill, the latter was deemed preferable because shrinkage:

(a) Allows and uncontrolled flow of rainwater into the mine;
(b) Supplies no support to the country rock in the long term;
(c) Has been used unsuccessfully at the dike mine;
(d) Causes greater dilution problems.

A similar comparison was done for sub-level caving and chambering with the former being selected because chambering:

(a) Requires close tunnel spacing for the loading tunnels;

(b) Has a manual loading system;

(c) Has a higher development ratio;

(d) Could have loading and/or pressure problems because with little overburden or pressure the pillars could remain solid.

Also, in essence sub-level caving is an improved chambering method.

In comparing the final alternatives - cut and fill and sub-level caving - firm reasons could not be established with available data for selecting either method. It was therefore decided that further investigation would be required before a final decision could be taken.

Draft designs for both mining methods were made and some directions for further study indicated.

Sub-level caving

The suggested layouts (see annexes I and II) show the required development on a main access level and on an intermediate level. These layouts are practical and in line with current ideas on sub-level cave practice elsewhere. The final design will only be possible after tests are carried out to establish the ellipsoid of draw and draw characteristics for the particular ore and waste roc and tunnel configuration.

Production potential

This system will easily produce the required tonnage by blasting one fan ring per day (see annexes III A and B for examples), with a burden of only 1.5 metres. It is not possible to give figures for dilution and recovery ratio at this stage; this will only be possible once the draw tests have been completed. The final decision will be based on the economics of having to haul and treat an increasing percentage of waste compared to the increasing recovery of diamonds.

Development requirements

Sub-level caving requires a large amount of development per unit volume of ore reserves. It is estimated that to open up each intermediate level will require ± 1,000 metres of development. As levels will be mined at the rate of one every 10 months, the development rate should be set at about 150 metres per month to allow the necessary time for construction.

Ventilation requirements

The amount of air allowed per production tunnel will be dictated by the need to dilute diesel fumes produced by the loading equipment. A figure of $0.08 m^3$/sec per kW of diesel power should be adequate. Allowing for the following:

	% ventilation
2 production tunnels	100
2 spare tunnels	50
3 charging/drilling tunnels	50
2 maintenance tunnels	50
Balance of tunnels closed	0

A maximum of $3.6 m^3$/sec gives $18.0 m^3$/sec assuming a 45 kW diesel loading unit. For development it was assumed that eight tunnels would be operating simultaneously. By careful planning these could be ventilated with $12 m^3$/sec. A further allowance of $5 m^3$/sec for leakage and inefficiency gives a total of $40 m^3$/sec as the minimum ventilation requirements for the mine using sub-level caving. It is suggested that a fan for each section of ore body would be more flexible than one main fan on the surface.

Equipment requirements

The following list indicates the type and rough size of equipment that should be considered:

Loading:	Production	$0.3-0.75 m^3$ LHDs
	Development	As above or $\pm 0.3 m^3$ rocker shovels
Drilling:	Production	Small mobile fan drill rig or bar mounted $\pm$ 100 mm piston rock drills
	Development	Conventional air-leg mounted rock drills
Hauling:	Production	LHDs as above
	Development	LHDs as above
	Main haulage	3 ton locos + 2 ton cars (battery or electric trolley)

Productivity

It is estimated that the productivity potential for this system when including the necessary development labour requirements will be 9 tons/man/shift.

Cut and fill stoping

The suggested layouts (see annexes IV and V) show a typical level layout and the proposed development required in each stope. No attempt has been made at this stage to predict a mining method for pillar extraction. It is felt that these are practical proposals and although some refinements are expected to be developed, for initial design requirements this is sufficient.

Production potential

It is estimated that a maximum of 80,000 tons per annum can be obtained from this layout. This is based on a cycle as follows for each stope:

	Days
Production	16
Preparation	4
Filling	16
Fill curing/draining	12

During the production phase advances of 2 m per day per stope will be required to achieve the production quoted. Dilution in this operation will be minimal, but dilution of the pillar ore will be relatively high and recovery could be quite low. Pillar mining will supplement production at a later stage, probably after two to three years of operation.

Fill requirements

This method presupposes the availability of suitable fill material. It was not possible during the time allowed to confirm this. However, possibly run-of-mine tailings with a sand-and-cement mix would be a suitable fill material. Tests will be required to establish a suitable mix and to confirm setting and curing times together with pump-ability tests to establish the design criteria for a fill plant and pumping system.

Development requirements

Total development requirements are much lower for this method and it is estimated that approximately 1,700 metres will be required to open up each level. However, as each level will only need replacing about every 2 1/2 years, the rate of development is ± 60 metres per month.

Ventilation requirements

It is estimated that 3 m^3/sec should be adequate to ventilate each stope so that 18 m^3/sec will be sufficient for production. For development and stope preparation a further 12 m^3/sec has been allowed. This together with a 5 m^3/sec allowance for miscellaneous ventilation and 5 m^3/sec for leakage and inefficiency gives a total minimum requirement of 40 m^3/sec.

Equipment requirements

Loading:	Production	15 kW scraper winches
	Development	Small rocker shovels
Drilling:		Conventional air-leg mounted rock drills
Hauling:		3-ton locos + 2-ton cars (battery or electric trolley)

Productivity

Productivity for this system in the stoping section will be much lower than for sub-level, but because of the reduced development requirements the overall figure is expected to be approximately 6 tons/man/shift.

B. Overall design for the underground mine

The infrastructure both on the surface and underground has been so designed that it will be adaptable to either mining method. This allows some two years before any final decision need be taken on the mining method. Details of the layout and the underground layouts mentioned in previous sections are given in annex VI.

Shaft requirements

The main shaft is designed to handle both men and material and all broken rock. Alternative designs (annex VII) are shown; the more simple design B is locally preferred.

The return ventilation shaft (annex VI) can be sited on the surface at either of the two positions shown. The expert suggests the easterly position for the sub-level cave layout and the westerly position for the cut and fill layout.

Underground and surface haulage

All broken rock from development and production would be transported to the shaft by either battery or electric trolley locomotives pulling trains of 1- or 2-ton cars. This system has worked in the area at the dike mine. One point to consider is that it is felt the shaft cages should be designed to hoist 2 tons per trip so they should either be designed to take two 1-ton cars or one 2-ton car depending on final selection for the haulage.

At the surface the ore/waste rock would be transferred to storage bins sited adjacent to the shaft prior to lorry haulage to the plant, the waste rock dump or the ore stockpile.

Pumping

It is always difficult to predict water volumes to be encountered underground. Previous drilling in the area has apparently encountered little underground water. Fairly large volumes will enter the mine from the open pit particularly if sub-level caving is adopted as the preferred mining method. It is therefore not possible to give any indication of the pumping requirements but in design it is felt that chambers should allow for the larger requirement and only install pumps according to final predictions and design criteria.

Ore stockpile

It is recommended that an ore stockpile be created by mining additional ore from the pit during the next five years. This stockpile would serve the four main functions of:

(a) Supplementing open-pit production in the event of adverse weather or loading equipment hampering production;

(b) Supplementing production during shortfalls caused by the transition to underground mining;

(c) Supplementing production if any problems occur to affect production throughout the life of the underground mine;

(d) Supplying the plant during the construction of the waste mat for sub-level caving.

C. Schedule of operations

Broad estimates of development (annex VIII A and B) and schedules (annex IX A and B) give a feel for the timing of the proposed changeover. They indicate that in both cases the target is attainable. However, many unforeseen problems can and do occur in a five-year schedule. It is emphasized that speed is essential in this project, and every attempt should be made to speed up wherever possible.

The schedules are of the direct mining-related activities and obviously the necessary civil, electrical and mechanical activities would be tied in to suit this programme. Diagrammatic sections showing the extent of preproduction development are shown in annex X A and B.

Waste material

If a sub-level cave system is adopted it will be necessary to dump waste into the open pit over the two sections of the ore body. This must be done after the open pit operation has been completed and before a start can be made on underground production. It should be achieved by transporting ground back from the waste dump together with any waste removed from underground during this period.

Consideration should be given to raising the height of the waste dump by 5-10 metres. This would serve two purposes: first, it would shorten the haul distance releasing some truck capacity to help build the ore stockpile; second, it would provide for easier reloading for the waste required to be repositioned in the pit.

Extra ore requirement

A stockpile should be created, which means additional reserves would be required in the open pit. This could best be achieved by steepening the haul road from the 184 metres bench and deepening the pit by up to 14 metres. This could be achieved with minimal extra waste mining and should make about an additional 10 months of ore available from the pit.

II. DIKE MINING PROBLEMS

The expert visited the mine, although it is inoperative, viewing both the surface outcrops and the underground section. No improvements to the final mining method could be suggested based on this brief view and discussions held with local personnel. It was very difficult ore body with adverse country rock conditions and it is felt that the method described is the best alternative under the circumstances.

III. LECTURES ON DIAMOND MINING

The expert held three main lecture sessions lasting a total of nine hours, the subjects covered being:

(a) Examples of conversions from open pit to underground with particular reference to the problems involved;

(b) World methods in underground diamond mining;

(c) World current trends in underground diamond mining.

These lectures appeared to be well received and provoked much discussion. In addition to these the expert held discussion sessions with local personnel on the following subjects:

Higher technical education in England and South Africa

Diamond mineral processing techniques

Mine design systems and techniques

Diamond ore deposit geology

Mine community life in England and South Africa

These sessions also seemed to create a lot of interest and each discussion period was about 1 1/2 to 2 hours in duration.

IV. OBSERVATIONS

During the period spent at the mine the expert had a chance to view most of the existing operations and wishes to record certain points for completeness of this report and for possible future action by local personnel possibly with assistance from outside experts.

A. Pit operations

The general condition of the pit is fair but more attention should be paid to haulroad and loading area ground surface conditions. This should pay dividends in reduced tire and maintenance costs for trucks and loading equipment and increased productivity.

Fragmentation problems exist here as in most kimberlite operations. However it is felt that the drill hole size could be reduced with closer burden and spacing of holes. Also the explosive efficiency quoted of 0.5 kg/m^3 is too high and consideration should be given to increasing the explosive charge per cubic metre of kimberlite.

B. Plant operations

The plant operation is somewhat inefficient due to its stop/start nature. Also the equipment design and operating parameters are probably not optimum. Local personnel indicated a desire for assistance and advice on process plant operation. Dust control seems to be ignored in this plant compared to most diamond process plants elsewhere.

C. Managerial ability

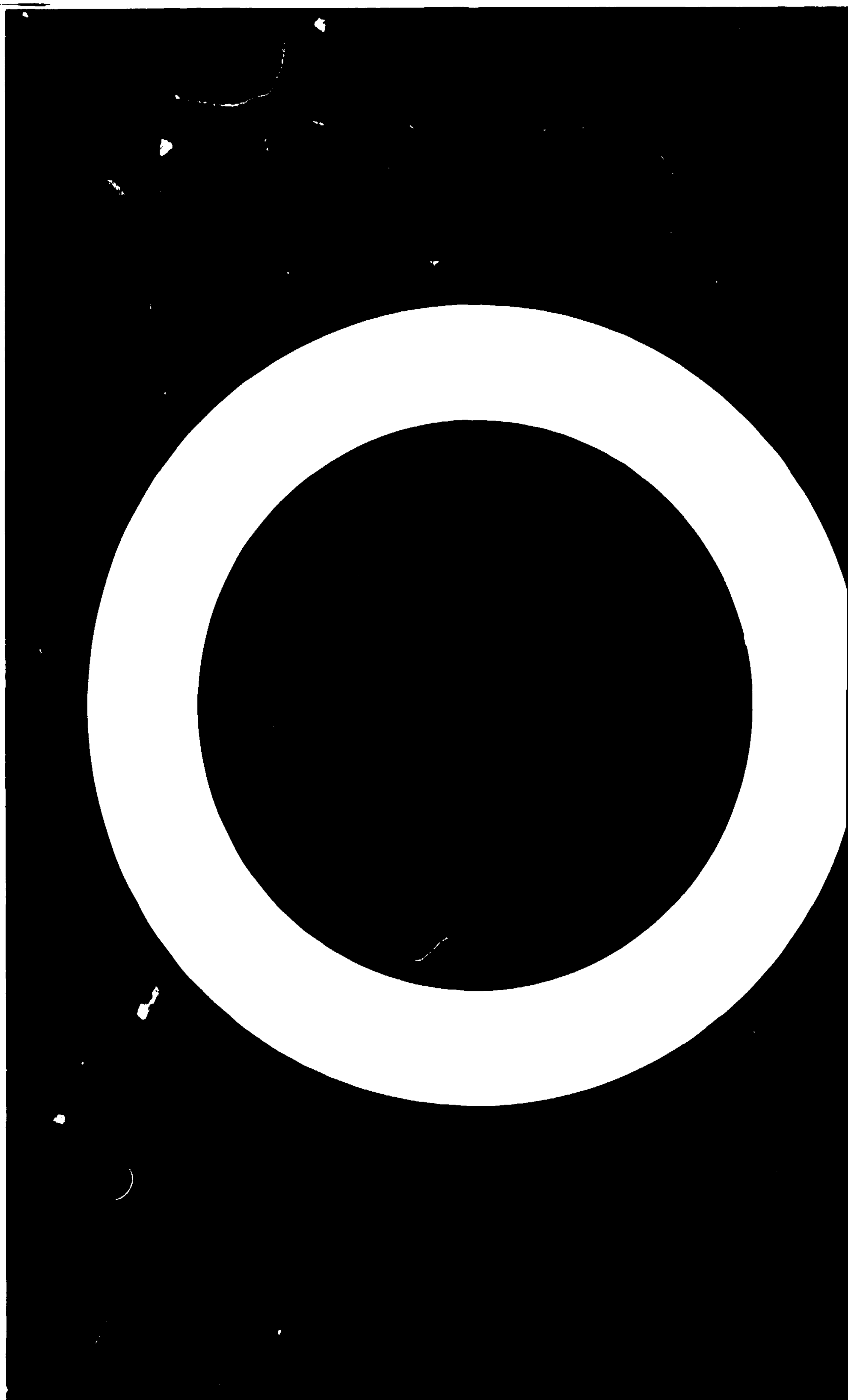
There was a desire to improve managerial ability by senior staff and many requests to know how to motivate staff. Assistance in this field would be welcomed.

D. Financial justification

There was a general desire to know how Western businesses would conduct economic comparisons and financial justifications. The existing systems in China make this very difficult to explain, but assistance in this field is obviously felt to be needed by local personnel.

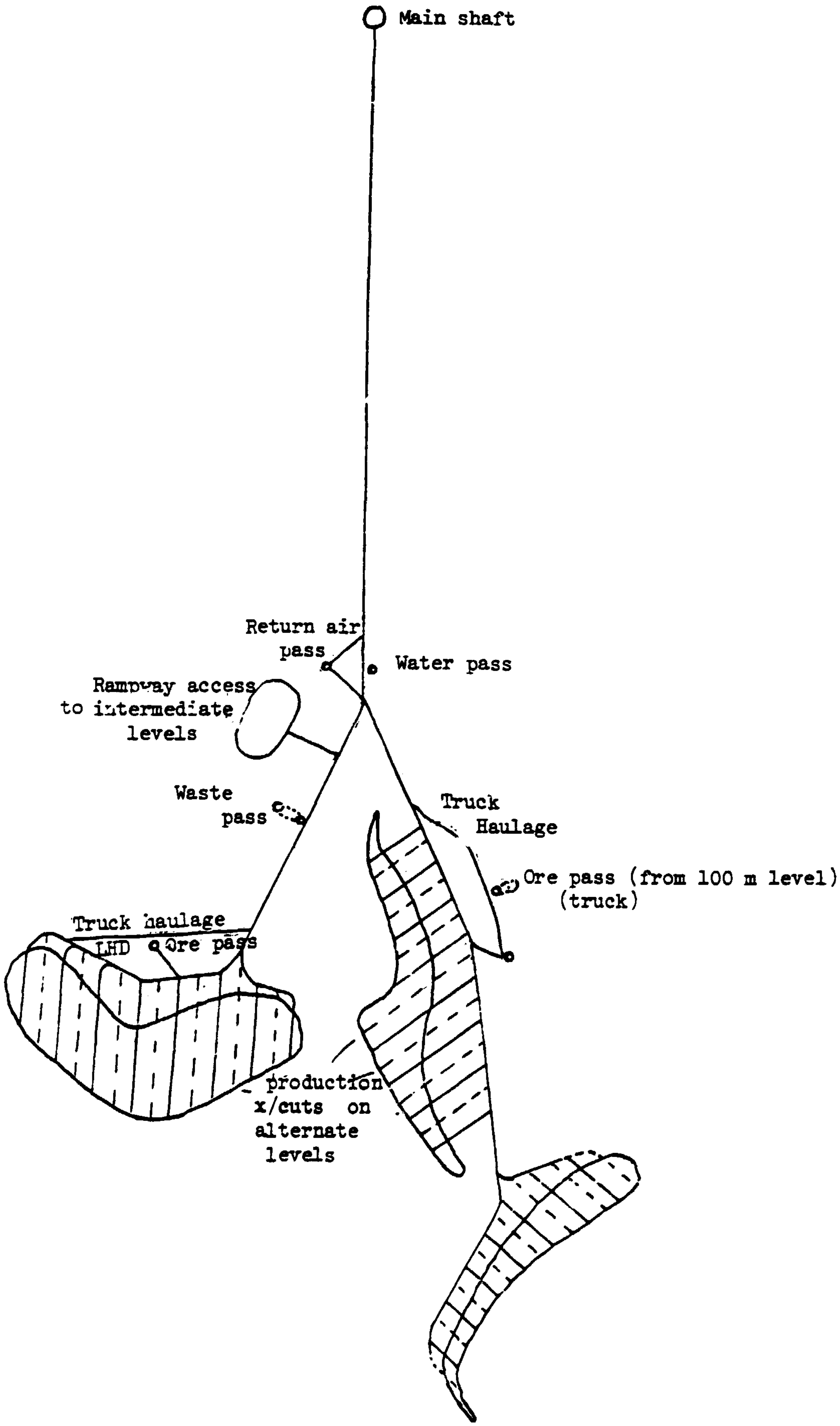
E. Safety

Safety standards are far behind most operations known to the expert. When this was mentioned all local personnel agreed and said that they wished to improve this aspect of their operations.



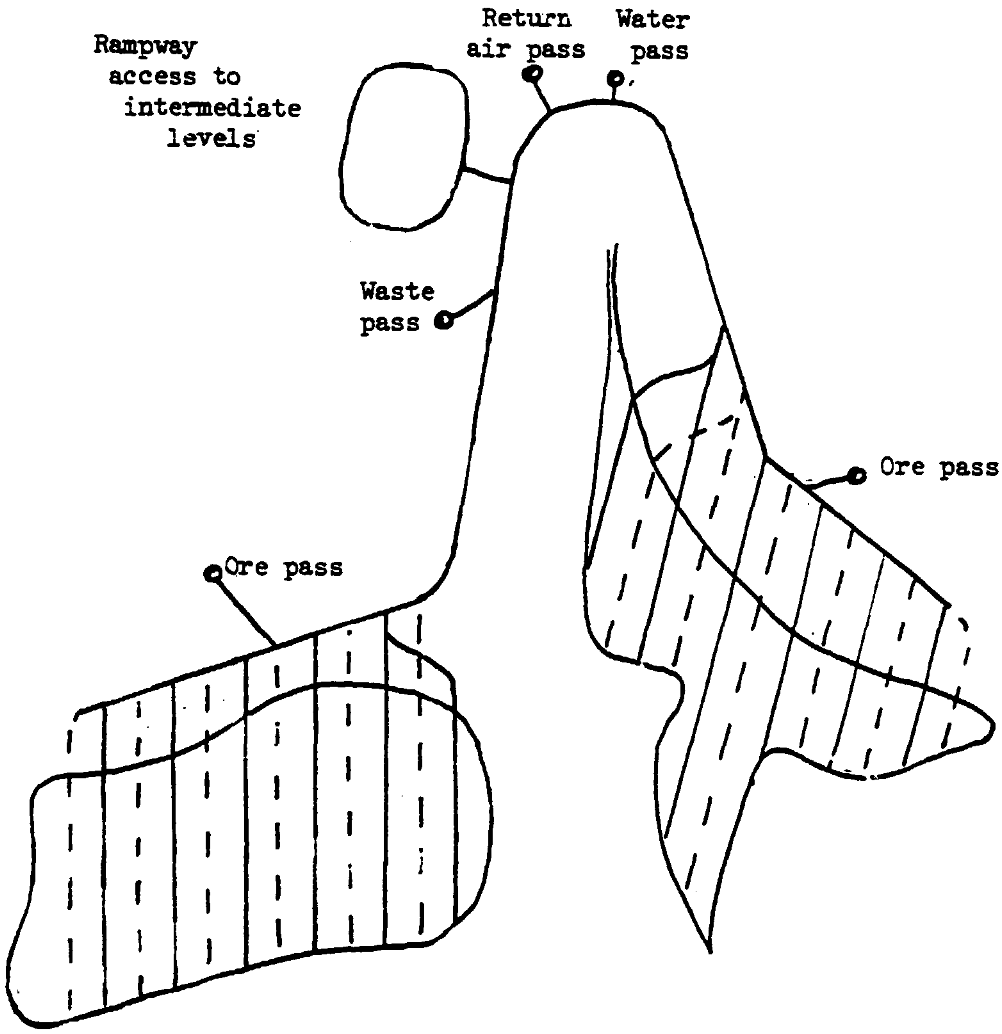
Annex I

SUB-LEVEL CAVING LAYOUT - 200 m LEVEL



Annex II

SUB-LEVEL CAVING LAYOUT - INTERMEDIATE LEVEL (± 100 m LEVEL)

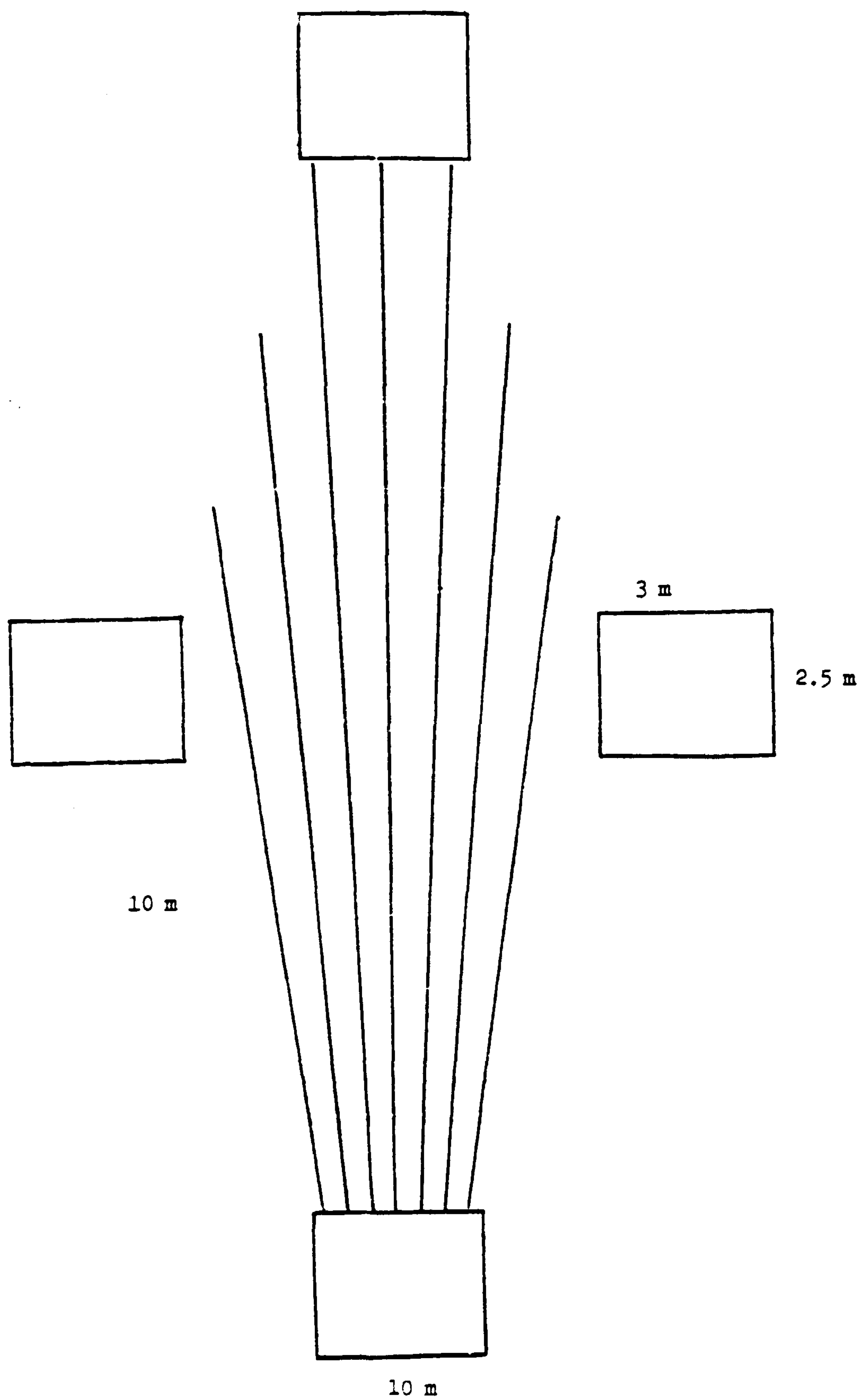


Annex III

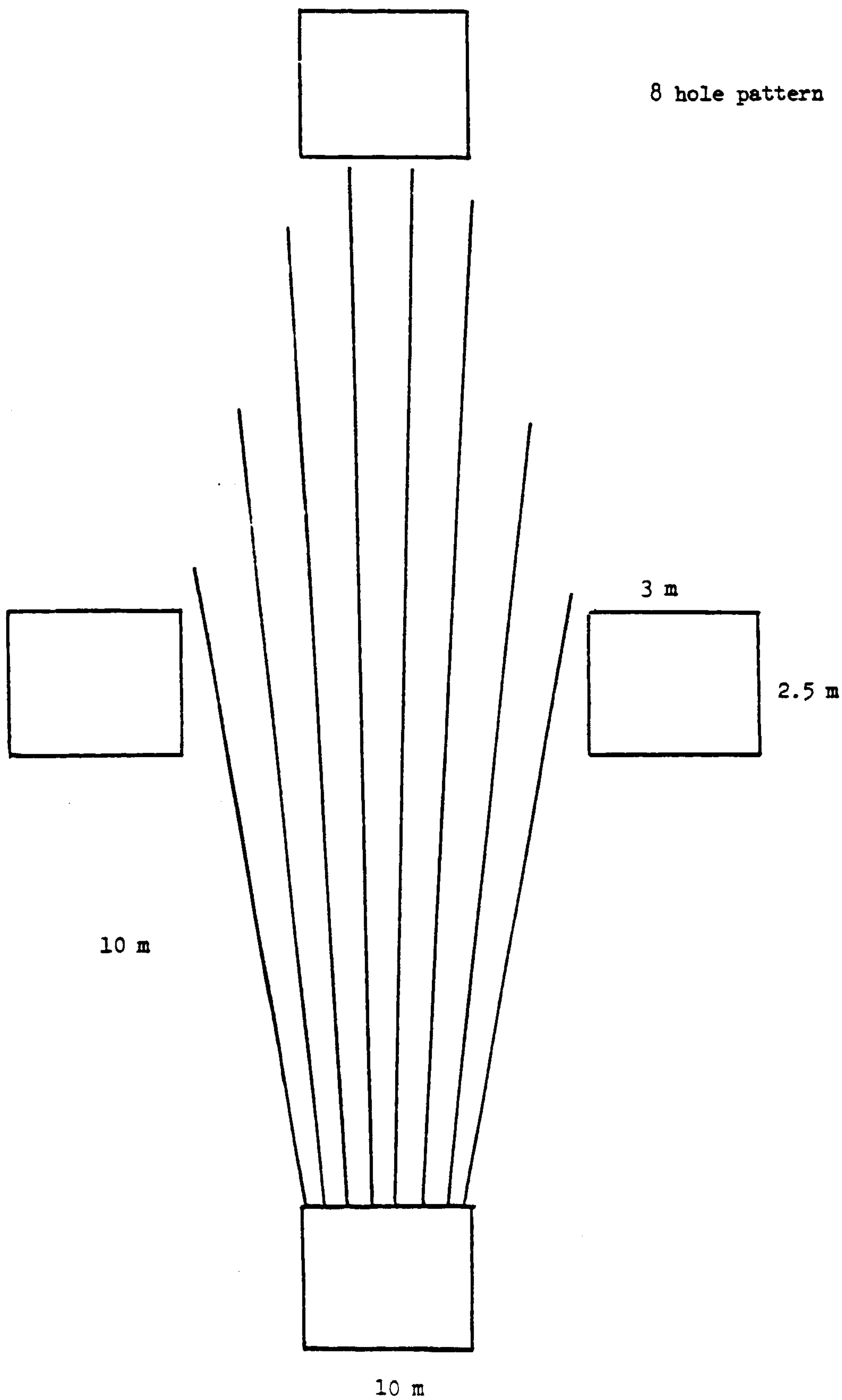
SUB-LEVEL CAVE

POSSIBLE TUNNEL SPACING AND DRILL HOLE PATTERNS

A. Seven-hole pattern

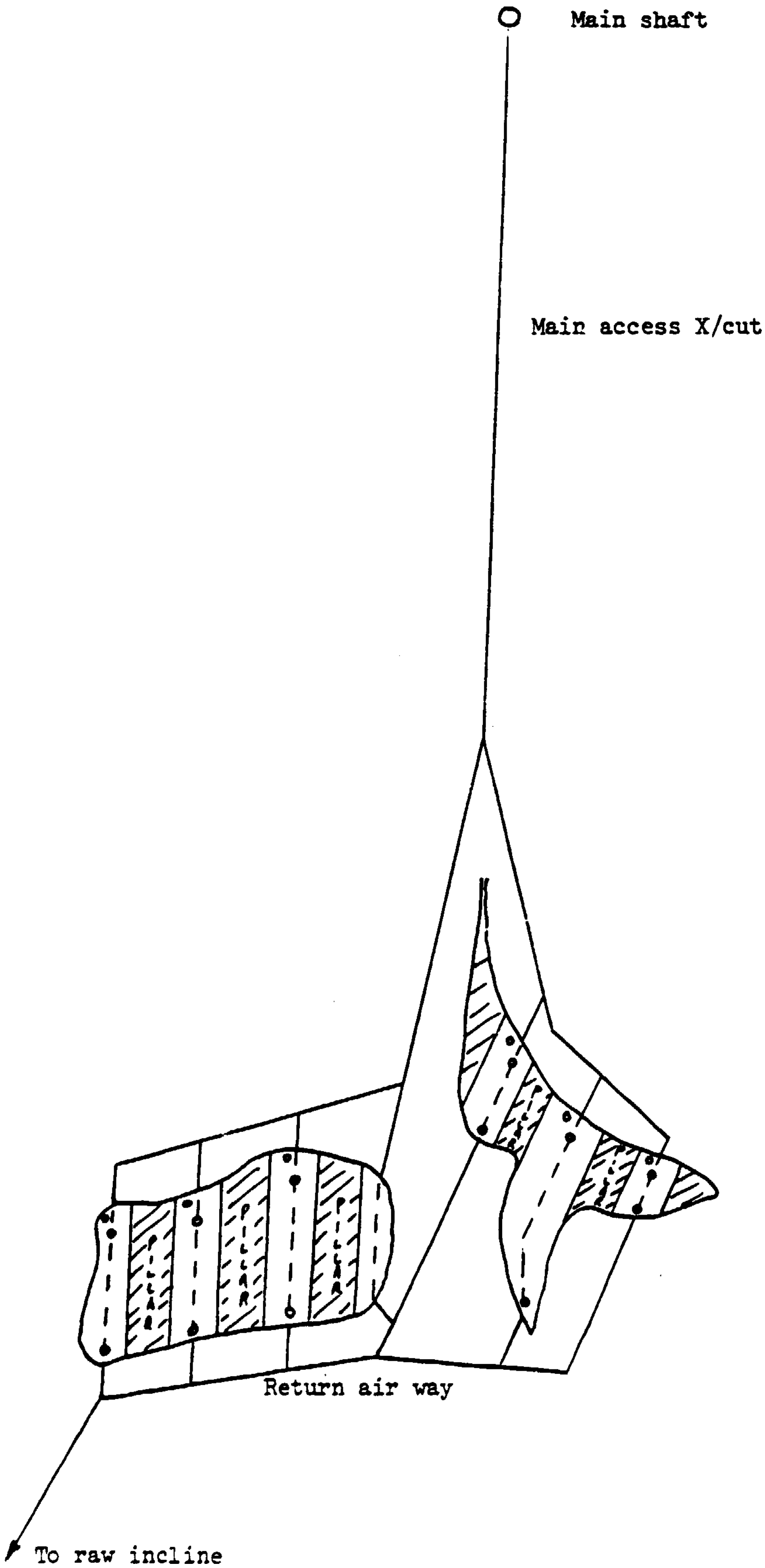


B. Eight-hole pattern



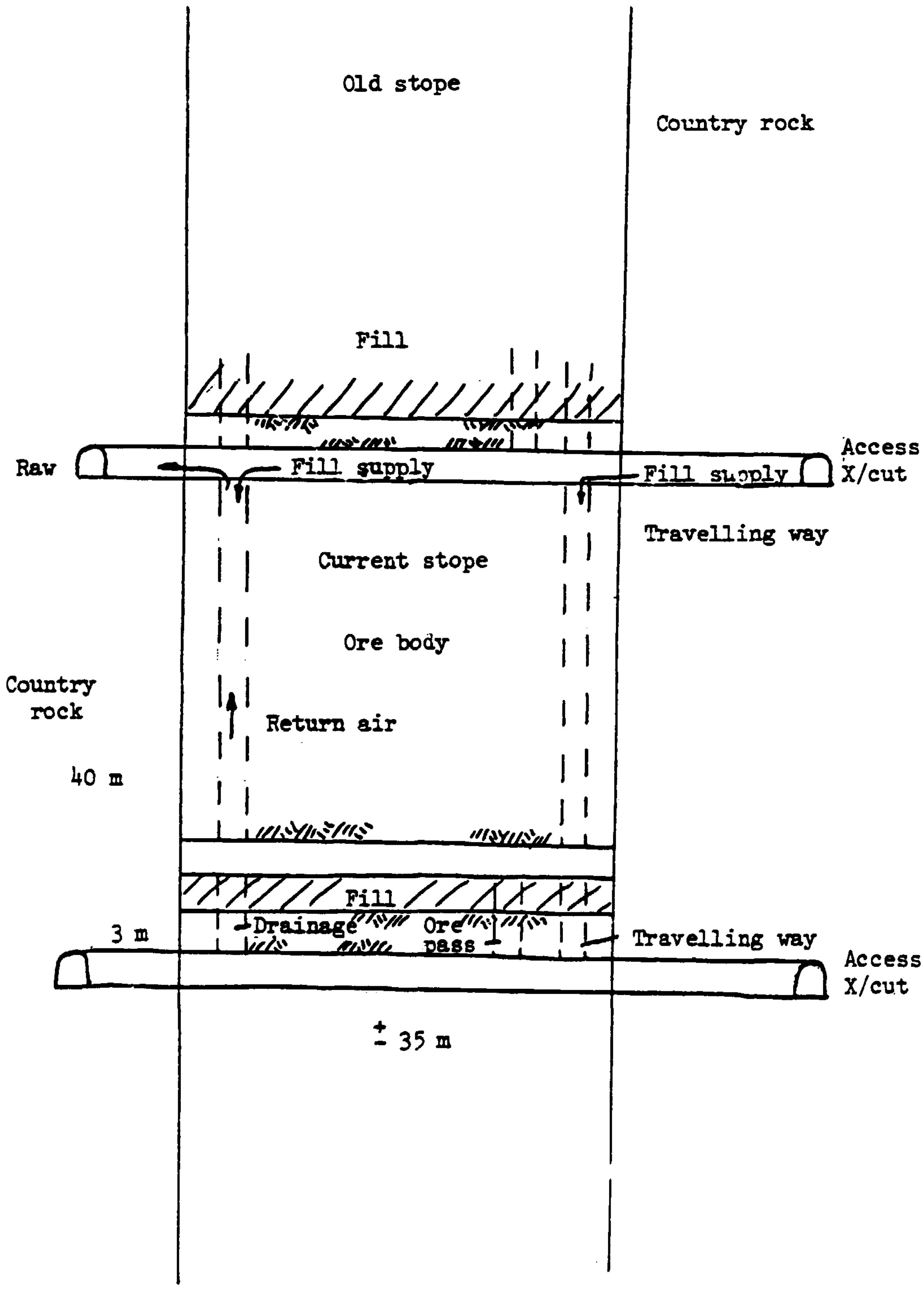
Annex IV

CUT AND FILL STOPING LAYOUT - 100 m LEVEL



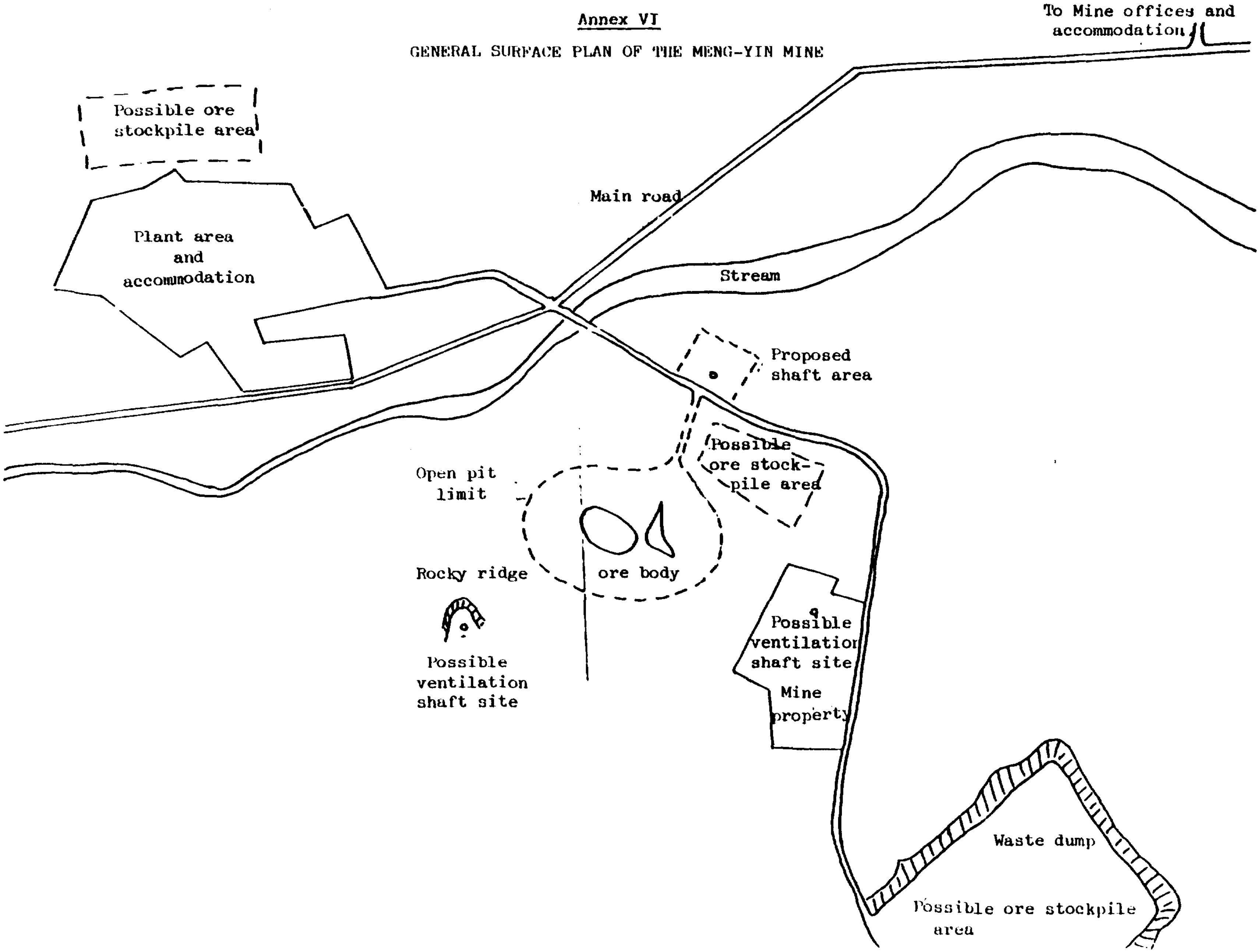
Annex V

DIAGRAMMATIC SECTION OF CUT AND FILL STOPE DEVELOPMENT



Annex VI

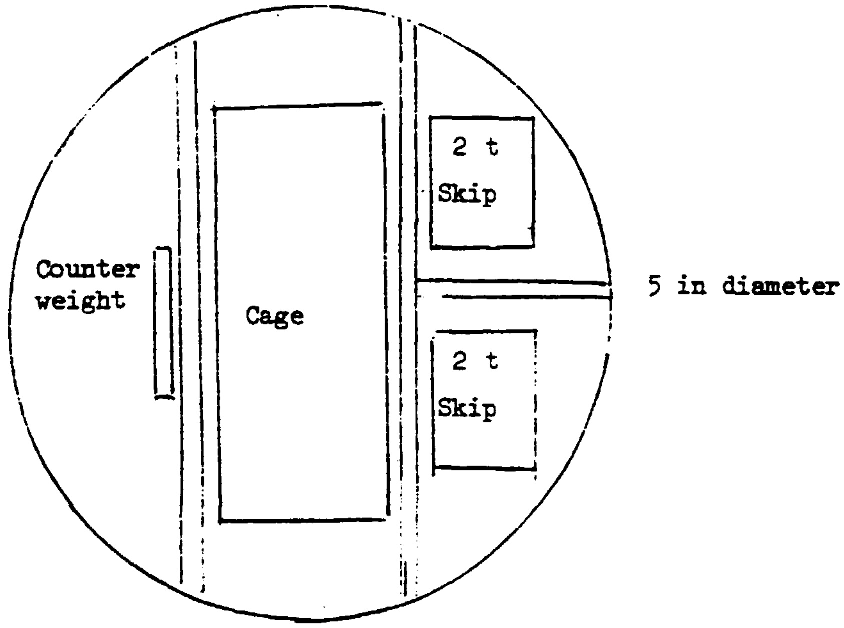
GENERAL SURFACE PLAN OF THE MENG-YIN MINE



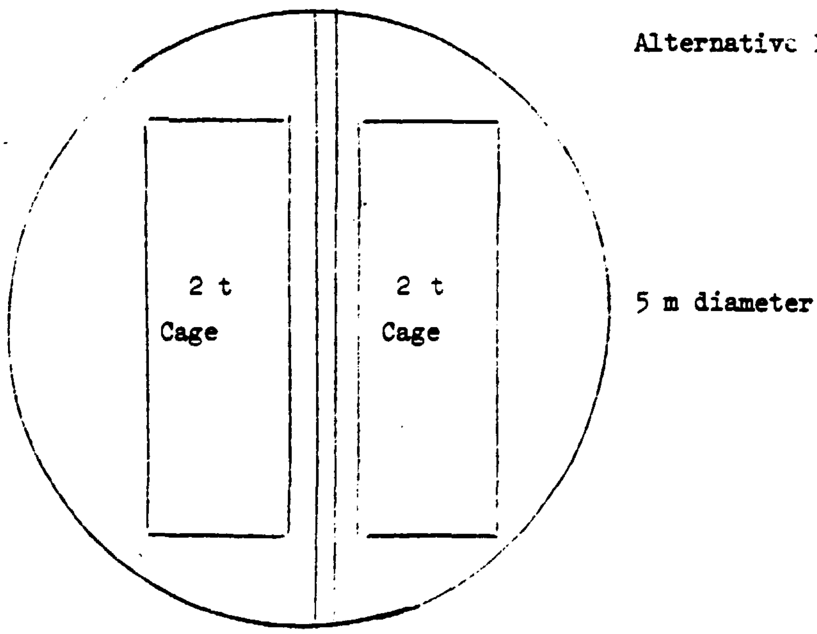
Annex VII

ALTERNATIVE SHAFT LAYOUTS

Alternative A



Alternative B



Annex VIII

ROUGH ESTIMATES OF PREPRODUCTION DEVELOPMFNT

A. Sub-level caving method

		Level (m)	Depth (m)
Shaft sinking			305
Main access X/cut		120	200
		160	200
		200	50
		240	20
		280	200
Pump station			200
Water pass			160
Main return airway:	flat		170
	incline		170
Ore passes			80
Waste pass			40
Return air pass			50
Rampway			240
Production tunnels		120	760
		130	760
		140	550
		150	250
		160	300

B. Cut-and-fill method

	Level (m)	Depth (m)
Shaft sinking		305
Main access X/cuts	120	200
	160	200
	200	20
	240	20
	280	200

Pump station			200
Water pass			160
Main return airway:	flat		100
	incline		150
Ladderway			60
Production tunnels		120	805
		160	400
Stope development		120	840

Annex IX

CONSTRUCTION SCHEDULE

A. Sub-level caving method

1 2 3 4 5

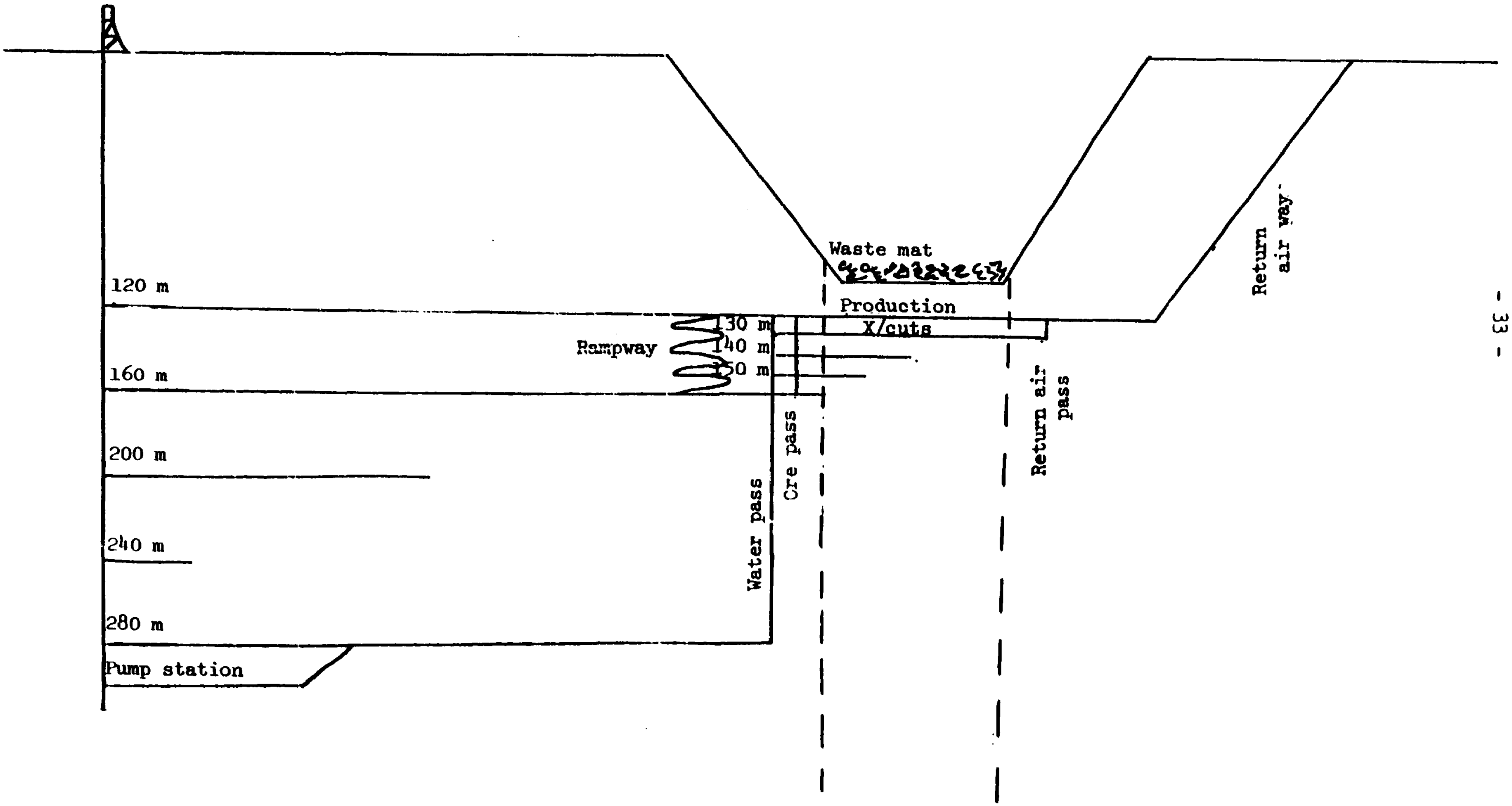
Planning and design
Government approval
Purchase of land
Site establishment/drilling
Shaft sinking
Station cutting
Equipping
Pump station
Access X/cuts
120 m production X/cuts (rock)
Main R.A.W.
160 m production X/cuts (rock)
Waste pass
Ore passes
RAW pass
Rampway
120 m production X/cuts (kimberline)
130 m production X/cuts (rock)
130 production X/cuts (kimberline)
140 m production X/cuts (rock)
140 m production X/cuts (kimberline)
160 m production x/cuts (rock)
150 m production X/cuts (kimberline)
Water pass
Waste material construction
Start production

B. Cut-and-fill method

Annex X

PREPRODUCTION DEVELOPMENT

A. Sub-level caving method



B. Cut and fill method