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Final Report

Evaluation of Coal Mining Operation at Moatize, Tete province in Mozambique

prepared by
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O. Executive Summary

In September 1989 UNIDO charged Montan-Consulting GmbH of Federal Republic of Germany with the task of evaluating the underground coal mining operations in the Moatize coal basin, situated in Tete province of Republic of Mozambique.

The contract stipulates recommendations with regard to

* method of work
* expansion of number of working faces
* introduction of mechanized mining
* blasting and mucking out procedures
* roof support
* repair/replacement of existing equipment

Main objective is the preparation of action plans for three production scenarios, representing the annual production capacities of

(Scenario A)	500,000 tons	-	from the existing underground mines
(Scenario B)	1,000,000 tons	-	using the underground mining potential of the Moatize deposit
(Scenario C)	10,000,000 tons	-	on the same basis as Scenario B

Next to an outline of procedures to be followed for each Scenario, the equipment investment costs should be estimated for budgetary purposes.

Field work was carried out during October and November 1989; the final project report was accepted by the Client in February 1990.

Among the known coal deposits in Mozambique, Moatize deposit is the richest and best explored. A major part of the coals can be classified as metallurgical coal with medium volatile matter, high ash, low water and low sulphur contents. As a Gondwana type coal, its quality is superior to others of the same type. Moatize coal is, therefore, a well established export product on the international coal market.

Production started in the forties. Since 1950 a railway connection to Beira exists which can be considered as the backbone of the mining activities at Moatize. Terrorists destroyed this vital connection to the export harbour in the early eighties to paralyse the coal transport. As a consequence, production of the mines had to be reduced to a strategic minimum for 7 years now.

As it is expected that the security situation of the country will improve in the years to come, the Government of Mozambique wants to look into the possibilities of rehabilitation of the Moatize coal mines, bearing in mind the considerable lead times until the mining activities in Moatize have recovered to their previous performance level.

This study is confined to the underground mining options, excluding coal transport to the coast and marketing policies etc.

As to the surface mining possibilities, it is referred to the studies being conducted by the Mozambican/Brazilian cooperation. Because of the probable higher utilisation of the reserves, these studies deserve particular attention.

After an intensive fact finding which covered preferably the geology of the deposit, the quality characteristics of the seams, the mineable coal reserve potential and the operational aspects of the existing mines, the following salient features affecting this study's objective may be emphasized:

- Though the deposit contains some 50 m thickness coal/area unit, only 4 - 5 m is mined by the Chipanga seam bottom slice. Rapid facies' changes with high mineral contaminations of the coal seams have resulted in this extremely high reduction of the mining potential.

- Size and layout of the mines are mainly determined by the pronounced fault pattern of the deposit. Two faulting directions are preferred. Fault displacements detected reach from hundreds of meters to below 1 m at spacings very unfavorable for mining.

- Occurrences of high gas emission rates of 60 m^3 CH_4/t_{rom} and more, limit the production capacity of a mine, since the mine air is not allowed to contain more than 1% CH_4 and air velocity and air cross-sections are pre-determined.

- The geological conditions dictate which mining method is best suited to yield highest profits under safe working conditions for the Moatize deposit. Room and pillar mining is the only method applied and well established. A review on whether and how the mining method should be altered, confirmed that under the prevailing geological conditions, the presently applied method should be retained. Nevertheless, operational improvements seem possible for future mining ventures in the deposit. Suggestions and recommendations have been presented.

- Due to the high methane release and the pre-determined cross-sections of the mine workings, there is no need to increase the production per working face. The productivity advantage of mechanized mining cannot be made use of.

- Successful mechanisation in other areas of the mine does not seem possible, as the working conditions are unfavorable.

- The cokability of coking coals is heavily affected by the coal storage time at the surface: After a period of 3 months' storage the Swelling Index drops from 7-6 to 3 and below. As a consequence production and selling must be harmonized accordingly.

- The currently operating Chipanga III and IV mines are facing depletion during the next years and can, therefore, be eliminated in the Scenarios.

- The basis for Scenario A is formed by the following input:

  - Chipanga VII mine (presently flooded) at a design capacity of 160,000 t.p.a.

  - Chipanga VIII mine after rehabilitation at a design capacity of 160,000 t.p.a.

  and

  - Chipanga XI mine (presently flooded) at a design capacity of 90,000 t.p.a.

  ____

  410,000 t.p.a.

  ==============

  To begin with, it is proposed to dispense with the construction of a coal washery, as the reserve potential is of fairly good quality.

- In addition to Scenario A, four completely new mines, each with a design capacity of 120,000 t.p.a., have been planned for Scenario B in exploration Section 5 and the Central Section. The target production of Scenario B thus arrives at a figure of 890,000 t.p.a.

  In the case of Scenario B, the construction of a new coal washery will be required.

- Scenario C is not feasible due to geological and operational constraints. A number of some 70 mines would be required to achieve the annual production of 10,000,000 t.p.a.

In Chapter 7 of the Study proposals are outlined as to how the working conditions/procedures of the currently practised method could be improved by the introduction of new systems, new materials and new technologies. The recommendations aim at improved operational and economic results and also at improved mine safety.

Based on the information, data and findings compiled so far, Action Plans for the three Scenarios have been developed.

Action Plan Scenario A

After a 4 years' construction period, the envisaged target production of 410,000 t.p.a. will be reached and can be maintained over a period of 10 years without additional mine capacities to the three existing mines.

Annexes 8 to 13 provide details on production, required activities and their timing, as well as the required capital for the procurement of equipment. The amount of 32 million US$ fob as of 1989 has been estimated for equipment investment costs.

Action Plan Scenario B

In addition to the existing mines, 4 new mines will have to be developed to achieve the target production. A construction period of 9 years has been considered necessary under realistic circumstances.

Since the quality data of the reserves so far explored in Section 5 and the Central Section are certainly inferior to those of the existing mines, the construction of a coal washery was included in this scenario.

Analogous to Scenario A, details on production built up, required scope of activities and their timing are laid down in Annexes 9 to 11, 13, 14 and 15.

The estimate of equipment investment costs for budgetary purposes arrived at some 92,5 million US$ fob as of 1989.

Of the two Scenarios, Scenario A is considered the more realistic, reliable and economically advantageous one.

1. Introduction

For seven years now CARBOMOC's mining activities have been suffering from the interruption of the railway transport between Moatize and Beira. As a consequence, the coal production was reduced to below 100,000 t.p.a., a quantity which is far below the economic break-even point and no longer enables the company to run profitably.

There are hopeful indications that the political situation of the country may improve and guerilla attacks to the vulnerable railway line can be excluded for the future, thus permitting the preparation of a restoration of the Moatize mining operations at the previous production level of 500,000 t.p.a. and even an expansion of production at higher levels.

UNIDO, on behalf of CARBOMOC, invited international tenders to evaluate the current mining operations at Moatize, prior to detailed planning of major rehabilitation works. The respective contract was awarded to Montan-Consulting GmbH, FRG in September 1989.

The Terms of Reference stress two major objectives:

1.) Recommendations on the following topics are expected, in view of an increased production:

- a different method of work
- expansion of the number of working faces
- introduction of mechanized mining
- changes in the current blasting/mucking out procedures

- method of roof support
- repair or replacement of existing equipment

2.) The main component of this report should be the development of plans of action for 3 production scenarios:

a - at 500,000 t.p.a. (as already achieved in 1981),

b - at 1,000,000 t.p.a. (estimated to be the overall design capacity of the 5 existing mines),

c - at 10,000,000 t.p.a. (including the expansion of mining operations to other sections which are sufficiently explored).

These plans of action should define the necessary steps to be taken for the sustained achievement of the respective target production. They should include budget cost estimates for equipment repair/replacement, found to be essential for the implementation.

The study will be confined to the technical aspects of underground mining in the Moatize coal basin. Neither coal transport to Beira nor the mining potential by open-cast mining will be considered in this report.

2. Execution of Work

The study commenced in the middle of October 1989, when a team of three engineers left for Mozambique. Following initial contact meetings with UNIDO in Maputo, as contract counterpart and with the Gabinete do Programa do Carvao (GPC), the responsible Mozambiquanian Authority for the promotion and development of the country's coal resources in Maputo, the team stayed for two and a half weeks in Moatize with CARBOMOC, the operating company.

The local fact finding process in the operating mines was assisted by the technical management of operations who was very obliging in offering any support desired.

The chief-geologist of the Regional Government at Tete acted as liaison officer during the field work.

Back in Maputo the key facts and findings were discussed in close cooperation with UNIDO and GPC:

End of November 1989 the team of experts returned to Germany to finalize this report.

As a basis of the report, the following information was made available:

a.) Programa do Carvão de Moatize
for Ministério dos Recursos Minerais
Gabinete do Programa do Carvão

from Grupo Portugués:
EDP, CIMPOR, CONSTRUCOES TECNICAS;
TEIXEIRA DUARTE, PARTEX-CPS 1987

Technological Concept for Development of New Underground Mines of MOATIZE/MOÇAMBIQUE for Empresa Nacional de Carvão de Mocambique from AUSTROMINERAL GmbH, Vienna, Austria 1985

Relatório sobre pesquisa preliminar da Secção Central do jazigo de Moatize (Provincia de Tete, RPM)
for Ministério dos Recursos Minerais
Instituto Nacional de Geologia
Delegação do Ministério dos Recursos Minerais/Tete
from V/O Zarubezhgeologia, USSR 1987

Relatório final sobre trabalhos geológicos de prospecção e pesquisa pelo carvão na bacia carbonífera de Moatize R.P. de Mocambique - Projecto Moatize II 1981 - 1984
for Ministério dos Recursos Minerais
from LIMEX-Bau-Export-Import (Kombinat Geologische Forschung und Erkundung (GFE), Halle R.D.A.

b.) Various discussions with all parties involved

c.) Mine visits underground and at surface

d.) Documents received from the technical mine management, e.g. mine maps, statistical data, geological information, operational data etc.

Due to the inferior quality of all the mapping documents received, these could not be copied and, therefore are not annexed to this report.

3. Geology of the Moatize Coal Deposit

As basis for this study, a brief summary of the known geological facts was found indispensable. For more in-depth information, reference is made to the "Technological Concept for the Development of New Underground Mines at Moatize" prepared by Austomineral GmbH, Vienna in 1985, Chapter 4.

3.1 Location, general description

The Moatize Coal basin is part of the Moatize-Minjowa coal basin and is situated N.E. of the Zambesi River, about 20 km NE of the provincial capital of Tete.

The coal deposit comprises an area of some 250 km^2 and occurs in the drainage region of the Moatize, Revubue and Murungoze rivers. It is oriented in NW-SE direction along a prominent graben extending approx. 50 km along the strike of the deposit.

The existing deep mines are located on both sides of the meandering Moatize river, in the vicinity of Moatize.

The coal-bearing Karroo sediments are surrounded by Precambrian crystalline basement. The graben structure is mainly characterized by the northern boundary of the syncline which is defined by a major fault, the Border Fault ("faille bordière").

For general orientation see Annex 1.

3.2 Stratigraphy

The formation of bituminous coals in the southern hemisphere is attributed to the so-called Gondwanaland, which is correlated to Permian Age. Thus, the conditions of coal formation distinguish remarkably from those in the northern hemisphere. This is a fact that cannot be emphasized enough when dealing with the deposit's characteristics.

The Moatize coal basin is bedded in a crystalline basement complex of Precambrian Age and made up of sediments of the lower Karroo formation. Dikes of doleritic composition cut through the Karroo sandstone-shale-coal formation. They are even younger than the major block-faulting of the graben structure.

Only the strata of the lower part of the Productive Series which contain the Chipanga Seam are of significance for mining purposes. Of the 6 seams in the sandstone-shale sequence of the Productive Series, this is the only seam containing a mineable section at the bottom, called "bottom slice", with more than 4 m thickness. The coal-bearing measures are attributed to the lower Permian (Mid to Upper Ecca) Age.

The important lower part of the Productive Series includes at the bottom basal conglomerates called tillites, corresponding to Upper Carboniferous strata (Dwyka).

The standard stratigrafic section of Moatize coals is shown in Annex 2.

Most probably of Jurassic Age are the doleritic dikes which cross the sediments in many places and represent a severe mining constraint.

3.3 Lithology

The Basement Complex and Tillite Series are of the typical composition found in other Gondwana coal deposits, e.g. in South Africa.

The Productive Series comprises a sequence between 244-470 m in the Moatize basin, on average 325 m.

It consists of shales, mudstones, siltstones and fine sandstones with varying carbon contents that give them a dark colour. The strata are subject to frequent and rapid facies changes, both in the host rock layers as well as in the proper coal seams.

The seams generally have high ash contents and are contaminated with frequent clay-silt-sand interbeddings of a few millimetres up to 1 m thickness. Due to these barren intercalations with frequent and abrupt lateral facies changes, the economic value of most of the seams with their otherwise impressive thickness is notably reduced.

Even the Chipanga Seam, considered to be the only seam worth mining, with a total seam thickness of 34.80 m contains only 67 % of coal in the standard seam profile. Only a few seam slices in the lower seam are sufficiently clean and persistent with regard to their lateral extension, to qualify them for systematic underground exploitation.

This Chipanga "bottom slice" is developed within the whole Moatize basin with the same quality having an average mineable seam thickness of some 4-5 m. Throughout the Moatize basin a shale intercalation, called "Xisto normal", 10 cm thick, about 10 cm above the seam floor, is a typical marker horizon which is of great help for correlation purposes.

The composition of the floor of the worked seam is also of importance for mining purposes. Locally known as "Muro", this hard silt/sandstone with a sleek surface greatly facilities scraping of coal in the existing underground mines.

As with other Gondwana coal deposits, doleritic intrusives occur in the Karroo continental sediments.

In most cases they appear in the form of moderately to steeply inclined tabular bodies, cutting discordantly through the sediments; sill-like formations have only been observed in a few locations. Due to their homogenous composition and hardness, freshly exposed dikes present problems of penetration.

Thicknesses vary between less than 1 m and up to 50 m (the Great Dike). Coal in contact with the intrusives has thermally been altered to natural coke and is no longer worth mining.

3.4 Structure

The Moatize coal deposit is bound to a NW-SE trending graben which is characterized by a major fault pattern. The most prominent structural feature of the coal basin is the large Border Fault ("faille bordière") in the NE, extending over 30 km in a straight line and dipping some 45^{o} towards SW. The border of the graben on the SW side is formed by the 4 km long steeply dipping Mt. M' Pandi Fault and a stepped fault system, limiting the contact between the coal-bearing sediments and the crystalline basement rocks, thus creating a series of fault blocks.

As typical for a graben structure, most fault displacements are "normal", which can be explained by an intense structural disruption, closely related to the stepwise formation of the Zambeze Valley further to the south. No reverse faults could be observed so far.

Generally speaking, the deposit is intersected by a well pronounced fault pattern that can be described for the currently mined area as follows:

- Great Border Fault : rupture of the Moatize graben in contact with the Precambrian basement complex, displacement 100 - 400 m, direction of strike NW-SE in a straight line over several kms, dipping angle some 45^{o} to 70^{o} to SW; in its southern forefield stepped fault blocks which form the subject of mining activities.

- Faults of > 25 m displacement are considered to be mining limits for the individual mines. Their direction is preferably rectangular to the Great Border Fault, i.e. in NE-SW direction.

- Faults of displacement between 10 - 16 m are encountered every 250 m, their direction of strike is also more or less in the dipping direction of the deposit, i.e. NE-SW direction. They occur over some 100 meters. Though posing mining problems, they can be mastered by the flexible adaptation of the layout of room and pillar mining.

- Faults of displacement between 3 - 10 m occur in an even closer spacing of 50 - 10 m, preferably in the same direction of strike as mentioned above, but also parallel or diagonal to the direction of the Great Border Fault or the direction of strike of the deposit.

- Faults of displacement between 0,5 - 3 m occurring every 30 - 50 m with preferred direction of strike, rectangular and parallel to the striking direction of the deposit, but also other directions are encountered.

  Frequently they are only present over short distances and often transfer into flexures which might emerge as faults in the close vicinity again.

  Furthermore, a dike system is exposed in the basin, preferring the NNW-SSE direction at some distance from the Great Border Fault; the dikes measure from a few meters thickness up to 50 m (the Great Dike), have an average dipping of 60 - 70^{o} and can hold their direction over several kms.

It is in fact the presence of intensive faulting in the Moatize deposit, in combination with the high ash contents of the seam coals why - under the prevailing conditions - only the relatively clean and in terms of quality constant bottom slice of the Chipanga seam is being mined in comparatively small mine units. The difficult mining conditions can best be characterized by the fact that in spite of extensive surface drilling in the future mining area of the existing mines, the actually encountered structural conditions reveal a much more intensive fault pattern than predicted by the drilling results.

To give an example of the faults encountered, but not to serve as representative for the deposit, reference is made to Annex 3.

Besides the faulting structure of the deposit, several synclines and anticlines exist. The dipping strata can be interpreted as part of a true folding process with the general NW-SE strike direction. The existing mines start from the outcrop of the Chipanga seam and follow the dip angle of 15 - 20° in the upper part, to reach moderate dip angles with increasing depth. The axis of the worked syncline runs parallel to the Great Border Fault. Once the syncline bottom has been crossed, the strata are sharply upturned at dip angles of 50 - 80° towards SW and finally cut off by the displacement of the Border Fault.

3.5 Other geological features affecting mining operations

3.5.1 Occurrance of methane

The high concentration of carboniferous matter in the Moatize basin on the one hand and the intensive fracturing of the whole rock body on the other hand, gives way to an easy and high emission of CH_4, a genuine product of the carbonization process, when voids are created in the rock massive by mining activities. The mining method itself can influence the process of deliberation of methane; in the case of room and pillar mining, as applied in Moatize, there are many mine workings open which need careful control to avoid methane explosions. If more than 5 % CH_4 is contained in the air currents of the mines, one sparkle caused by any reason whatsoever, is sufficient to initiate the known fatal mine disasters by a methane explosion.

The CH_4 rate varies greatly in the individual mines, 15 m^3/min is presently the highest value.

Referring to the production, the specific gas rate can amount to 60 - 150 m^3 CH_4/t_{rom}, which means that CH_4 can be considered as a safety risk, if intensive dilution below 5 % in the air is not protected by an adequate ventilation system.

3.5.2 Hydrogeology

Hydrogeological investigation results were not made available. However, statistical records of the current mine operations indicate that the average influx of water into the mine workings amounts to some 40 m^3/t_{rom} or 350 m^3/d.

Due to the shallow mining depth and the fractured rock body, water will infiltrate inevitably into the mine workings. The mines presently working are situated below the meandering Moatize River which forms the major source for these water influxes.

Water in a mine is considered a disagreeable phenomenon resulting in many disadvantages to the mine operations. Apart from additional special services to pump the water to the surface, the performance of the miners is remarkably reduced in several ways.

3.5.3 Rock mechanics

It is well known that the balance of tensions/stresses in the rock body is disturbed by underground mining. The effects of the induced inbalance of loads and stresses, depend on the geometrical dimensions of the mine workings and the natural properties of the surrounding rock. In the case of the Moatize basin, these facts must be born in mind when the rooms and the pillars are designed, in order to establish and maintain a new balance between load and strength of the natural rocks.

4. Coal Quality

Moatize coal is a bituminous coal i.e. coking coal with relatively high ash, low sulphur and very low moisture contents. Owing to its naturally high friability, it reacts rapidly with oxygen of the environment which results in a notable reduction of its originally good cokability, normally indicated by the Free Swelling Index (FSI). Indeed, the high proportion of naturally degraded grain sizes and stockpiling over longer periods (several months), represent serious problems for selling the Moatize coal on the international metallurgical market.

When speaking about Moatize coal, it must be recalled that this refers exclusively to "Chipanga seam bottom slice coal".

The total Chipanga seam can be generalized as follows:

Total thickness of Chipanga seam : 32 - 36 m
of this ~ 37 % rock intercalations, rejects

13 % intergrown material (≥ 35 % ash)
of this 8 % coal
5 % rock

20 % partings with changing layers of coal and intergrown material (> 25 % ash)
of this 15 % coal
5 % rock

30 % clean coal (≥ 15 % ash)
of this 25 % coal
5 % rock

Under optimal beneficiation conditions, this would result in

48 % coal
and 52 % rejects

The clean coal portion would yield the following qualities:

60 - 70 % coking coal of the fraction
0 - 11 mm (< 25 % ash)
30 - 40 % steam coal of the faction
0 - 11 mm (> 25 % ash)

The conclusion can be drawn that a maximum of 30 % of the total seam would yield coking coal under the premises of a wet beneficiation process. These are recent results from investigations in Chipanga VIII mine.

As the seam thickness and also the seam composition, particularly of the upper seam sections of the bottom slice, the so-called realça layers, vary in other areas of the basin, different results may be obtained.

The concentration of mining to the bottom slice of Chipanga seam can - to a major extent - be explained by the generally excessive ash contents of the r.o.m. coal from the other seams or seam sections and by their unsteady structural and quality characteristics.

Thus, all subsequent analytical and technological information refers to the Chipanga bottom slice only:

Average thickness 4,5 m (< 10 % dirt bands of shale so-called realça (Tonstein)).

Results of the last representative quality analyses carried out in 1989 by the Institute of Mining Research in Harare/Zimbabwe, comprising raw coals of the Chipanga III, IV and VIII mines. (Samples were taken at 3 different heights of the fresh coal face).

Proximate analysis air-dry basis:

Moisture	0.9 %
Ash	20.65 %
Volatile matter	18.01 %
Fixed carbon	61.35 %
Sulphur	0.79 %
Phosphorus	0.0098 %
Swelling Index	6 - 8
Calorific value	27, - 29,000 KJ/kg

These values do not differ from the averages of the last 20 years and permit a coal classification of low to medium bituminous coal with a medium Free Swelling Index.

In the dry-screening plant of Moatize, the following size distribution of the r.o.m. coal during 1989 (10 months) was recorded:

0 - 11 mm	66 %
11 - 25 mm	19 %
25 - 80 mm	11 %
> 80 mm	4 %

This is persistent with previous size distributions although an increase of the lower fractions, especially the fraction 0 - 11 mm, can be observed.

Size distribution within the fraction 0 - 11 mm:

0 - 0.5 mm	27 %	related to 66 % of the total r.o.m. coal
0.5 - 1.0 mm	11 %	
1.0 - 2.0 mm	22 %	
2.0 - 5.0 mm	22 %	
> 5 mm	18 %	= 82 x 0,66 = 54 %
	100 %	

The fraction 0 - 5 mm represents 54 % of the total r.o.m. coal.

Striking is the fact that the ash content in the fraction 0 - 11 mm is low, while it is high in the fractions > 11 mm.

The explanation can be given by the maceral analysis of the coal:

Mineral matter ~	10 % (preferably argillaceous)
Vitrinite	(49) - 77 %
Exinite	0,3 - 4 %
Inertinite	12 - 23 %

The high vitrinite content is responsible for the cokability of the coal and also its brittleness. The percentage of inertinite is typical for the Gondwana type coal. The basic material of inertinite consists of coatings of plant cells which during sedimentation of the dying plants, are bonded with argillaceous material, called the carbo-argillitic intergrowth. It is this process which causes the enrichment of high ash material in the coarse fractions, on account of the fine fraction.

<u>Facit</u>: The process of size degradation yields a low ash coking coal in the fraction 0 - 11 mm.

Quality analyses of the CARBOMOC laboratory for Jan. - Oct. 1989

Type of coal	Moisture %	Ash %	Vol. Matter % dry	Fix. Carb. % dry	Sul. % dry	Phos. % dry ash free	Cal.V. MJ/kg dry	Di-lat. %	Contr. %	S.I.
R.o.m. coal	3.0	22-26	23.0	56	0.9	0.036	35	64	18	7,5-8,5
Cok. c. < 11 mm	2.5	16-19	22.5	62	0.9	0.036	35	66	20	8 -8,5
Other fractions		> 30								

The CARBOMOC Laboratory practises a well established sampling and analyzing procedure in the mines, on the stocks and the screening plant, to control the company's selling product, as far as quality values of the <u>operating coal mines</u> are concerned.

Systematic quality analyses from the <u>exploration sections</u> are confined to moisture, ash content and volatile matter.

For these sections, too, exploration results revealed that the Chipanga seam "bottom slice", with respect to the constancy of seam structure and quality, proved to be the most economic seam worth mining.

The following table gives a summary of analyses from 268 exploration drillholes which were sunk by GFE-Halle in 5 different sections during 1979 and 1984

Sections	Chipanga Seam Bottom Slice		Clean Coal			
	Thickness	Clean Coal	Thickness	Ash	Volatile Matter	
	m	%	m	dry %	dry %	dry ash free %
1 (Chip. x)	4.85	92.0	4.46	18.3	14.9	18.2
2 A	-	-	-	19.7	20.4	25.4
3/1 (Chip. XI)	4.65	100.0	4.65	21.5	14.4	18.3
4 East	4.85	80.4	3.90	22.4	18.1	23.3
3 Centre	5.10	81.0	4.13	21.7	17.1	21.8
4 West	4.55	83.9	3.82	23.2	16.7	21.7
5 North	4.75	87.4	4.15	20.8	17.0	21.5
5 South	4.65	85.0	3.95	21.7	17.2	22.0
Average	4.77	87.0	4.15	21.3 ====	16.4	20.8

For comparison reasons, the average values of the other explored seams are quoted for the same sections

Seams	Total seam		Clean Coal			
	Thickness	Clean Coal	Thickness	Ash	Volatile Matter	
	m	%	m	dry %	dry %	dry ash free %
Chipanga total	36.76	59.3	21.81	26.7	17.4	23.7
André	2.78	(76.3)	(2.12)	(27.8)	(21.9)	(30.33)
Grande Falesia	11.30	63.4	7.17	28.2	19.1	26.6
Bananeiras	19.93	62.3	12.42	27.4	18.5	25.5
Sousa Pinto	22.67	37.4	8.48	28.9	16.5	23.2
Total average	93.44	55.7	52.05	27.4 ====	17.9	24.7

These figures may corroborate why even in the future, Chipanga seam bottom slice is the only seam considered for underground mining:
- relatively clean seam coal
- low ash of the clean coal

The most sensitive and adverse constituent of the Moatize coal is the ash content. Owing to its origin as Gondwana type coal, the fraction < 11 mm amounts to an ash content of some 18 %, while the fraction 11 - 80 mm shows an ash content beyond 30 % of the screened products.

Therefore, in this context, it is recommended to investigate the technical and economical feasibility of a coal washery, to improve the quality of the selling products and even extend the basis of the mineable seams with higher ash contents.

Volatile matter content is the leading indicator for the rank of a coal and thus its preferred utilization. Though in places considerable deviations have been analysed, the coal from Chipanga bottom slice can be classified as low-volatile bituminous. This, however, does not prevent the occurrence of high gas emission rates in the mines, which require clarification of this up-to-date unsolved phenomenon.

Coking tests by GFE-Halle on clean coal samples with a cut-off of 1.4 g/cm^3 density, indicate that coking properties follow a regional trend, i.e. they deteriorate in the western part of the Moatize deposit as shown below:

Origin by Sections	Ash dry %	Volatile Matter dry ash free %	FSI	Dilat.	G index	
3/1	7.7	15.3	-	-	0.965	
3/2 - 4	8.3	17.5	7.5	8	0.947	↑
4	7.8	18.7	7.5	11	1.005	increasing
Central Section	7.7	19.3	8.5	65	0.988	rank of coal
R.o.m. Coal	9.3	21.6	8.5	20	0.992	decreasing
2 A/5	8.3	22.5	9.0	68	1.027	coking
5 North	7.3	22.6	9.0	114	1.043	
5 South	9.8	24.2	8.5	72	1.030	properties
2A 1-4	9.4	25.5	8.0	111	1.035	

According to the international classification standard of coals, the r.o.m. coal from Chipanga bottom slice is classified as a low-volatile bituminous coal with modest to good coking properties, despite high ash contents. The code number is 434 (Vb).

It must be mentioned again that the coking ability of the Moatize coal, suffers considerably when the coal is stockpiled at the surface. Repeated analyses revealed that the FSI values had dropped from 6 - 8 to only 3 within a period of 3 months. This is a challenge for commensurate marketing, trading and shipping of the production, as far as coking coal is concerned.

5. Coal Reserves Calculations

5.1 General remarks

During the last 20 years, several coal reserve calculations were carried out for the Moatize coal basin, both for geological in-situ reserves and mineable reserves. Under the present mining conditions, the extracted r.o.m. coal is practically identical to mineable coal, since there is only a minor loss in the dry-screening process.

Calculations were executed by:

R.L. Thonnard	(1969 - 1973)
GFE-Halle,GDR	(1979 - 1984)
CARBOMOC	(1981 - 1982)
Zarubezhgeologia, SU	(1985 - 1988)

There are fundamental differences with regard to area extension, coal quality and seam structure definition in these calculations, so that they are not comparable.

While THONNARD calculated the reserves of the entire coal basin and also indicated the mineable reserves of the Chipanga bottom slice coal, within the then valid concession area, GFE, Halle concentrated on the specific exploration sections 2a, 3, 4 and 5, focussing on mineable reserves of Chipanga bottom slice coal.

CARBOMOC's calculation is mainly concerned with the mineable reserves remaining to be extracted, by the presently operating Chipanga III, IV, VII, VIII and XI mines.

Applying a similar methodology to GFE, Halle, the SU geological team explored the reserves of Section 1 and Central Section, which is destined for underground mining.

5.2 Location of sections and their designation for underground mining

According to the most recent information (see Annex 1), only two sections are left for underground mining:

Section 5
and Central Section,

since the other sections are now being studied for open-cast mining.

Both sections are situated NW and W of the existing mining area.

Section 5 covers an area of some 3.6 mill. m^2 in the north western corner of the coal basin, adjacent to the mining area of Chipanga VII mine.

The Section 5 is divided into a northern and southern area by a major, tectonically complex graben and horst structure which is intersected by the Great Dike (50 m thickness).

The northern area extends over 1.4 mill. m^2 and forms a relatively uncomplicated syncline with a NNW-SSE striking axis. Its SW wing is cut off by the graben structure mentioned above.

The southern area, occupying some 1.1 mill. m^2, is situated in the structurally highest part of Section 5, its NE border is formed by the Great Dike.

The coal seams generally dip between 6° and 10° to SSW; local folding and tilting caused dips of up to 30°. The structure is characterized by relatively intense block faulting along NW-SE and NE-SW striking faults.

The Central Section covers an area of some 15 km^2. It is surrounded by and has common borders with Section 3, Section 4, Section 5 and the existing mining area. The Revubue River forms its NW border. As can be seen in Annex 1, this Section is by far the largest, enjoying the highest reserve potential, compared to the other exploration sections, excluding Section 2.

Prominent structural elements are the two parallel NW-SE striking tectonic zones 2.5 km apart, one forming the NW border of the Section, the other one, the SE boundary. Their displacement measures 300-400 m. The area between them is intersected by a block faulting pattern with displacements of 30 to 90 m. The striking direction of the faults runs parallel or perpendicular to the general strike line of the tectonic zones. Thus 7 big blocks were created as potential mining areas.

As to the mineability of the Chipanga bottom slice, it has to be stated that major areas in the west, center and south of the section are covered with more than 250 m thick overburden, excluding the application of room and pillar mining. It has to be thoroughly investigated which mining method of these reserves is best.

5.3 Criteria for the reserves calculation in the exploration sections

Since this report concentrates on the mining potential of the Moatize coal basin by means of underground mining methods and room and pillar mining is deemed to be the only feasible mining method, underground mining operations are restricted to the extraction of one slice only. The Chipanga seam bottom slice was found to be the one slice that can be mined with the most economic results out of all the other seams in the Moatize basin. Therefore, all reserve considerations are restricted to the reserves of this part of the deposit in the following.

(It is emphasized that these aspects are not valid when considering open-cast mining).

The following standard criteria for mine development issued by CARBOMOC are observed, as far as the reserve calculation of the exploration sections are concerned:

- Designated reserve areas are not to be cut by faults with a vertical displacement of > 25 m, as faults of this size are considered as being natural mining limits.

- Minimum thickness of mineable seam 0.75 m.

- Rock intercalations ⩾ 0.5 m and multiple coal plies ⩽ 0.25 m interbedded with waste partings < 0.25 m were not considered as reserves.

- coal layers ⩽ 0.5 m intercalated with waste bands of 0.5 m thickness were not considered as reserves.

- Partings of impure coal containing less than 50 % coal were not calculated as reserves.

- Density of in-situ coal 1.45 t/m^3

The reserve calculations distinguish three groups of ash content

< 25 %
25 - 30 %
30 - 40 %

As to FSI-values, a differentiation at number 3 should be applied

> 3 coking coal
< 3 steam coal

Excluded from the reserve calculation of the Chipanga bottom slice should be the crown pillar, comprising a section of 45 m below the surface.

As far as reserve classification according to the degree of information is concerned, 2 classes were distinguished

- C_1 and C_2 (corresponding to indicated and inferred reserves according to the U.S.-Bureau of Mines and Geological Survey nomenclature)

C_1 Class

Fundamental characteristics of the deposit and the technical mining factors are ascertained (by drilling). Reserve contours are determined by methods usually applied in an exploration campaign.

C_2 Class

Only limited information of the deposit to be explored is available to elaborate its fundamental characteristics and technical mining conditions. Information from the adjacent and already explored area may be used for exploration purposes, in order to close information gaps.

Geological in-situ reserves are only of limited value to a mining engineer. The coal quantity to be extracted and sold is the objective of his activities.

Therefore, in this report, pragmatically only the mineable reserves are quoted which result from the geological in-situ reserve by a series of deductions:

- Safety pillars are left to protect certain objects on the surface, e.g. principal roads, important buildings, rivers etc..
- To both sides of major faults tectonic barriers are considered in the mining layout.
- Also to both sides of doleritic intrusives, as this material is converted to natural coke. (2 x the thickness of the dike)
- The highest portion of reserve losses results from the pillars as essential constituent of the apppled mining system. Inherent to this system, the pillars take the function of roof support. The design of the pillars is a function of the geological structure of the deposit, of the depth of mining and of the safety factor which is required by the mining regulations.

  As shown in Annex 4 at depths of > 200 m, the reserve losses increase to some 79 % in the case of the Moatize Basin.

5.4 Results

Mineable coal reserves of Chipanga Seam Bottom Slice

Section 5 — explored by Limex-Bau Export, Import Kombinat Geologischen Forschung und Erkundung (GFE), Halle, R.D.A.

Section 5	Average thickness to be worked	Area	Total mineable reserves	Mineable reserves by ash content 1,000 t		
	m	1,000m^2	1,000 t	< 25%	25-30%	30-40%
Southern Part	3,65	1,064,5	5,300	3,840	1,130	0,324
Northern Part	3,62	1,360,3	6,980	5,040	1,940	-
Total Section 5		2,424,8	12,280	8,880	3,070	0,324

Extract from Table 95 and 102 of Relatório Final sobre trabalhos geológicos de prospecção el pesquisa pelo carvao na bacia carbonífera de Moatize, R.P. de Mozambique - Projecto Moatize II, 1981 - 1984.

Central Section explored by V/O ZARUBEZH GEOLOGIA, (Kußness basin) S.U.

Central Section	Average thickness to be worked	Area	Total mineable reserves	Mineable reserves by ash content 1,000 t		
	m	1,000m^2	1,000 t	< 25%	25-30%	30-40%
	-	-	58,268	-	20,832	37,436

Thereof 28,788 t mineable coal reserves of Category C_1 with ash content 30 - 35 %

Extract from Table 8.2 of Relatório sobre pesquisa preliminar de Secção Central de jazigo de Moatize, Provincia de Tete R.P.M. Estado dos trabalhos 1.06.1987

Summary	Mineable reserves	By ash content		
	1,000 t	< 25%	25-30%	30-40%
Section 5 Central Section	12,280 58.268	8,800 -	3,070 20,832	0.324 37.436
Total Sections	70,548	8,800	23,902	37.760
	100%	12,6%	33,9%	53,5

The total reserves left for underground mining are grouped into the reserve classes C_1 and C_2. They form a sufficiently large basis for future underground mining operations.

More than half of the reserves have an ash content > 30%. In comparison to the reserves of the current mining operations, the ash content is high. Consequently investigations are indicated to plan adequate beneficiation facilities, once mining in these sections is envisaged.

Certain reservation is indicated with regard to the mineability of the Central Section reserves as already explained above. This should mean an incentive for the investigation of this section in due time, to find an appropriate approach for mining.

5.5 Criteria for reserve calculations in the mining areas of the operating mines:

These criteria differ somewhat from those for the sections:

- Size of a mining area:	≥ 250,000 m^2
- Fault displacement limiting mining	≥ 25 m
- Minimum thickness of overburden in the seam outcropping area	≥ 15 m
- Maximum dip of strata/ seams	≤ 40^9
- Minimum seam thickness	≥1.80 m
- Intercalations of Tonstein	≤ 10 % of a panel
- Deductions for dolerite veins	2 - 3 x its thickness to both sides
- Deductions for faults	$X_D = \frac{\text{height of displacement}}{\tan x}$
- Ash content of r.o.m. coal	≤ 25%
- Density of in-situ coal	1.45 t/m^3
- Pillar losses	according to pillar design calculations

5.6 Results

The following tabulation reflects the reserve status of the 4th quarter of 1989.

Chipanga mines	Geological reserves mill. t	Mineable reserves mill. t	Area 1,000 m^2
III	1.5	0.10-0.13	165
IV	1.6	0.26	300
VII (now flooded)	4.2 (C_1) 6.5 (C_2)	1.30 1.20	800 1,350
	10.7	2.50	2,150
VIII	3.4 (C_1) 3.6 (C_2)	1.00 1.10	600 700
	7.0	2.10	1,360
XI (now flooded)	3.2 bottom slice 1.1 upper slice	1.30 0.36	500 320
	3.3	1.66	820
Total mines	24.1	6.62-6.65	5,595

As a rough average only one quarter of the geological reserves are calculated as mineable reserves with an ash content < 25%. Compared to the reserves in the so-called sections, the low ash content of the reserves of the operating mines is remarkable. This is a necessary condition as no coal washery is installed at the site.

5.7 Summary reserves

A total of approx. 77 million t of mineable reserves, allocated in reserve classes C_1 and C_2, are explored in Chipanga seam bottom slice of the Moatize coal basin and are awaiting their extraction by underground mining with room and pillar or other methods yet to be developed.

The calculation of reserves mineable by underground methods, is rather conservative, as there are more areas amenable to underground mining, as for example the planned mines Chipanga IX and X (2,5 mil. t altogether).

However, it should be emphasized again that mining of Chipanga seam bottom slice represents only a fraction of the coal resources of the Moatize basin.

The new approach to mine to total seam sequence, by opencast methods, deserves great attention.

6. Brief Characterization of the Moatize Underground Coal Mines

6.1 Historical background

Underground mining in the Moatize coal basin started in the early 40's, already applying the current extraction method of room and pillar mining. At the end of the 40's, Moatize was linked with the Beira harbour, by a 580 km long railway, enabling the export of coal and alleviating the supply of the mines.

Mining started from the outcrop of the seams André, Bananeiras and Chipanga but due to quality reasons, soon concentrated on the Chipanga seam bottom slice only. In the second half of the 70's, two severe methane-dust explosions happened, causing the death of hundreds of miners and the destruction of the mine installations; the Chipanga V and IV mines are closed ever since.

In 1978 all mines were nationalized and CARBOMOC took over responsibility for them.

The Chipanga III and IV mines which are currently operating, started production in 1957/1958. The Chipanga VIII mine which only opened up in 1976 is also in operation. The Chipanga VII and XI mines which are also young in age (with start-up in 1972 and 1980 respectively) were allowed to flood since 1983, as they were no longer needed to cover CARBOMOC's production target. The railway to Beira as the neuralgic point for the Moatize coal mining operations, had been paralysed in 1982 by RENAMO terrorists' attacks, thus resulting in a sudden stop of coal transport to the export harbour Beira.

This situation regarding cut-back of production is persisting for approx. 7 years. The revivement of the Moatize coal mines is fully dependent on the rehabilitation of the railway to Beira. Transport of coal to Beira by 30 - 40 t trucks as an alternative, proved to be uneconomic; that is to say, transport costs would have risen to 34 US$/t.

6.2 Moatize mining areas, mining method and layout of mines, status of mine developemnt

A brief description of the a.m. topics, describes in general the present situation which represents the basis for the subsequent conclusions stipulated by the contract.

The size and delineation of each mine are mainly dictated by the geological features of the deposit, the block faulting. On the other hand, the great Border Fault in the N and the outcrop of the seam in the S are natural limits, common to the existing mines, except for Chipanga XI mine. Thus, the mine extension in the dipping direction reaches 1,200 - 2,000 m, while that to the striking direction varies between 1,000 and 2,000 m. The application of room and pillar is restricted to a maximum working depth of some 250 m below surface. This depth in the existing mines coincides somehow with the elevation of the synclinal axis.

In the context of this report, the following areas are highlighted:

Present mining areas:

Chipanga III, IV, VII, VIII and XI mines.

Future mining areas:

Exploration Section 5 and Central Section.

None of the other areas are relevant for strategic considerations of underground mining in the Moatize coal basin.

It is well known that the Sections REVUBUE and CALAMBO, adjacent to the Moatize basin, represent huge coal resources but their present exploration status prohibits their consideration in this report.

The general mining method applied in all underground mines is room and pillar mining of the Chipanga seam bottom slice, the salient feature of it being the coal pillars which are left in-situ as they are destined to take over the function of a roof support. Its foremost advantage is its ability to adapt to the changing geological conditions - as is necessary in the case of the Moatize deposit, while its most adverse feature is its low recovery rate referring to the coal reserves. At a depth of > 200 m, the recovery rate is only 20 %, due to the necessary dimensions of the pillars at that depth. Annex 5 gives a graphic representation of the standard pillar dimensions complying with the mine regulations. Annex 4 indicates the panel recovery rates.

All mines have more or less the same type of access and panel layout. All mine workings are driven in the seam slice. They are developed from the outcropping seam by driving 2 - 3 main inclines along the seam dip (at some 15°), preferably in the centre of the defined mine take, thus allowing mining on two wings. One incline serves for intake air, manriding, coal haulage and material transport.

After crossing the crown pillar (45 m thick section below surface) panel development starts on both wings of the seam.

A set of three entries are driven along the strike of the seam floor every 140 - 230 m from the main inclines. The three entries are called

via superior (upper gateroad)
via de banda (central gateroad, haulage)
via inferior (lower gateroad).

Their centre distance depends on the working depth. The entries are connected by raises in certain distances for haulage, ventilation and manriding purposes.

A set of entries forms a mine level. A working panel is formed by the seam section between two adjacent levels and its lateral extension to the mine boundary. Each panel is subdivided into working sections by barrier pillars at some 120 m in the striking direction.

Annex 6 shows a scheme of a mine's layout, main and panel development.

Coal winning progresses from the upper levels to the lower ones, each panel being mined by retreating in the striking direction.

Panel extraction is performed in two stages: First, raises from the lower level are advanced to the upper level with a section of some 6 - 8 m^2. In the second stage, the section is enlarged by winning the upper realca layers of the seam slice and widening the width of the raise to some 16 m^2 in a retreating process. Winning is carried out by drilling and blasting.

Scrapers are employed for face haulage. This type of work organization and equipment has proved to be very flexible and adaptable to the local geological conditions. It should be recalled that the floor of the mine workings is neither even nor flat in either the direction of the dip or of the strike. This characteristic of the deposits is unfavorable for a more sophisticated and highly mechanized mining system.

The individual mines have attained the following development status:

Chipanga III mine has reached the syncline. Since the uprising limb beyond the syncline axis is step-faulted towards the Great Border Fault, the reserves of the mine are facing depletion in the next years.

Chipanga IV mine has already crossed the syncline axis and is preparing to mine the lower section of the uprising limb. Although it is also near the Great Border Fault, no fault has been discovered so far. This extends the mine's life some years over that of the Chipanga III mine.

Chipanga VII mine, being a young mine with relatively high reserves, is presently flooded. The mine is still developing towards the syncline axis and well prepared to contribute to CARBOMOC's production of the years to come.

Chipanga VIII mine, at present operated at a low production, that is exclusively originating from panel development, can be considered to belong to the same class as Chipanga VII mine, though it holds less reserves than that mine.

Chipanga XI mine, now flooded, has just developed 300 m of the main inclines. The mine had been started to conduct trial operations of mechanized working with the Austrian cutting machine AM 50. Due to adverse conditions, the test had to be suspended in late 1984.

At the same time, experimental mining in the upper slice of the Chipanga seam had been carried out. However, it was concluded that the coal is of inferior quality, and, therefore, not worth mining any longer.

6.3 Work organization

The current working times of the operating mines are:

Working times	Chipanga Mines		
	III	IV	VIII
Winning shifts/day	2	2	2
Haulage shifts/day	2	1	2
Maintenance shifts/day	1	1	1

Number of personnel employed with CARBOMOC in November 1989

	Pay roll	Shift attendancy
Mine workers underground	479	402
Workers surface	554	524
Employees	318	279
Total CARBOMOC	1,351	1,205

The average rate of absenteeism is approx. 11 %

Organization of the face crews

A face crew comprises 7 workers per shift. It normally works in two faces. The organization of this work is valid for development drivages and also in the proper production panels.

The face crews are assisted by special crews for support setting and repair and for transport of material and equipment.

The standard cross-sections of the mine workings are

Descenderia geral	(main incline)	12.0 m^2
Volta de ar	(ventilation incline)	10.5 m^2
Via superior	(upper gateroad)	6.2 m^2
Via de banda	(haulage gateroad)	8.7 m^2
Via interior	(lower gateroad)	7.5 m^2
Communicacoes	(cross-cuts)	4.4 m^2
Montagem e Desmontagem	(raises in the panel barriers)	6.2 m^2

The standard performances are fixed as follows:

	Rate of Performance m/shift	Production t/shift
Via dupla avanço Raises advancing	0.8 each	16
Via realça Raises retreating	0.6 each	20 - 30
Descenderia geral Main incline	0.55 each	20
Volta de ar Ventilation incline	0.55 each	20
Via de banda e via superior Haulage upper gate	0.8 each	19
Via inferior Lower gateroad	1.6	19
Montagem/desmontagem e paralela Raises in panel barriers	0.8 each	16

6.4 Selected technical data of the mine operations

6.4.1 Coal winning

Specific consumption of explosive (safety cartridges)	0.45 Kp/t_{rom}
Specific consumption of detonators	1.1 pieces/t_{rom}
Explosive consumption per hole	400 gr/hole
Meters drillhole per t_{rom}	1.3 m hole/t_{rom}
Standard length of drillhole	1.4 m
Drilling machine, type Victor flameproof, electrically driven	115 V 1.1 KW
Drilling performance	3 m/min
Consumption of drillrods	1 piece/1000t_{rom}

6.4.2 Coal haulage

Scraper haulage downstream the winning faces

Double drum scrapers

Driving performance	15 KW
Rope diameters	10/12 mm
Scraper box capacity	0.35/0.45 m^3
Maximum working length	120 m

Loading performance

during advancing	50 - 60 t/d
during retreating	60 - 80 t/d

Rope consumption	100m/1000t_{rom}
Consumption of return pulleys	2 pieces/1000 t_{rom}

Chain scraper conveyors

They are of a minor capacity of 80 - 100 t/h and serve as intermediate conveyors between the scraper haulage and conveyor belt haulage. Their length is up to 50 m.

Belt conveyor haulage

Technical specifications:

Drive rating	37 - 45 KW
Belt width	600/650 mm
Haulage speed	1.25 m/sec
Length (centre distance of drums)	up to 350 m in main incline
Haulage capacity	80 - 100 t_{rom}/h

Construction available

surface	870 m
underground	4,320 m
total	5,190 m

Belt length employed	10,400 m

Capacity of raw coal bunkers: 10 - 20 t

Load out bunker capacities (t)	Fraction < 11 mm	Fraction 11/12 mm	Fraction 25/80 mm
old screening plant	26	29	29
new screening plant	100	50	50

Capacities of railway waggon and truck fleet:

Railway waggon	40 t	pay load
Dumper Berliet	9 t	" "
Dumper Kraz	7 t	" "
15 Dumpers Leyland	31.5 t	" "

6.4.3 Mine support

In general, only the inclines are supported by square sets. Furthermore, in all places where the risk of roof fall is recognized, as is regularly the case in the vicinity of faults, supports are set in an orderly pattern. Standard support material is timber.

As far as geological conditions and the working procedure permit, the mine workings are not fitted with support. This means a tremendous saving of costs and in productivity when comparing the mine with other ones fully supported.

6.4.4 Ventilation

Main ventilation:	Chipanga Mines		
	III	IV	VIII
Air quantity exhausted by the main fan m^3/min	1800	1816	2519
Depression (mm W.C.)	74	96	84
Orifice (m^2)	1.32	1.17	1.74
Degasification ($CH_4 m^3/min$)	7.20	1.81	5.03
Gas emission during the production phase (m^3/min)	1.30	0.35	3.00
Gas emission independent of the production time (m^3/min)	5.90	1.46	2.03
Specific gas emission rate of the production phase (m^3/t_{rom})	15.5	3.1	61.1

Striking are the low orifice values and the high gas emission rates which pose problems with regard to the desired introduction of mechanized mining due to the high production rates.

Control air currents

Room and pillar mining in combinatin with high gas emission rates, demands special attention of the control of the open airways of a mine, in order to prevent gas concentrations.

The following ventilation constructions are installed:

Chipanga Mines	Air dams	Air locks	Air throttle devices	Air cross-overs
III	183	8	3	2
IV	184	10	10	4
VIII	11	5	15	2
Total	378	23	28	8

Average damming area to be constructed	5.5 $m^2/1000\ t_{rom}$
Consumption of cement	5.5 bags/1000 t_{rom}
Consumption of tiles	230 pieces/1000 t_{rom}

6.4.5 Water drainage

Due to the totally fissured rock body, all mines have to cope with water influxes and extensive pumping installations had to be assembled.

The total water influx was indicated at 350 - 380 m^3/d on average per year. During the raining season, the influx rates increase considerably, although there is a certain time lag.

As a rule, the water is pumped to the surface in three cascades for a fully developed mine.

Pumping equipment and capacities installed:

Main water drainage

number of pumps	18
individual pumping capacity	50 - 90 m^3/h
pumping head	95 - 240 m

Auxiliary water drainage

number of pumps
their overall pumping capacity 400 m^3/h

6.4.6 Supply of electric energy

Electric energy is the sole source of power installed in the mines; this means that no compressed air is available as is usual for coal mines.

The supply base is the Cabora Bassa hydroelectric power station some 150 km away.

A 6.6 KV line feeds all consumer points from the central receiving station. Upstream, the actual consumers are transformers of adequate capacities, installed to transform the current to the 550 V network line.

The overall installed electric power,	
0.5 KV line :	6.3 MVA
The effective load used :	2.1 MW

A breakdown gives the following distribution:

	Installed KVA (Transformer supply)	Effective load KW
3 operating mines	2094	1465
Screening plant	305	90
Workshops	155	108
Water supply	332	232
Miners' houses and other social installations	320	224
Remaining installations	3100	-
Total	6300	2100

Each mine is equipped with one underground transformer of 400/640 KVA.

Besides this, an emergency power supply is installed to avoid flooding of the mines and interruption of ventilation and water supply, in the event of main line power cuts. The two diesel driven generator sets have an installed capacity of 1016 KVA.

Because of the lack of a metering device, it is not possible to indicate the exact specific power consumption of the individual mines. According to estimates, this figure may be in the region of 20 KWh/t_{rom}.

6.5 Planning ratios of the mines

Specific drivage in coal		32.5 m/1000 t_{rom}
of which for		
main development	18.2%	
panel development	32.8%	
production area	49.0%	
Specific drivage in rock		1.5 m/1000 t_{rom}
Specific requirement of mine support		15.0 m/1000 t_{rom}
Specific gas emission		115.0 m^3 CH_4/t_{rom}
Specific quantity of mine water pumped		41.7 m^3 H_2O/t_{rom}
O.M.S. at the face		~ 2.85 t_{rom}/MS
Overall O.M.S.		0.675 t_{rom}/MS

Total length of open mine workings	Km
Chipanga III mine	6.2
" IV mine	8.8
" VIII mine	3.7
	18.7

6.6 Technical and economic results

6.6.1 Production (1000 t_{rom})

	1988 * actual	1989 estimated
Chipanga III mine	3.7	21.5
" IV "	13.8	27.0
" VIII "	6.4	12.5
	23.9	61.0

* 7 months production stoppage due to lack of explosives.

The full production record since 1972 is contained in Annex 7.

Since the destruction of the railway to Beira in 1982, the company's production had to be reduced below 100,000 t.p.a..

6.6.2 Operating costs

The cost structure of 1988 is reflected in the following table:

Labour costs	10^6 MT	%	MT/trom
Mines underground	194.535	13	8,140
Mines surface	113.158	7	4,734
Administration	288.223	18	12,060
Expatriates (technical management)	259.321	16	10,850
	855.237	54	35,784
Repair and maintenance	22.610	2	946
Spare parts	431.698	27	18,063
Overhead costs	145.806	9	6,101
Social services	120.310	8	5,034
Total	1.575,661	100	65,927

at a rate of 800 MT = 1 US$ equivalent to 82.4 US$/$t_{rom}$
============

Supposedly no capital costs were incurred.
Adding the fictitious transport cost to Beira of some 34.00 US$/$t_{rom}$
=============

the total costs f.o.b. amount to at least 116 US$/$t_{rom}$
===========

This is self-explanatory and needs no comment.
The break-even point is estimated at a production of approximately 350,000 t_{rom} annually.

6.6.3 Present marketing situation

The present marketing situation can be characterized as follows:

- Since no transport system for larger coal quantities to Beira is available, coal export opportunities are zero.

- The domestic demand for steam or coking coal is limited to small consumers in the area of Tete, such as breweries, cement kilns or sugar factories. The potential demand may be in the order of 10 - 20,000 tpa.

- Reportedly smaller quantities are delivered across the border to Zimbabwe and Malawi, but it seems that these quantities are bought on spot market terms.

- As to the qualities and prices of the coals sold, only vague indications are known. Obviously at present, coking coal quality is sold at steam coal prices.

- As explained earlier, the mines cannot produce coking coal (as the main product of CARBOMOC) on stock, hoping that future demand of big lots can be satisfied easily. Within 3 months storage time, the Free Swelling Index would drop from > 6 below 3.

This means that the coal can no longer be sold as coking coal.

- As a consequence of this irreversable process, the mines' production has to be adapted to the realistic sales level, or to a lowest strategic minimum.

- Under the prevailing conditions, heavy company losses will also have to be born in the future.

- This situation can only be changed positively, if the political implications presently destabilizing the country are overcome and a free, unrestricted railway transport to Beira can be reestablished.

- To emphasize again the heavy burden imposed on the Moatize coal, even under unrestricted production, transport and marketing conditions, the produced coking coal has to reach its final destination and be used within 3 months. Any logistic measures have to take this burden into account.

- It is an unsettled question sofar, what percentage of the r.o.m. coal can be sold as coking coal. On the one hand, it is the company's natural objective to sell as much coking coal as possible, but the possibility for upgrading the r.o.m. coal to coking coal, is limited by the present dry-screening process. The quality specifications of coking coal on the international market are more stringent than can be met by the Moatize coal, unless high price rebates are accepted. This, in turn, affects the company's economic result sensitively.

- For this reason, we recommend to study the establishment of a coal washery at the mine site or in Beira.

7. Evaluation of Coal Mining Operations

Based on the preceding information, this chapter will deal with the evaluation of the current coal mining operations, aiming at an improvement of the overall performance. Recommendations will be given to specific topics which are indicated in the Terms of Reference of this contract.

7.1 Alteration to the presently applied method of work

The selection of the method of work is of paramount importance for a mining venture, as it is the key determinant for its economic success. The method chosen will have to be the one with the highest economic result and at the same time, the safest one.

Among the many factors which influence the final decision, the natural conditions play a major role. Therefore, the salient features of the deposit are highlighted again with respect to the applicability of mining methods, in the case of the Moatize coal basin.

- There are 6 comparatively thick seams contained in a flat syncline, at a shallow depth of about 300 metres. Their outcrop at the surface permits easy access by inclines for underground mining.

- The coal seams and surrounding rock are characterized by a rapidly changing facies structure to the lateral extension; as with Gondwana type coal, the seams are high in ash and low in moisture and sulphur. As to the rank of coal, they include coking and non-coking coals.

- Most seams are contaminated with high percentages of barren layers of varying structure and composition, with the exception of the Chipanga seam bottom slice which, therefore, proves to be a section of economic mineability.

- The structure of the deposit is characterized by three features:

  a.) The ondulating sedimentation both to the direction of dip and of strike, representing severe impediments to easy mining.

  b.) The high frequency of cross faulting at narrow spacings. Four types of faults have been discovered, with displacements of > 100 m, 90 - 50 m, ~ 25 m and 5 - 3 m. Each of them has its particular influence on the mining possibilities, i.e. they have a differentiated bearing on the deterioration of the mining conditions.

  c.) The irregular occurrence of doloritic intrusives, predominantly as steeply inclined dykes, also represent mining obstacles.

- Due to the high accumulation of coal in the basin (some 52 m pure coal/area unit) and the fractured and fissured rock body, a high methane release rate has been observed, requiring proper safety measures in order to avoid explosions in the mine.

- The Moatize river meanders over the mining area. Thus water inevitably penetrates through the fissures and fractures of the rock body into the mine workings, requiring special measures to keep a mine running under these conditions.

Taking these conditions into account, a reassessment of the presently applied mining method of the Chipanga seam bottom slice has been conducted.

If the distinguishing characteristics of mining methods by type of roof treatment are employed, the currently operated room and pillar method makes use of a part of the mineral as means of roof support.

Its main advantage is the high degree of layout flexibility in response to changing geological conditions, as is required for mining the Moatize coal seams. No other mining method known, can be considered as a real alternative to room and pillar mining.

To explain this unique characteristic of the method, one has to keep in mind that its essential feature is to drive rooms in the mineral, each of a designed section, spaced at well defined intervals and allowing for pillars left in-situ. Other advantages are the low initial capital investment outlays required to start up coal production and the low level of qualification of the personnel employed, since the method is easy to run. Under more favourable geological conditions, i.e. a more even floor level, even mechanization would be possible. However, in the case of the Moatize deposit, the unsteady oscillating ups and downs of the seam floor present conditions adverse to mechanization. Nevertheless, these aggravating conditions can be mastered successfully by the conventional system.

Disadvantageous are, at first instance, the high percentages of the reserves left unmined in the many pillars, which make up an inherent constituent of the method. The portion of reserves lost will increase with the advance of mining to the depth and finally render the method uneconomic. Other disadvantages are the low productivity of the mine operation, low production rate per working face and, therefore, the low production capacity of the mine.

Weighing all the pros and cons, one arrives at the conclusion that the presently applied method is the most adaptable one to the specific requirements imposed by the geology of the Moatize deposit.

Nevertheless, an attempt is made to sort out the possibilities as to whether and how the present situation can be improved. One matter of concern is the question whether it is possible to increase the reserves' recovery rate. It is anticipated that the pillar dimensions have been designed in accordance with the load requirements. Retaining the advantages of room and pillar mining that are unrivaled among the mining methods, it may be possible to weaken the pillars, by working slices from them systematically. However, it cannot be ruled out that a caving process is induced.

This would then be the transition to <u>caving methods</u>, the second large category of mining methods. They, however, have to be excluded from the application in this case because of

- uncontrollable rock mechanical risks caused by the caving pillars,

- uncontrollable methane concentrations in the gob areas which represent explosion risks,
- the most probably proneness of the coal in the gob area to spontaneous combustion,
- high water influx rates.

For the same reasons, longwall or shortwall mining can be eliminated from a closer study whether their introduction is offering. In addition to the a.m. constraints (except for the pillar control risks, as caving by itself proved to be feasible after trial operations) neither enough working panels of economic size exist nor can they be designed to warrant investigation of the applicability of this method in greater depth. Nevertheless, certain aspects of this mining method have been considered in the subsequent chapters, not excluding longwall/shortwall mining categorically.

The hydromining method - another mining method of the caving category - can also be excluded from detailed examination. The workability of the coal by high pressure water jets would not pose any problems and pumping of the coal slurry to the surface would be possible at fairly low cost, owing to the shallow working depth. However, next to the methane risks to be expected in the mined-out areas, a steep rise of the ultra fine fraction, forming the coal slurry, is anticipated. This, in turn, would create problems of the coal beneficiation and its usage as coking coal or even for other purposes; grain sizes below 0.5 mm are difficult to be marketed.

Looking at the third category of mining methods which is characterized by backfilling of the mined-out areas, to prevent roof caving and thus limiting surface damages, one has to state that these methods are very costly and for this reason, are confined to mining of minerals more valuable than coal.

For economic reasons, they cannot be considered as alternatives to room and pillar mining.

A final remark may be permitted:

The strata sequence of the coal basin include hard layers of sandstone and siltstone/claystone, prohibiting surface mining methods in the past. Today's technology of open-cast mining and coal beneficiation is such that it seems promising to investigate thoroughly the feasibility of open-cast mining for the whole Moatize coal basin. If this is answered positively, the coal reserve base can be expanded tremendously to the benefit of the country.

7.2 Investigation of possibilities of whether and how mechanization of mining could be introduced, however, keeping in mind the economic results.

The question of mechanisation of the development headings as well as of the coal winning sections in the underground mines of CARBOMOC has to be carefully examined.

In the course of basic considerations on mining systems, the conclusion has been drawn to retain present room and pillar mining.

The application of longwall/shortwall mining, however, cannot be ruled out entirely, due to the future exploration and thus improved level of information on the deposit in Section 5 and the Central Section.

For this reason, the following deals with room and pillar mining in its main part and with a condensed study regarding the possibilities of longwall/shortwall mining in a second part.

7.2.1 Aims of mechanisation

In general, the following aims of mechanisation can be highlighted:

- Increase of heading and mining performance
- Reduction of manpower i.e. decrease of labour costs
- Increase of productivity i.e. decrease of specific costs per ton
- Increase of production per working point which leads - provided that production remains unchanged - to a decrease of working points
- Relatively protective treatment of surrounding rock, in case of coal cutting
- Improvement of underground working conditions and increase of safety conditions.

These aims, however, are not of equal ranking; in the case of CARBOMOC, it has rather to be verified whether any kind of mechanisation would offer a real improvement of profitability, because the investment costs and the linked financing costs have to be raised in hard currency. In any case, a detailed feasibility study according to international investment guidelines would be necessary prior to a decision.

7.2.2 Preconditions of mechanisation

Mechanisation must take into consideration the geological conditions of the deposit and the technical conditions of the existing underground mines at Moatize. The conditions can be specified as follows:

- Geology
  - strength of coal and adjacent rock strata
  - tectonic fault pattern and size of fault displacements, dimensioning of mineable seam areas
  - doleritic intrusives
  - gas content
  - rock mechanical aspects
- Mine Infrastructure
  - transport facilities
  - energy
  - road sections
  - coal haulage facilities
  - mine layout
  - workshop facilities
- Qualification of Manpower
- Organisation

7.2.2.1 Geology

The strength of the Chipanga coal and of the adjacent rock strata was examined by the Austromineral Ges.m.b.H., Austria in 1984.

The following rock samples were tested: Sandy claystone, pure claystone, coal slate, hard coal and clayish slate. All samples tested had a compressive strength of less than 8KN/cm^2. All samples are cuttable in view of the application of a coal cutting device. The Chipanga coal in particular, tends to disintegrate, due to a vitrinite content at an average of approx. 70 %.

The Chipanga seam dips at 15° to 20° on the southern wing of the syncline and at more than 35° on the northern wing of the syncline. The workings' inclination changes frequently due to the alternating strike direction of the seam.

The main inclines (descenderia geral) are driven downwards at an angle of up to 18°. (Belt conveyor installation limits the angle). The gateroads along the strike are almost horizontal but the road floor dips according to the seam inclination.

There are also seam areas present with an ondulating floor which leads to up- and downward heading of gateroads.

The main faults (Border Fault, M'Pandi fault) limit the area of the coal deposit. The deposit itself is divided by major and minor faults. The major faults have vertical displacements of more than 25 meters and limit the mine areas. The minor faults are encountered at regular distances of 50 meters and still have vertical displacements of 3 meters and more. The major fault pattern indicates a NW-SE trending structure. (For more information see chapter 3)

There are several dikes of doleritic composition. They occur in the form of tabular bodies which cut through the strata. The strength of this intrusive rock is higher than 16 KN/cm^2 and so far not cuttable.

Because of the presence of faults and dikes, it is hardly possible to locate regular, undisturbed mining areas with a greater length than 100 meters.

The high gas emission rate of the Chipanga seam (60 - 80 m^3/t_{rom}) and the amount of gas released during coal winning, limits the daily production rate. The relation between production rate and gas emission rate is shown in a calculation for a road heading operation.

The following standard figures have been assumed:

- road section $12\ m^2$
- average air velocity $2\ m/s$
- maximum permissable CH_4-content in mine air $0.9\ \%$
- gas emission rate $80\ m^3/t_{rom}$

Air volume V_{min}:

$12\ m^2 \times 2\ m/s \times 60\ s/min = \underline{1440}\ m^3/min$ (standard fan)

Maximum CH_4 emission:

$$\frac{1440\ m^3/min}{x\ m^3\ CH_4/min} = \frac{100\ \%}{0.9\ \%} \quad ; \quad x = 12.96\ m^3\ CH_4/min$$

Maximum mineable coal per min:

$$\frac{12.96\ m^3\ CH_4/min}{80\ m^3\ CH_4/t} = 0,162\ t/min$$

The maximum mineable coal volume should not exceed 0.162 t/min, which is about 9.7 t/hour. However, the average cutting ability of a small-size road-header (continuous miner) is about 36 t/hour. (See report "Technical Concept for Development of New Underground Mines", Austromineral, Vienna 1985).

This calculation refers to average operational figures and does not consider peak values of methane emission which would lower considerably the maximum mineable coal volume per hour.

An increase of the assumed mine air volume could be achieved by enlargement of the road section and by increase of air velocity, up to the peak value of 4 m/sec according to the Mozambiquan Mining Regulations.

According to an estimated running time of the continuous cutting machine, of approx. 40 % x 8h = 3.2 h per shift, the maximum shift production amounts to 3.2 h x 9.7 t/hour = 31 t per shift.

The assumed gas emission rate is derived from calculations carried out by CARBOMOC which are based on measurements of the return mine air. It is urgently recommended to carry out additional measurements in order to determine the desorbable CH_4 gas content of the coal.

As a further additional measure, an underground degassification test can be proposed. It should be examined as to whether it is possible to pre-drain CH_4-gas from the coal seams by under-pressure through drill holes, ahead of the working area. The success of such a gas pre-drainage is dependent upon the time available, the influence exerted on the individual mining panels by adjacent panels and on the permeability of the coal.

The main rock mechanical points of interest concerning mechanisation of coal winning, are the dimensioning of the underground workings and the dimensioning of the coal pillars. The room and pillar layout and the mined seam thickness of up to 4,5 meters have to be taken into consideration.

Summary

The geology of the coal deposit in Moatize cannot be regarded as very favourable for underground mechanisation. High gas emission, tectonic faults and inclinations up to 35° are highly disadvantageous for modern winning machines. In a new mine planning, these factors have to be carefully examined, prior to the introduction of any kind of mechanisation.

7.2.2.2 Infrastructure

One of the substantial key points of mechanisation is the infrastructure of the mine. Concerning the infrastructure of the Moatize coal mines, the following aspects have to be taken into consideration.

Transport

Transport of material in the main incline (Descenderia Geral) is done by mine cars which are pulled by an electrical single-drum winch installed at the mine mouth. The maximum transport load of this transport system is about 1.5 tons. Transport in the gateroads has to be done by hand. The only additional transport devices are manually operated hoists.

Energy and Water

Each underground mine network relies on one transformer (3.3 KV/550 V, 400 - 550 KVA), which feeds all electrical equipment underground. This transformer is located at the main incline including the main substation. Due to increasing cable length between substation and consumer, voltage drops are common.

There is no compressed-air network in the underground mines.

Fresh water pipes are installed both in the inclines and in the gateroads.

Road Sections

The standard road sections are in the range of 4 m^2 (cross-cuts) and 12 m^2 (gateroads, inclines); due to the increasing pillar dimensions - as a consequence of increasing depths - the sections of the roads are reduced.

As a rule of thumb, the minimum sections requirement for the successful employment of a machine is some 9 - 11 m^2. This means that the present road sections are not favourable for a mechanization underground.

Coal Haulage

Coal haulage relies on scraper winches and chain conveyors at the coal winning points. Haulage in the gateroads and in the inclines is carried out by belt conveyors (belt width 650 mm). The conveyor construction stands on the floor.
A plate for stabilisation of the construction is fixed between the upper and lower belt. The trough angle of the belt is less than 15°; the average belt velocity is 1.5 m/s and the maximum capacity is around 120 t/h.
The main belt conveyors are used for man-riding.
An increased production would require completely new coal haulage equipment.

Workshops

There are electrical and mechanical workshop facilities which are sufficient for the actual underground equipment, but need supplementation depending on the types of equipment introduced into the mine.

Summary

The operation of modern equipment for coal winning involves the handling of heavy machinery parts, the maintenance of hydraulic and electronic systems and the supply with energy, water and compressed air. The present infrastructure of the Moatize coal mines is not yet prepared for modern underground technology.

The following essentials are still unavailable:

- transport systems, capable of transporting heavy machinery parts
- compressed air hoists, compressed air tools
- powerful energy supply network
- compressed air network
- communication means
- sufficient road sections
- ventilation control systems
- coal haulage systems with integrated long-distance conveyor belts and bins
- workshops for hydraulic as well as electronic systems
- advanced CH_4- and CO-measuring units and fire fighting equipment.

These above deficiencies have to be taken into consideration for the planning of mechanized coal winning.

7.2.2.3 Qualification of manpower

For the operation and maintenance of modern mechanized underground machinery, it is necessary to have educated and trained personnel available.

By educating technicians, engineers and specialized workers in the GDR, this precondition for the application of modern technology has been fulfilled. Nevertheless, it is necessary to increase the number of trained personnel and to add training in the field of electronics and hydraulics, in order to meet a certain level of mechanisation. Moreover, the number of intermediate level supervisory personnel has to be increased.

7.2.2.4 Organisation

The present organisation of the mines does not allow for a separation between production personnel and engineering staff. This leads to problems concerning responsibilities and management.

Another point is the two-production-shift-system which limits productivity.

The wage and salary system does not correspond with the personnel performance.

Thus, improvements in the personnel sector should be achieved for:

- mine management
- distinction of responsibilities

- working time per day (number of shifts)
- control of mine activities
- shift monitoring and
- wage-system with incentives.

7.2.3 Steps towards mechanisation

The most modern mechanized coal winning system is not always the most favourable. Therefore, some basic mechanisation steps are suggested, taking into consideration both coal winning systems: room and pillar and longwall/shortwall mining.

7.2.3.1 Room and pillar System

The possible mechanisation of room and pillar mining includes both development works and coal winning procedures.

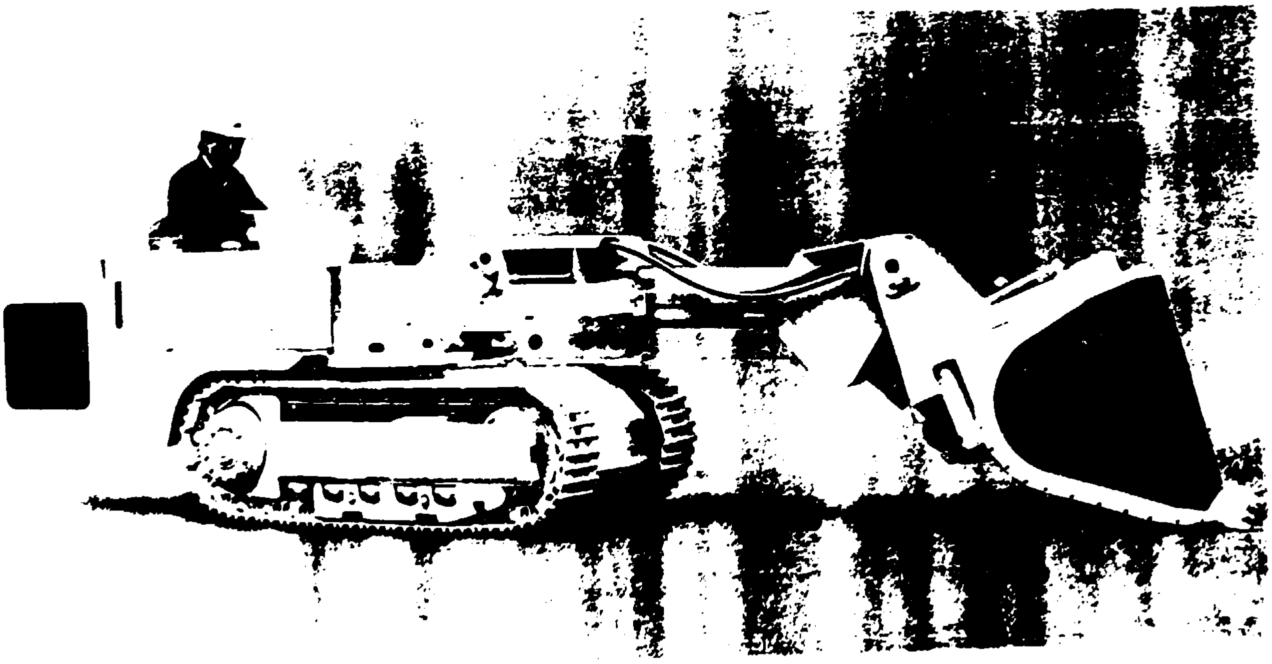
The actual winning system consists of drilling/blasting. A double-drum scraper onto a chain-conveyor serves as a mucking device. One heading team, as a rule, works alternatively in two parallel working points.

The following steps of mechanisation can be proposed:

- loading-machine, for mucking of the blasted coal
- drilling-jumbo, for drilling boreholes, blasting and rock-bolting
- combination of both units
- continuous cutting machine; light type of road-heading machine for developing and coal-winning; continuous loading is integrated in the system.

7.2.3.1.1 Loading machine

Heading or coal winning is performed by drilling and blasting. To facilitate the loading process, a loading machine can be used for mucking out of the blasted coal debris; the loading machine consists of a crawler travelling unit, loading shovel and body including the drive unit. The loading machine can be driven either by an electric-hydraulic motor or a compressed air motor. To improve the loading performance, the machine could be equipped with a telescopic boom. This would enable the machine to load without using the crawlers which is advantageous in inclined headings.



The loading machine should have dimensions which enable it to operate in road sections of less than 9 m^2. The loading capacity should correspond to the maximum blasting performance:

length of cut	1.6 m
road section	12 m^2
bulk density	1.4 t/m^3
coal debris volume	approx. 27 m^3

This leads to a loading capacity of about 30 m^3/h. The operational weight of such a loading machine is about 6 - 7 tons.

Advantages:
- relief of physical work
- high loading efficiency
- short loading intervals
- can be used for support works
- better cleaning of road floor

Disadvantages:
- higher investment cost (compared to scraper winch)
- higher energy consumption
- better qualified personnel required for operation and maintenance
- operation limited by floor gradient:
  upwards 15^o
  downwards 10^o
- machine is sensitive to operation at transversal inclinations, critical angle is about 8^o
- loading chain conveyor at the heading face is required

7.2.3.1.2 Drilling jumbo

At present, boreholes are drilled by manually operated electric drilling machines. A higher drilling efficiency is achieved by a drilling jumbo. This crawler-based vehicle is equipped with an electro-hydraulic boom, which is fitted by a high-performance drilling-jack.

The theoretical drilling performance is about 6 m/min.

Due to high mobility, the jumbo could operate in two parallel working points which are combined for one working team.

Advantages:

- higher winning efficiency compared to manual operated drills
- flexible system concerning seam irregularities
- can also work as a roof-bolting machine
- relief of physical work

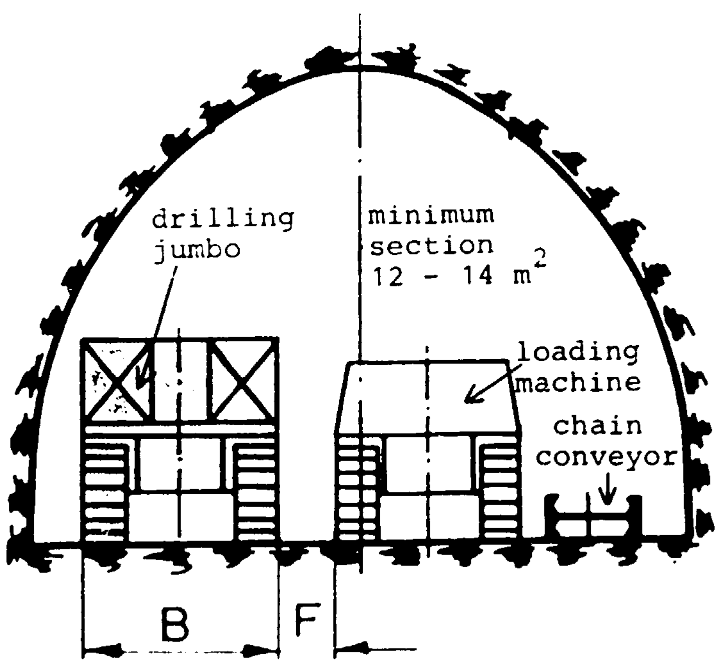
Disadvantages:

- higher investment and operating costs (compared to manual drills)
- higher energy consumption
- better qualified personnel required
- operation limited by floor gradient:
  upwards 15°
  downwards 10°

- machine is sensitive to operation at transversal inclinations, critical angle is about 8^{o}
- higher pillar safety factor required (see report "Technical concept for Development of New Underground Mines") Austromineral, Vienna, 1985.

7.2.3.1.3 Combination of loading-machine and drilling jumbo

The combined operation of loading machine and drilling jumbo needs a larger road-section. The minimum section for two vehicles of lower operational weight is about 12 - 14 m^2



Both vehicles could operate independently in parallel headings, but the connection drifts between the two parallel roads have to be adapted to the vehicles' dimensions.

Advantages:

- increased winning efficiency compared to single vehicle operation

Disadvantages:

- very high investment costs per heading system
- larger road-sections required
- other disadvantages correspond to the disadvantages of loading machine, respectively drilling-jumbo

7.2.3.1.4 <u>Continuous mining machine (Road heading machine)</u>

(see also "Technological Concept for Development of New Underground Mines", Austromineral, Vienna, 1985)

This light weight type of road-heading machine can be used as a continuous cutting machine, replacing drilling and blasting.

The machine is equipped with an axial or radial cutting head (boom-type). The installed power and the operational weight depend on the hardness of the strata to be cut. Loading and intermediate haulage to the belt conveying system is performed simultaneously and continuously.

Advantages:

- continuous, mechanized cutting, resulting in improved control of roof strata compared to blasting method
- high winning efficiency
- high advance rate
- homogenous cutting of road section
- better safety conditions

Disadvantages:

- high investment costs
- better qualified personnel required
- minimum cross section of 12 m^2
- operation limited by floor gradient (depends on type of machine)
- machine is sensitive to operation at transversal inclination
- dimensions of machine and length of energy supply systems and controls make special layout of room and pillar system essential
- high water consumption for cutting and cooling
- higher CH_4 gas emission rate due to higher cutting ability
- hard rock strata (> 8 KN/cm^2) have to be blasted

7.2.3.1.5 Evaluation of mechanized mining machines

The above listed advantages and disadvantages of the individual mining machines portray the problems which are bound to occur with the introduction of mechanisation. The obstacles concerning the operation of these mining machines are

- geological conditions

- necessary infrastructure and
- necessary operation and service personnel.

However, the main obstacle is the high investment costs, not only for the winning machines but also for the complete infrastructure which has to be adapted to the technical demands of the selected form of mechanization. As another important cost factor, spare parts and adequate store houses have to be included. As an example, the approximate investment costs of the above illustrated equipment are calculated as follows:

- Loading Machine (operational weight 7 t)	200,000 DM fob
- Drilling Jumbo	750,000 DM fob
- Continuous Cutting Machine (light type)	1,100,000 DM fob

The experimental mining of the Austrian road-header AM 50 has shown the technical problems of a continuous cutting operation in Moatize. It has never achieved full winning efficiency , compared to European standards.

	Average performance
AM-50 Moatize	20 - 30 m^3/h
AM-50 Europe	35 - 45 m^3/h

The calculated cost advantage of 0.6 US$ per ton r.o.m. is relatively low regarding the accuracy of the estimated overall costs.

The operation of advanced equipment has to be elaborated in a feasibility study which also evaluates the profitability along international guidelines.

7.2.3.2 Longwall faces with caving method

The possibility of longwall faces cannot be ruled out today from the geological point of view, due to the incomplete geological information on the western part of the Moatize coal deposit. (See Chapter 5)

During the years 1980/1981, a longwall trial operation was executed at Chipanga IV mine and terminated as a result of the uncontrollable roof and consequently the caving.

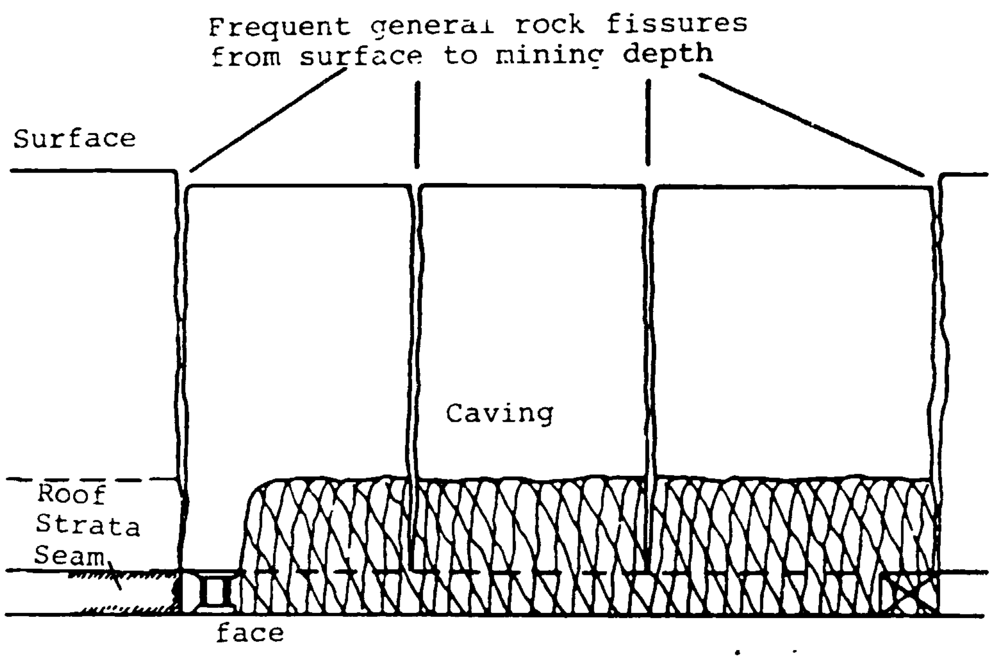
7.2.3.2.1 Conditions for application of longwall/shortwall mining

At present, geological knowledge about the deposit and the following planning parameters for a face layout have to be considered:

- the face line should remain perpendicular to the observed faulting directions
- the face length should be adapted to the distances between the fault lines, but the minimum length must still guarantee the controlled caving of the roof strata
- the maximum fault displacement should not exceed half of the mined seam thickness
- the panel size should guarantee a production of 3 - 4 months
- the inclination of the face line should be lower than 15°
- the planned production rate must be calculated according to the maximum gas emission rate
- the surface should be free of buildings, traffic lines and other sensitive objects.

For the possible mechanisation of a longwall face, the following technical aspects have to be considered:

- the winning machine should be able to mine the complete thickness of the seam slice (Chipanga seam bottom slice 2.0 - 4.0 m)
- the supports must cope with the higher rock pressure due to the close-to-the-surface mining



- the gateroads of the face must be supported by steel supports
- the infrastructure (coal transport, ventilation) must be adapted to the higher production rate of a face.

7.2.3.2.2 Longwall equipment and safety aspects

A typical longwall equipment which meets all demands is comparable to the longwall equipment in the coal mines in Europe. This would mean an investment sum in the range of 8 - 14 million US$ per face.

A similar amount must be added for the infrastructure of the mine. This investment cannot be justified as yet, due to the lack of sufficient mining areas according to the present geological data.

Another key aspect is the safety risk of a longwall operation under these conditions:

- high gas emission rate
- proneness to spontaneous combustion due to caving method
- mining under close-to-surface conditions which includes the water inundation hazard.

From both profitability and safety points of view, the longwall operation should not be considered.

7.2.4 Summary

Regarding the present stage of coal mining technology in Moatize, the mechanisation of coal winning is bound to require high investment costs. Moreover, the difficult geological conditions, the lacking infrastructure and major aspects of mine safety make a successful mechanisation dubious.

This assessment can not rule out the possibility that new basic data might make a certain degree of mechanisation e.g. loading machine/continuous miner feasible. From the current point of view, the present mining system should be optimized and the equipment should be modernized by new investments.

7.3 Improvements of current blasting and mucking out procedures

7.3.1 Actual mining method

The actual mining method in Moatize comprises drilling and blasting of the coal in the advancing stage of approx. 6 m^2 section. The mucking out of the blasted coal is performed by double-drum winches with scraper-buckets. The scraper bucket loads the material via a chute onto a chain conveyor. During retreat mining, the winning room is expanded to approx. 18 m^2 section. Some workings are protected by wooden supports, consisting of bars and timber props to prevent rockfalls or roof pressure.

A complete winning and heading operation consists of two parallel roadway drivages which are developed by the same heading team.

The overall winning efficiency (productivity) including advance and retreat mining amounts to 3.6 t/manshift, related to all manshifts of a parallel roadway drivage.

7.3.2 Problems of the actual mining and development method

The present mining method has a low working point production. This is valid in particular for advance mining, compared to the blasted coal volume of retreat mining. The figures are related to a cut length of 1.60 m:

Advance mining approx.	15.3 t per cut
Retreat mining approx.	30.7 t per cut

Under normal circumstances, one cut per roadway per day is achieved.

The difficulties can be classified into three groups:

Working Conditions

The rather high temperatures and insufficient ventilation reduces the human working capacity. Due to the high gas emission, long waiting periods following blasting are necessary to dilute the gas accumulation of the working point.

Technical Conditions

There is only one electric drilling machine per working point. The scraping length of the winches is often too long, up to 100 meters, (optimum length in W. Germany is below 30 meters).

The transport of material and equipment is carried out by hand in general, with the exception of the main inclines. There are no compressed-air powered tools and hoists for all secondary work underground.

Organisation

There is only a two-shift production.

The mining and heading in the parallel-drivage is not organized in such a way that certain working procedures are scheduled (rhythmic work procedure).

Due to the long manriding times, the working time is significantly reduced. The replacement of shift personnel takes place outside the mine.

Additional aspects of safety are dealt with in another chapter.

7.3.3 Proposals for improvement

The following proposals shall offer some general improvements. Detailed calculations backing these proposals have to be elaborated in a feasibility study.

7.3.3.1 Compressed air network

It is proposed to introduce compressed air as a second energy source besides electric power for the rehabilitation of the two mines which have been closed down and for the development of new mines.

Regarding the actual mining method, the availability of compressed air would improve the operation by

- using two compressed air driven drilling machines per working point, increasing the drilling capacity by 100 % and by

- applying different kinds of compressed air driven tools and machines such as hoists which would facilitate material transportation and transfer of heavy parts.

The other advantages of compressed air are the following:

- the possibility to provide a "clean" type of energy in every section of the mine which means that at working points with very high gas emission, compressed air equipment could be employed.

- the list of compressed air driven equipment comprises further:

  - drilling machines
  - pick hammers
  - hoists
  - tools e.g. metal-saw
  - auxiliary fans
  - scraper and winches
  - loading machines
  - pumps
  - illumination

- the installation of a compressed air network is simple compared to that of electrical energy
- the compressed air can be used as an oxygen supply in the case of fire or explosion underground.

Disadvantages:

- expensive energy source
- the compressed air losses due to leakage is always between 15% and 30% of the complete air volume compressed.

Compressed Air Network

The compressed air is generated in a compressor on the surface; additionally there are cleaning- and control facilities.

The network underground serves as a pressure reservoir. The compressed air pipes of 150 to 200 mm diameter are installed in the main inclines and the main gateroads. In the mining districts the pipe sections are reduced. The equipment is connected via high pressure hoses to the network. There are control valves at regular intervals to close down individual roadways, in order to work on the compressed air pipelines.

The following calculation estimates the amount of compressed air in a mine with a production of about 160,000 t/year.

Compressed Air Consumption (est.)

	Specific air consumption	per 24 hours
	(Nm^3/min)	m^3
Driling equipment Pick hammers Other items e.g. - Pumps - Tools - Hoists	4 1 2 - 5	230,000 15,000 150,000
Total		395,000

Time factor	0.3
Air losses	15 %

The required air volume amounts to:

$$\frac{395{,}000\ Nm^3/24h \times 0.3 \times 1.15}{24\ h} = 5{,}678$$

which is approx. 5,700 Nm^3/h (95 m^3/min).

The necessary output pressure of the compressor station is about 7 bars.

The specific compressed air consumption related to a daily production of 600 t/d amounts to

228 Nm^3/t (Compressed Air Volume/ton of coal)

7.3.3.2 Loading procedure

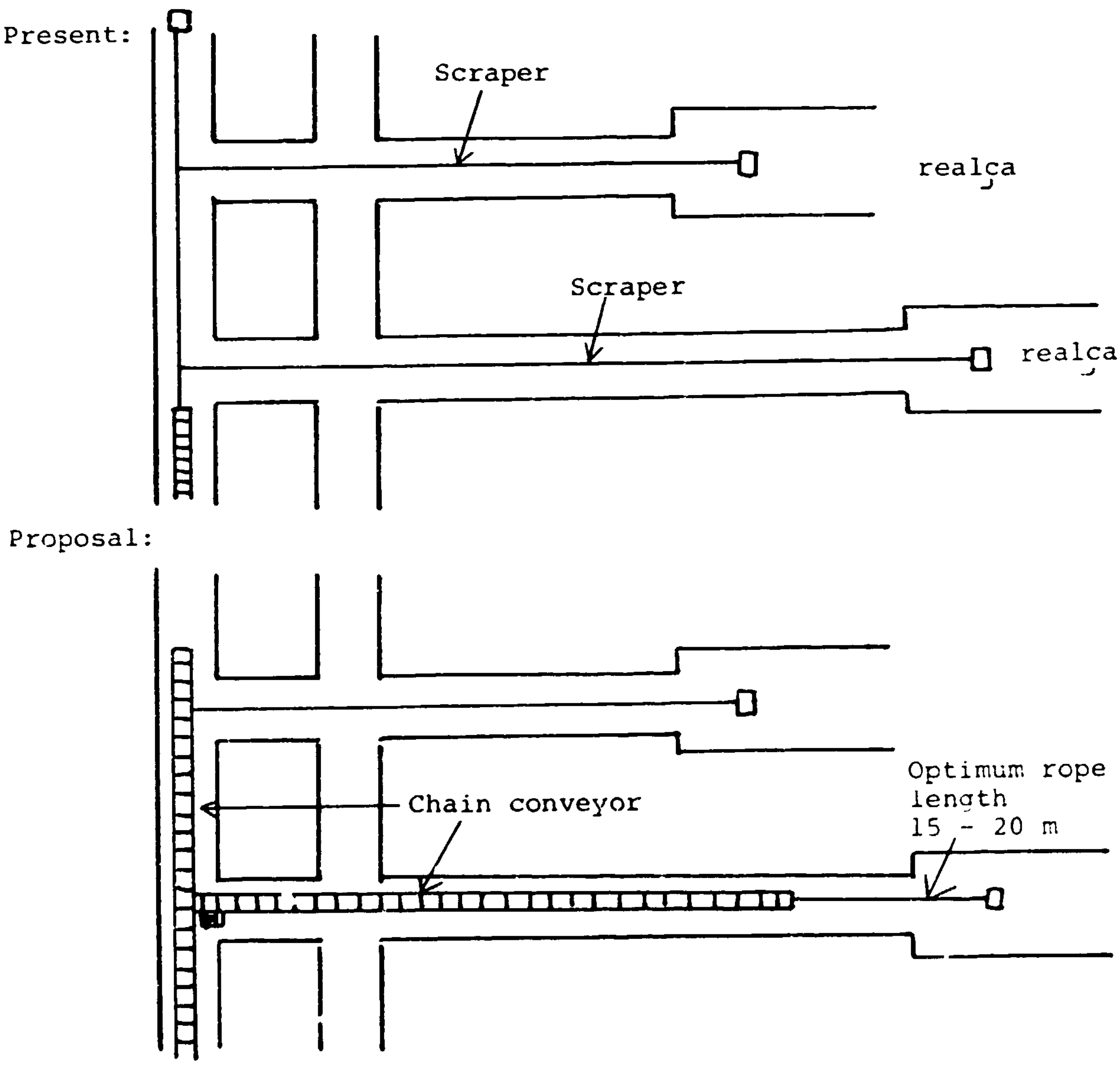
(Improvement of loading procedure by the operation of additional chain conveyors)

At present the mucking out and loading of the blasted coal is carried out exclusively by scraper winches.

Two operational facts have to be emphasized:

- the scraping distances can easily reach more than 100 metres
- due to practized arrangement one scraper transfers the blasted coal to another scraper before it is loaded onto a chain conveyor.

For this reason, it is proposed to install additional chain conveyors (light type) to shorten the scraping distances. (s. figure)



The availability of compressed air for hoists, tools and means of transportation for the assembling of the conveyor would be highly advantageous.

7.3.3.3 Blasting procedure

In order to minimize blasting costs an electrical coal cutting machine could be taken into consideration. A machine of this type is successfully being operated in the RSA.

The machine consists of a coal saw attached to a cutting beam which enables the machine to make a floor cut or a coal rib cut. By this cut, it is possible to blast the coal down to the floor, giving the following advantages:

- homogeneous floor cut
- coal is blasted downwards which prevents the scattering of the coal all over the road; easier loading procedure
- saving of explosives.

All this could result in a decrease of blasting costs.

As further data and costs on this type of machine are not readily available, this machine is not considered in the investment program. However, in the course of mine rehabilitation, a trial may be carried out.

7.3.3.4 Increase of production by 3-shift operation

The easiest way to increase the production rate is to extend the working time. This can be achieved in Moatize by increasing the number of shifts per day.

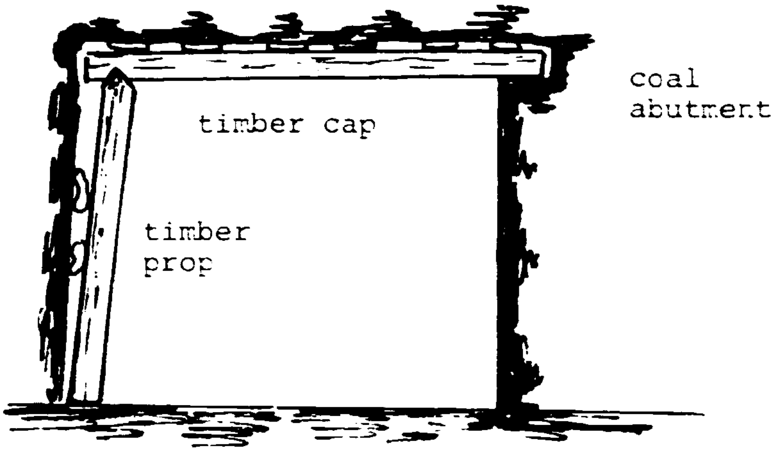
The increase of working time per day means:

- Increase of Daily Heading Rate and this results in a
- Higher Production per day. Additionally this results in a
- Higher Utilisation of the equipment and, therefore, a decrease of the
- Specific Equipment Costs per ton.

The additional effect of this proposal is the possibility of homogenizing production flow over 24 hours and thus reducing gas emission peaks which can result in a higher overall production.

7.4 Improvement of roof support system(s)

In the present underground mine areas, where higher rock pressure and danger of roof collapsing is encountered, wooden support in the form of timber props and bars is used as a means of protection. Sometimes the bars are directly holed into the coal ribside (s. figure), in order to save timber props.



The entrance area of the main inclines is supported by concrete walls and steel girder supports, in order to protect the inclines against loose alluvial material and water.

Faulting zones are protected by wooden support and sometimes by roof bolts.

7.4.1 Mine support

The main task of mine support has already been mentioned:

1. To secure road sections, protection against rock pressure in order to guarantee ventilation, transportation or man-riding,

2. Protection against loose rock strata which can result in larger rock falls.

7.4.2 Recommendation of steel support

It is recommended to replace the present timber support by steel support.

The reasons for the replacement are:

- Steel has several advantages compared to timber such as.

    - greater strength
    - less age wear
    - re-usability
    - easy installation
    - high tensility in case of overload
    - non-flammable

- Conservation of the forest reserve of Mozambique; in particular of rare woods.

There are different steel profiles on the international market which can substitute the present timber support by steel trapezoid support. It is possible to design a gliding steel support which can adapt its section to increasing rock pressure without deformation.

7.4.3 Precondition for steel support

The main precondition for steel support is the availability of a transport system which can easily handle the steel segments. Because of the high weight of steel, transport by hand over longer distances is impossible.

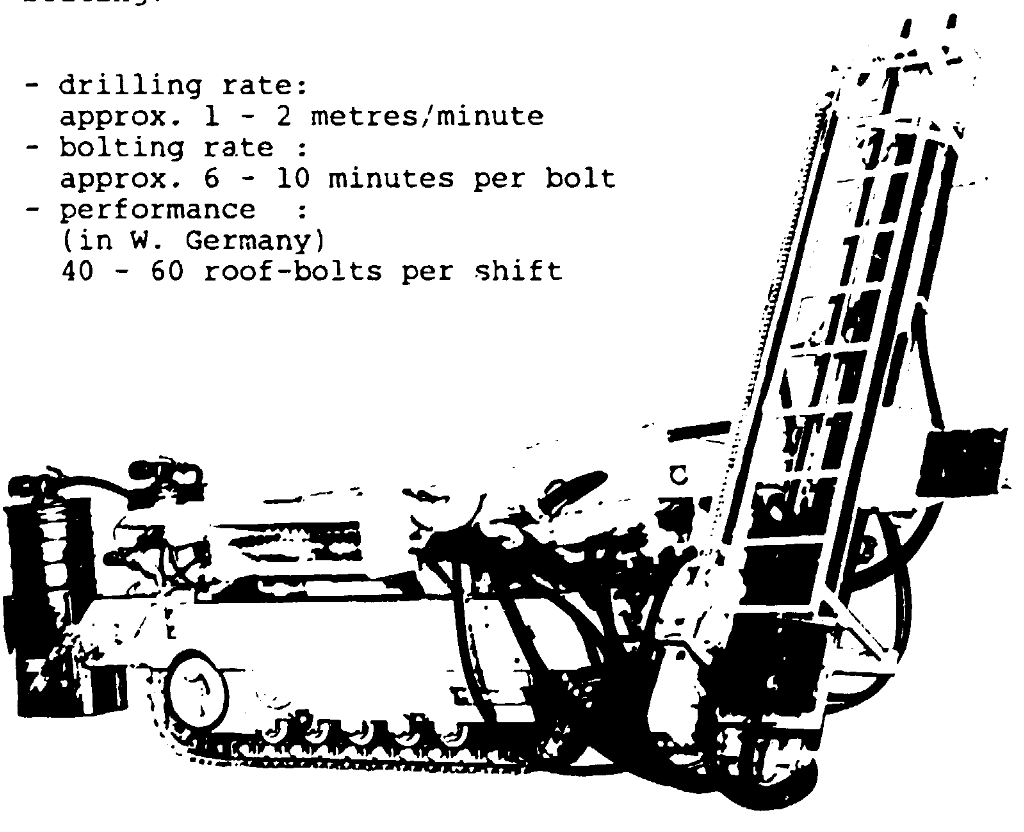
7.4.4 Roof bolting

For the protection of the roof strata against rock fall, it is proposed to apply more roof bolts.

The roof bolts connect the roof strata to one solid beam by pressing the metal plates of each roof bolt against the rock. The fully grouted roof bolts which are bonded by resin patrons over the complete length into the borehole prove to be very advantageous. Dislodgement of small size lumps can be prevented by wire mesh which is braced under the plates of the roof bolts.

The roof bolting can either be performed by manually operated drilling machines or by crawler-based drilling vehicles with hydraulic drill rigs. This kind of roof bolting machine is very efficient (s. figure). The following are typical data of mechanized roof bolting:

- drilling rate:
  approx. 1 - 2 metres/minute
- bolting rate :
  approx. 6 - 10 minutes per bolt
- performance :
  (in W. Germany)
  40 - 60 roof-bolts per shift



7.5 Possible expansion of the number of working points

The actual level of production at the Moatize Mines can be increased easily by expanding the number of working points.

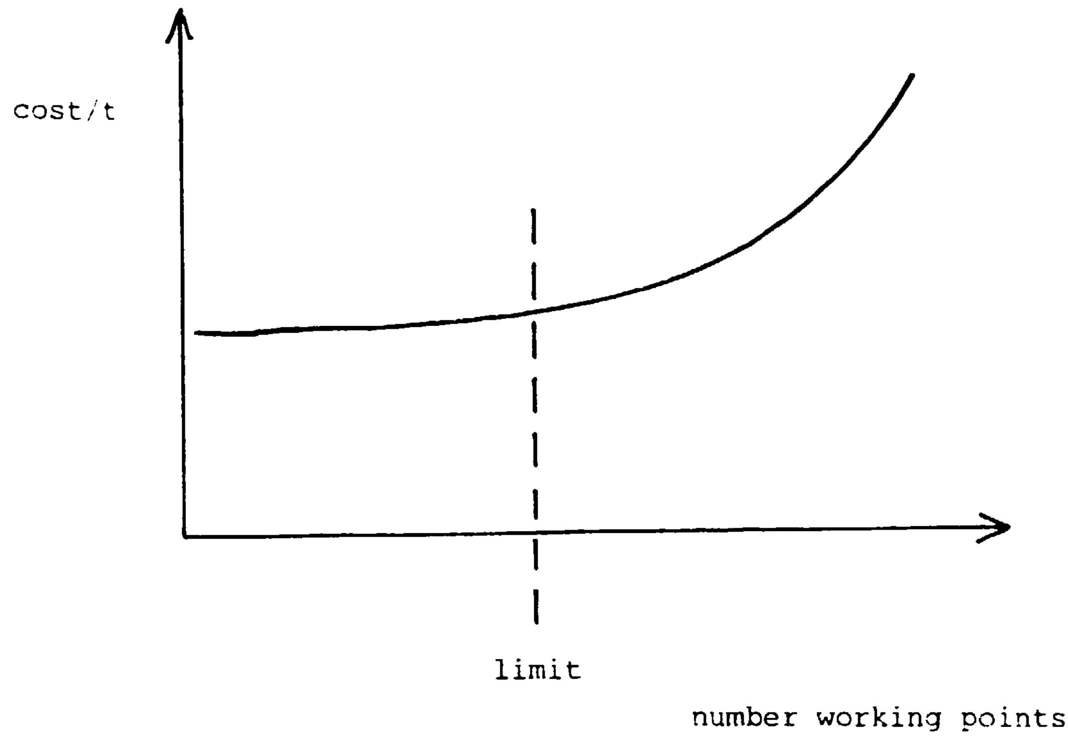
The present production level of 100 tons/d per mine - compared with a production target of more than 500 tons/d - demands an increase in the number of working points by more than 500 %.

However, the upper limit of working point expansion which means the absolute maximum production depends on:

- maximum gas emission rate which depends on the maximum ventilation capacity
- maximum coal haulage capacities
- availability of manpower
- availability of equipment
- progressive increase in operational costs.

The last point should be explained, due to its importance for the economic status of the mine.

Because of the difficult conditions underground in Moatize, e.g. geology, gas emission, layout and ventilation, it could be supposed that in the case of an increase of the number of working points, the operational costs (cost/t) rise progressively (s. figure)



The optimal limit of the increased number of working faces has to be calculated carefully. It is, therefore, highly recommended to achieve an increase of production by an increase of productivity.

Some proposals for an increase of productivity are given in Chapter 7.6.

7.6 Some general aspects of modernizing the mines necessary for an increase of production and productivity

Besides the technical proposals given in Chapter 7.3, some other technical aspects have to be considered for the rehabilitation and the planning of new underground mines.

7.6.1 Transportation

The present system of the room and pillar workings requires transportation in the following roads and inclines:

- main incline (descenderia geral)
- conveyor gateroad (via de banda)
- mining and development roads (avanco, realca)

The transportation in the main incline takes place by rail-bound mine cars which are pulled by a surface stationed winch. Transportation throughout the other workings is carried out by hand.

7.6.1.1 Main incline transportation

For the improvement of the winch system and for the increase in transport capacity, it is proposed to install a double drum winch which operates two cars running against one another, comparable to a shaft-winding system. The cars will use the same rail track, except for the meeting point, where a double track is used.

The complete system should be equipped with all facilities, necessary for manriding. The capacity of the winch depends on the length of the track and the maximum transportation weight.

Typical data of a double-drum rope winch:

maximum pulling force	57.5 KN
maximum rope speed	2.0 m/s
maximum rated drive power	2 x 75 KW
motor speed	1,500/375 min^{-1}

7.6.1.2 Conveyor gateroad transportation

The manual transportation of material and equipment weighing more than 1 ton e.g. a conveyor drive frame, is no longer possible. That is why a new transportation system is proposed for the gateroads.

This transportation system has to

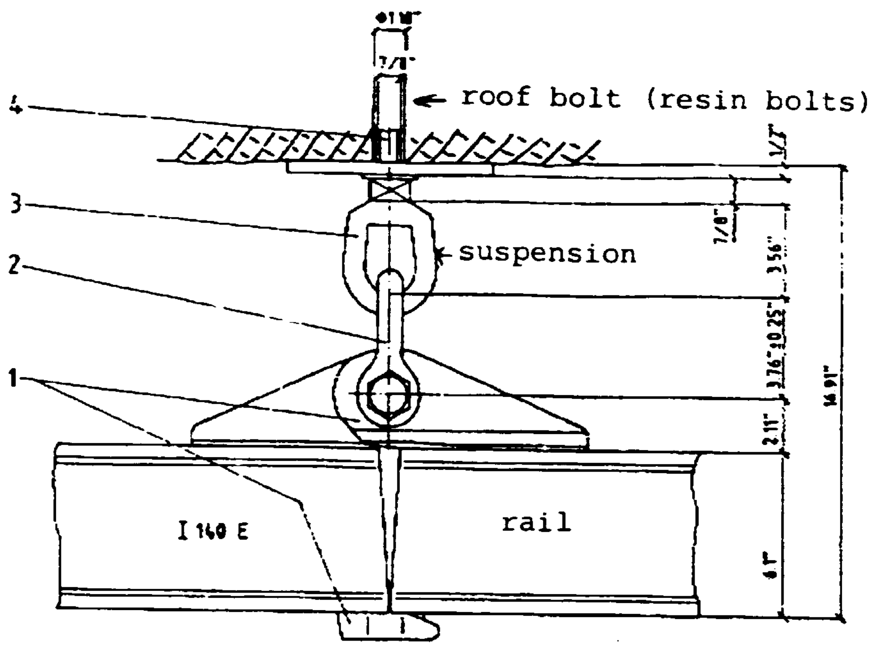
- be installed in the actual road sections, taking into consideration belt conveyors and man-riding
- adapt to the geological conditions such as road inclination and transversal inclination of road floor
- adapt to mine layout of room and pillar mining
- be of flameproof design
- be able to transport weights of up to 2 tons

This transportation system could be the "Suspension Monorail System" which is a reliable and robust transportation system in European mines.

The rail track is attached to roof bolts (s. figure). The suspension monorail has the advantage over floor-based systems (e.g. floor mounted rail system) that the floor conditions are neglectable and that the road section is utilized in a better way.

Furthermore, it is possible to use the monorail system for manriding by installing additional manriding cabins.

Another manriding system is the chair-lift-system which can be installed preferably in inclined roads.



7.6.1.3 Mining and development roads

Likewise, the transportation in mining areas can be carried out by the monorail system. In areas where no monorail system is installed, heavy equipment can be transported with open containers and winches.

In any case, there should be sufficient hoists for handling the transported materials.

7.6.2 Ventilation

The specific gas content of the Moatize coal (Chipanga Seam) and the high gas emission rate during coal winning and coal transportation, is the limiting factor of the coal production in the present mines.

7.6.2.1 Layout of ventilation

Based on the actual calculation figures of 60 - 100 m^3/t gas emission and the envisaged coal production of 500 tons/day, the ventilation system demands a mine fan of approx. 4,000 m^3/min. Taking into consideration the maximum air velocity of 4 m/s (mine regulations) an intake air incline section of > 16 m^2 is necessary.

At an air velocity below 4 m/s, as is usually employed, the actual incline section of 12 - 14 m^2 has to be enlarged or a second incline must serve additionally as intake air incline. For the return airway, a similar calculation is effective.

In order to avoid mine air crossings, the mine fan could be located opposite to the intake air incline on the other side of the mine take which could be described as "peripheral ventilation system".

This system has the advantage that no air flows have to be circulated back to the main inclines.

7.6.2.2 Monitoring of the ventilation system

Besides the ventilation control points underground where in certain intervals manual ventilation measurements are registered, stationary ventilation monitoring systems should be installed particularly in return airways, where the average gas content is constantly above 0.5 % CH_4.

The measured ventilation data can be transferred via data cable to the surface and recorded there. Monitoring can be combined with an automatic control which switches off the electrical supply to mining districts where the limit values of CH_4-content are reached. Besides CH_4, monitoring of CO, CO_2 and H_2S is also possible.

7.6.3 Communication systems

Various types of communication systems are used, according to the type of operation, for communication underground and from underground to the surface.

The following types of equipment are proposed for the Moatize mines:

- loudspeaker system
- telephone system

In principle all types of communication systems should fulfil the following conditions:

- degree of protection: flameproof; intrinsically safe
- compatibility, i.e. interfaces to other systems
- robust and simple design
- low maintenance, simple handling
- compact
- high comprehension level, good voice transmission

Loudspeaker System

The loudspeaker system consists of several loudspeakers and a power pack. The intrinsically safe intercom-system is advantageous in areas with higher noise level e.g. for communication along transportation lines and inside the mining districts.

Each communication set is equipped with a microphone and a signal button. Any announcement is transmitted by all the other communication sets. The batteries contained in the set are charged by the power pack and permit operation for several hours, even after a power failure.

Telephone System

The existing telephone system should be recommissioned. The basic conception of these telephone sets and the transmission characteristics accord with familiar telephone equipment.

The degree of protection permits its use in explosion endangered mine districts. Every intrinsically safe telephone functions independently of the main power supply and has an intrinsically safe type alkali-manganese battery.

Maximum distance between telephone exchange and mine sector may be up to approx. 20 km.

7.6.4 Preventive measures against fire and explosion underground

With regard to the proposed increasing production rate of the mines and new installation of equipment underground, the preventive measures against fire and explosion underground have to be improved.

Fire can originate from self-ignition of the coal or from other ignition sources. Precondition for a coal dust explosion is an explosive air-gas mixture (CH_4-content 5 - 14 %) and an ignition spark (> $600^{\circ}C$).

7.6.4.1 Fire preventive measures

To fight the danger of a mine fire, certain preventive measures are necessary in all underground mine districts. These are:

- protection of all underground workings by avoidance of inflammable materials; non-flammable ventilation doors to cut off mine fires; fresh water system with connecting pieces to high pressure water hoses
- protection of inclines or roads equipped with belt-conveyors; installation of water pipes and hydrants; in particular the drive stations and the transfer stations should be protected by automatic water sprinkler systems; additionally fire extinguisher (mine type) and water hoses have to be available
- protection of underground machinery
- securing of underground electrical equipment
- provision of a sufficient number of fire fighting equipment at a centralized location.

7.6.4.2 Explosion preventive measures

The main measures to prevent a CH_4-gas explosion are:

- supply of sufficient intake air volume for diluting the gas accumulations
- removal of coal dust accumulations
- CH_4-monitoring systems
- avoidance of ignition sources.

The installation of explosion barriers is an important factor besides these preventive measures.

The installation of rock dust barriers, as used now, has certain disadvantages:

- agglomeration of dust by air humidity
- removal of dust by mine air.

For this reason, it is proposed to install water trough barriers in the future. A water trough barrier consists of plastic troughs, filled with 40 litres or 90 litres of water, depending on the road section. Their arrangement is similar to rock dust barriers.

The shockwave of an explosion destroys the water troughs and the water spray should form a "water-curtain" in the road section, in order to extinguish the flame. For the water barrier calculation, a water volume of 200 litres for each square meter of road section is necessary.

7.7 Rehabilitation and repair of equipment in the presently operating mines

The underground visits made to Chipanga III, IV and VIII mines, also served the purpose to inspect the equipment underground. Furthermore, the mine management provided all data of the equipment for reviewing.

7.7.1 Belt conveyor system

The belt conveyor systems in operation were built in 1968 and 1969 with the exception of a few units made by the GDR.

The steel construction is simple and the idlers cannot be shifted to another position. The intermediate steel plate for stabilisation is often corroded and a large number of idlers are stuck, in particular at those belt conveyors which were temporarily flooded after their installation.

The belt edges are ruined and the belt joints are often in need of repair. Some belt materials are not inflammable.

7.7.2 Chain conveyor

The chain conveyors are on average 20 years old.

A large number of drive frames are corroded, the drum sprockets are showing wear and the deck plate thickness is reduced to a minimum. Some pan connections are lacking bolts and nuts and there are no spill plates to increase the conveyor capacity.

The chain pretension is often too low and chain flights and chain locks are in the wrong positions.

There are only a few conveyors equipped with modern fluid couplings and tensionable return stations.

7.7.3 Scraper winches

Most of the scraper winches were built in 1969. All winches are driven by electric motors.

According to the management, the operation of the winches is supposed to be simple. However, some winches are equipped with insufficient rope diameters (10 mm instead of 14 mm) which can lead to rope failure.

There are some new scraper winches in stock which were bought in the USSR.

7.7.4 Pumps and auxiliary fans

Water pumps and auxiliary fans were manufactured before and around 1980.

The pumps are generally in a bad condition, due to the corrosive mine water. This is visible by numerous leakages at the high pressure side of the pumps. There are different types of pumps in operation.

The auxiliary fans, with a few exceptions, are a 7.5 KW-type which is manufactured in the GDR. The fans are robust and reliable. The majority are not equipped with silencers.

The fan ducts have both 500 and 600 mm diameters. The ducting is of nonflammable material.

7.7.5 Electrical equipment

The electrical equipment which is generally old fashioned, but flameproof.

The electrical motors which tend to breakdown due to switch frequency, humidity or overload are repaired at the mine workshop which usually entails a new motor-winding.

Each electrical machine underground has its own individual switch, built into its own switch box. The protection is both thermic and magnetic.

In the case of CH_4 gas accumulation the electrical power is switched off by hand, according to the manually measured gas values. Not all the cables are properly placed in cable-holders which results in numerous damages to cables.

7.7.6 Lack of spare parts

The spare part storage situation at Moatize is absolutely insufficient. There is a great lack of nearly every spare part, such as:

- drive frames and return pulleys of chain conveyors
- bolts and nuts for conveyors
- belt material and idlers
- winch ropes
- sealings and connection pieces for pumps

- dipping varnish and copper wire for electrical motor windings
- telephone sets and other items.

The reason for the comprehensive lack of parts is:

- land transportation from Beira Port to Moatize is difficult due to safety problems
- the numerous types of equipment require an extensive spare part storage
- no more spare parts available on the international market for the older types of equipment
- the shortage of hard currency limits the buying of parts on the international market
- the absence of qualified personnel in the storage department of Beira prohibits a smooth flow of available spare parts from Beira to Moatize

The lack of spare parts in Moatize is one of the main operational obstacles and this has to be solved before an increase of production can be envisaged.

7.7.7 Repair and replacement

Due to the fact that the Chipanga III and Chipanga IV mines are scheduled to have an ultimate lifetime of 4 respectively 8 years, from an economical point of view it is not reasonable to make investments for the complete replacement of all underground equipment. On the other hand, in order to maintain production in these mines, it is necessary to make some investments for the replacement of worn-out machinery, e.g. chain conveyors and pumps etc.

The major share of the equipment should be repaired if necessary and some additional investments should be made for communication, CH_4-monitoring and preventive measures concerning fire and explosion prevention underground.

The Chipanga VIII mine has to be equipped completely new, in order to meet the demands of a yearly production of more than 150,000 t. This includes new equipment for mining and development, a new mine fan and a new infrastructure. All functioning and well maintained old equipment such as auxiliary fans and scraper winches will be reused.

A comprehensive new investment program is necessary for the Chipanga VII (160,000 t/y) and Chipanga XI (90,000 t/y) mines which will be rehabilitated according to the action programmes.

7.7.8 Summary

A major share of the presently operated equipment is obsolete and out-dated. This results in reduced operating periods, increased repair and maintenance and shortage of spare parts which mean that the operational costs are continuously increasing.

The necessary replacement investments are calculated according to the operational lifetime of the mines.

The following table shows the different investment requirements for each mine.

Mine	Equipment	Stages of investment
Chipanga III	old	repair, replacement (minimum)
Chipanga IV	old	repair, replacement (minimum)
Chipanga VIII	old	repair, replacement, new investment
Chipanga VII	-	new investment
Chipanga XI	-	new investment
New mines	-	new investment

8. Action Plan Scenario A

8.1 Identification and definition of Scenario A

The Terms of Reference postulate an Action Plan for a sustained annual production of 500,000 t_{rom}. The individual actions to be taken, their interaction and priorities, are to be defined.

In the meetings with the Client, it was mutually agreed that Scenario A refers to the present mining operations of CARBOMOC and that the objective be to resume the production of the previous level of 1981 as fast as possible.

8.2 Available elements of Scenario A

As agreed upon, the existing mines with their remaining mineable coal reserves, see Chapter 5, form the quantitative base for this Scenario.

Operating mines:	Chipanga III, IV and VIII
Presently flooded mines:	Chipanga VII and XI

Because of the low reserve base left, the Chipanga III and IV mines, will face depletion within the next 4/8 years; they will, therefore, no longer play an important role in this Scenario. The reserve base of the other three mines and their design capacity in terms of annual production will determine the structure of the Scenario.

8.3 Assumptions for the concept to determine the mine design capacity

As mentioned in Chapters 3, 6 and 7 the high methane emission rate is the determinant parameter, limiting the production rate of the mines to the top.

The dependence of the production from the air quantities available in the mine, is determined by the following formula

$P = K \times Q$ P = Daily production t_{rom}/d
K = 0,14833 ~ 0,15 t x min/m^3 x d
Q = Air volume of the mine m^3/min

The factor K is a constant as indicated, if the following assumptions are accepted:

- 2 winning shifts per working day,
  1 maintenance shift per working day.
- The methane emission rate during the winning shift is 50% above the daily average emission.
- The methane emission rate during the effective winning time of the winning shift is 50% above the average of the winning shift.
- Duration of a shift : 480 min
- Winning time/winning shift : 240 min
- Maximum admissable methane content in the air currents : 1 % CH_4
- Factor to compensate discontinuous air volumes : 1.2
- Maximum admissable air velocity : 4 m/sec
- Methane emission rate per t_{rom} : 60 m^3CH_4/t_{rom}
  (this figure has been adapted from information available but needs to be verified.)

Taking the maximum air volume delivered by the mine fan as the bottle neck capacity of the mine, the maximum production of the three larger Chipanga mines is calculated as follows:

Chipanga VII mine	:	0.15 x 3800 =	570 t_{rom}/d
Chipanga VIII Mine	:	0.15 x 3800 =	570 t_{rom}/d
Chipanga XI mine	:	0.15 x 2145 =	321 t_{rom}/d
			1461 t_{rom}/d

It is supposed that 3 mine ventilators are duly installed to supply the given air quantities at an optimal efficiency factor. In order to warrant mine safety, for each operating mine fan an identical stand-by unit must be readily available.

A further consequence of the air quantities as fixed above, is to check the incline sections of the intake and return air currents, in view of their size, because of the limitation of the air velocity at 4 m/sec. The existing cross-sections of the inclines providing for the supply of intake air, are some 12 m^2 (effective). Using the maximum air volume of 3,800 m^3/min would require a cross-section of approx. 15.8 m^2. Therefore, careful replanning of the layout and the ventilation requirements should guarantee the above production target figures. (See also Chapter 7.6.2.1)

The production targets for each of the 5 Chipanga mines is determined as follows:

<u>Chipanga III mine</u> : Due to the short lifetime of the mine, major investments should be avoided.

A production rise of some 25 %, related to the average production of the last years, has been considered a reasonable target, resulting in a daily production of 100 t/d; the present availability of equipment and spare-parts prohibits fixing of the production at a higher level. Under these conditions, the mine will be closed 4 years from now, due to depletion of reserves.

<u>Chipanga IV Mine</u> : The situation is similar to Chipanga III mine. Also a 25 % rise in production, opposed to the envisaged figure for 1989 was assumed, resulting in 34.000 t_{rom} p.a., as the annual target figure for the next 8 years. The mine will then also close due to depletion of reserves.

<u>Chipanga VIII mine</u> : Up to now, only some 16 % of the total mineable reserves have been mined. The main inclines are developed to the bottom of the syncline. At present the mine activities focus on panel development.

Under these circumstances, the mine should be redesigned for a production capacity of 160,000 t_{rom} p.a., as one backbone of Scenario A. This redesign would concern the following topics mainly:

- Protection of the required air volumes by review of cross-sections of inclines and review of main fan capacity and characteristic.

If required, additional actions must be considered and how they affect the time schedule of Scenario A.

- Recruitment and training of qualified miners, mechanics, electricians and other types of craftsmen, in compliance with the requirements of Scenario A.

- Completely new planning and design of the mine's equipment underground and at the surface and their cost.

- Provision of sufficient funds to finance the capital investment costs

- Preparation of the Project Time Schedule for the rehabilitation of the mine, encompassing all steps necessary with their interactions, to achieve the new production target.

- Coal transport to the central screening plant and overall review of the auxiliary surface facilities.

<u>Chipanga VII mine</u> : The mine is presently flooded. Of the total mineable reserves, so far only 14 % have been mined. Amongst the 5 existing mines, this mine has the largest area and holds the highest amount of reserves. The mine layout is characterized by the spreading of the main inclines at a certain depth into two different directions, to give access to the extended mining areas, in the deeper parts of the deposit.

Drainage of mine water would be one of the first tasks to effect recommencement of mining operations.

Similar to Chipanga VIII mine, a complete redesign of the mine for the production of 160,000 t_{rom}/p.a. is foreseen, as the two mines together should yield an annual production of 320,000 t_{rom}.

Reconstruction of the mine entrance sections also forms part of the initial work, prior even to drainage of the mine, as meanwhile this has collapsed.

Chipanga XI mine : This mine is the youngest of the five existing mines. Only 5,600 t_{rom} were mined when the main inclines were developed some 300 m long. The mine's reserves amount to only half of those for Chipanga VII mine. The present layout prohibits working of the two wings with the same performance. Therefore, the production target was reduced to 90,000 t_{rom}/p.a.

Furthermore, all statements made on Chipanga VII mine apply to this mine as well.

It is assumed that the marketing chances of the selling products and the production revenues are not too sensibly reduced by the ash contents, to make the construction of a new central washery essential for the quality improvement of the selling products, in view of their better acceptance on the international coal market.

Main result of these considerations is that the future production target from the existing mines achieves a sustained level of 410,000 tpa.

All above assumptions have to be verified prior to execution.

8.4 Production development schedule for Scenario A

Based on the information on the previous sections, the production development schedule has been drawn up as a realistic objective of Scenario A, see Annex 8.

These mines will produce 410,000 t_{rom} p.a. over a period of more than 10 years after a rehabilitation and construction period of 4 years. The lead time of 4 years is deemed necessary to carry out replanning/redesign of the 3 mines and for the tendering/ordering/delivering process of new equipemnt. In our opinion, the above target figure of 410,000 t.p.a. cannot be warranted otherwise on a sustained level.

It is, furthermore, our opinion that Scenario A is the most reliable and realistic of the three scenarios. (This, however, does not include coal transport and marketing aspects!)

8.5 Necessary actions for implementation of Scenario A and their timing

To ensure that all actions to be taken for the above task are recorded, a systematic approach was selected which is laid down in Annexes 9, 10 and 11.

The type of action is indicated to facilitate an estimate of the work volume and time required for its implementation.

Reference is made to Annex 12 as to the timing, the interactions and their consequences for the execution in subsequent or parallel steps.

As Scenario A is confined to the existing mines, with their relatively low ash coal reserves, the design and construction of a new coal washery is not recommendable, if high capital cost charges are to be avoided.

8.6 Budget estimates for the purchase of new equipment

Essential for the final decision is to ascertain the amount of money to be invested in this project for its viability. In compliance with the contract, a cost estimate for the purchase of new equipment has been compiled in Annex 13.

The overall capital cost requirement for purchase of new equipment amounts to approx.

32 million US$ as per 1989

9. Action Plan Scenario B

9.1 Identification and definition of Scenario B

The second Scenario B postulates an Action Plan for a sustained annual production of 1 million t_{rom} from underground mines of the Moatize basin. The individual actions to be taken, their interaction and priorities are to be defined.

In the meetings with the Client, it was clarified that next to the existing mines, new mines will be required to be developed in the so-called exploration sections which are reserved for underground mining.

9.2 Available elements of Scenario B

Next to the existing underground mines, as in Scenario A, only Section 5 and the Central Section, with their reserves in the Chipanga seam bottom slice, are destined for underground mining.

Though the base of some 70 million t mineable reserves in the exploration sections is impressive, see Chapter 5.4, two types of deficiencies affect their unconditional use in this Scenario:

- only 12.6 % of the total reserves is of the quality comparable with the remaining reserves of the existing mines; i.e. only 8.8 million t in Section 5 have an ash content < 25%.

- the reserves are attributed to reserve classes C_1 and C_2; more exploration work is required before sound planning of mining operations can be tackled. The reserves in the Central Section are covered by more than 250 m overburden. This means that the proven mining method room and pillar most probably will no longer be applicable.

9.3 Assumptions for the concept of Scenario B

Whether or not the methane emission rate is also the determinant parameter for the maximum mine production of the exploration sections, cannot be decided; it might well be that structural elements of the deposit play as important a role as the methane emission rate.

Though the planning and design of the new mines in the exploration sections can be carried out without restrictions, in contrast to the redesign of the existing mines in Scenario A, it is considered wise, due to lack of reliable data, to proceed from the experience of the past in the Moatize basin and also make use of our general expertise in underground coal mining.

Careful consideration resulted in the following target figures for the mines' annual production:

- two mines in Section 5, one in the northern and one in the southern block, each with a design capacity of 120,000 t_{rom} p.a.
- two mines in Central Section, each with a design capacity of 120,000 t_{rom} p.a.

For the realization of this concept, the subsequent programme was conceived:

It is considered unfeasible to coordinate the redesigning of the 3 existing mines and the design of 4 new mines in the exploration sections at the same time.

Therefore, the start of the various design works was proposed in three stages at staggered intervals

redesign of 3 existing mines
design of 2 mines in Section 5
design of 2 mines in Central Section

The duration of the planning and design cycles is estimated:

2 years for the existing mines, except for the already producing Chipanga VIII mine, which will only be modified, without interruption of its production
3 years for each of the 4 new mines.

Given this procedure, a gradual build-up of the target production of 890.000 t_{rom} p.a. over 10 years is considered realistic. At the end of 1996, the milestone of 500.000 t will be reached. At the end of the century, the target figure will be achieved and can be maintained at a sustained level over the next 5 years.

The gradual increase of the production has the advantage that marketing of the coal can keep pace more easily with the production; it must not be forgotten, that the extracted coal must reach its final destination within three months, if traded as coking coal, see chapter 6.6.3 and Chapter 4, because of the deterioration of the Swelling Index.

All these assumptions have to be verified prior to execution.

9.4 Production development schedule for Scenario B

Following the same procedure as for Scenario A, a production development schedule has been prepared which shows the annual production target over a 15 year's period, see Annex 14.

The target of 890.000 t_{rom} p.a. for the Scenario represents the total production of the 7 mines, (3 mines of Scenario A and 4 mines developed in the context of Scenario B).

This figure can only be maintained over a period of 5 years, beginning by the year 2000 and will afterwards decrease due to depletion of reserves of the already existing mines, unless new mines are developed in due time.

9.5 Necessary actions for the implementation of Scenario B and their timing

As with Scenario A, a list of actions necessary to ensure the production targets has been established, which is incorporated in Annexes 9, 10 and 11.

Timing of the actions, their interactions and the consequences for the execution in subsequent or parallel steps, is shown in Annex 15.

9.6 Budget estimates for the purchase of new equipemnt

Again, as in the case of Scenario A, the investment costs for the purchase of new equipement necessary for the implementation of Scenario B have been estimated. According to the equipment list in Annex 13, the overall capital cost requirement would amount to

70 million US$ as per 1989.

Certain reservations must be expressed, as the planning frame is not as certain as for Scenario A.

10. Action Plan Scenario C

10.1 Identification and definition of Scenario C

The third scenario, called Scenario C, postulates an Action Plan for an annual production of 10 million t_{rom} p.a. at a sustained level.

The production should stem from underground mines in the Moatize coal basin.

10.2 Assessment of Scenario C

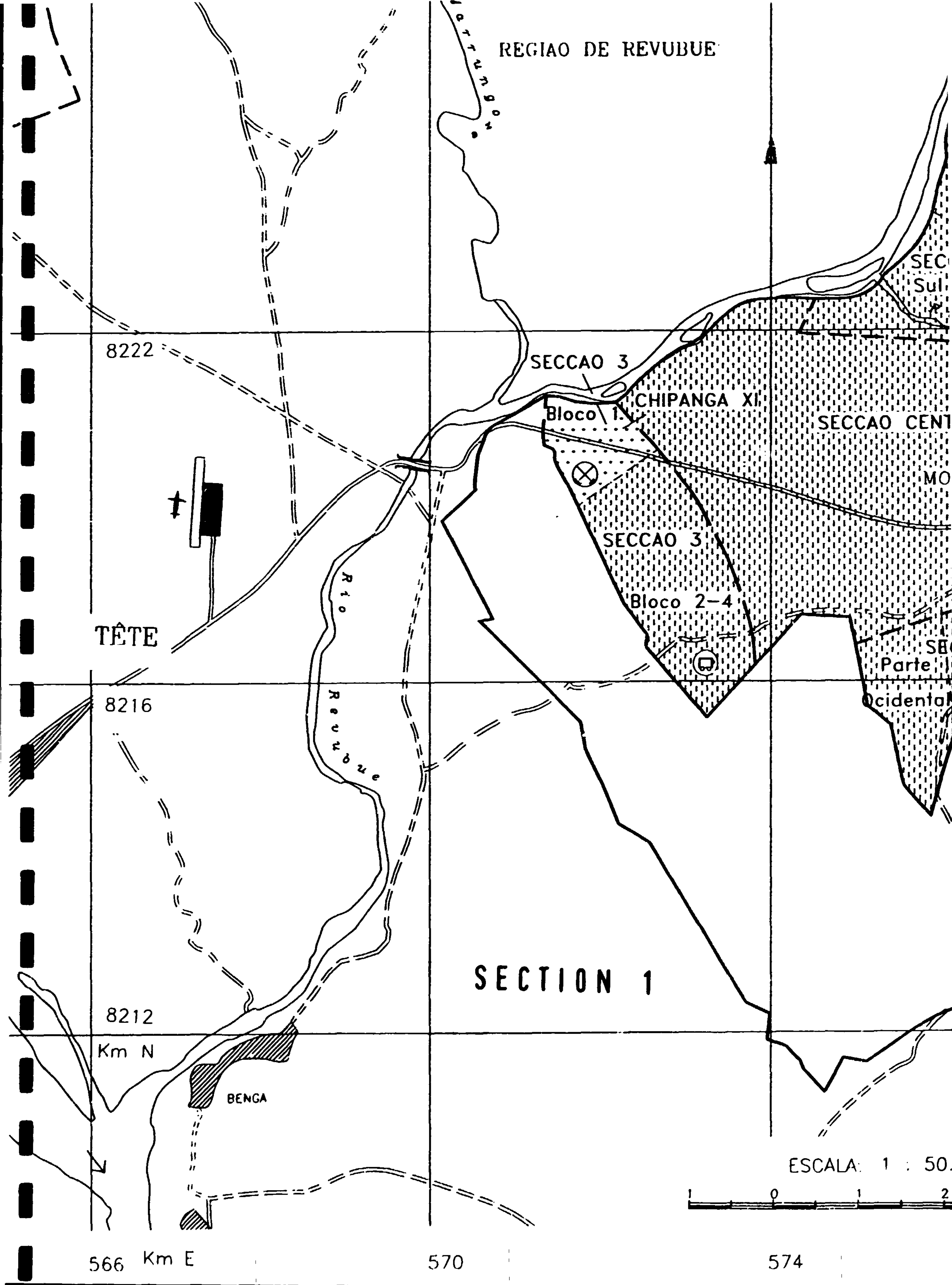
Based on the information of the previous chapters, it can easily be concluded that this Scenario is unfeasible. There are two reasons which advocate this assessment:

- non-availability of sufficiently explored coal reserves

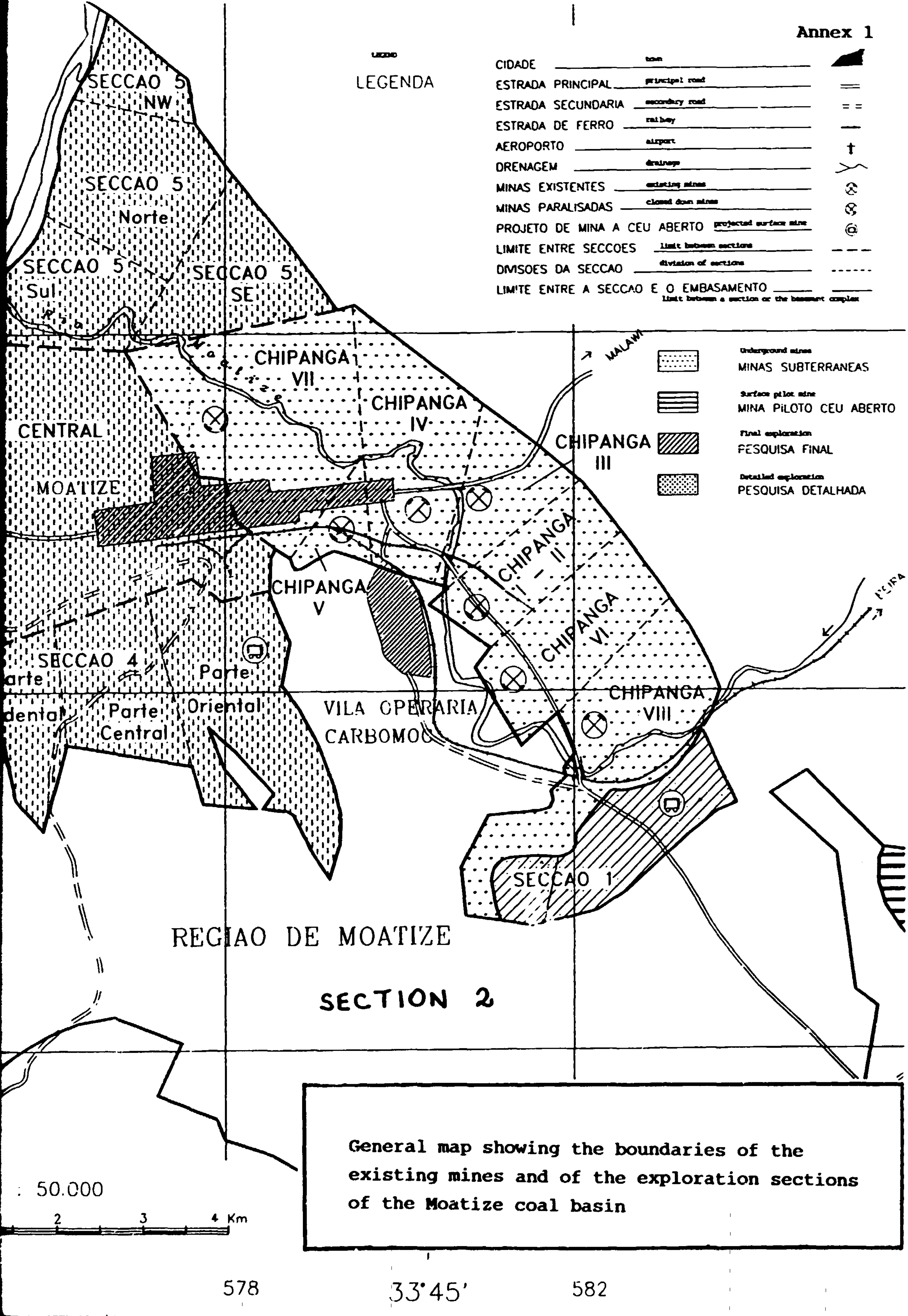
- based on the presently existing average mine size of 120 - 140,000 t and assuming that mining conditions in the new mines to be developed, would not differ significantly from those presently known. The number of mines required to achieve the desired target production would amount to more than 70. A mining venture of this structure would scarcely be manageable.

Annexes

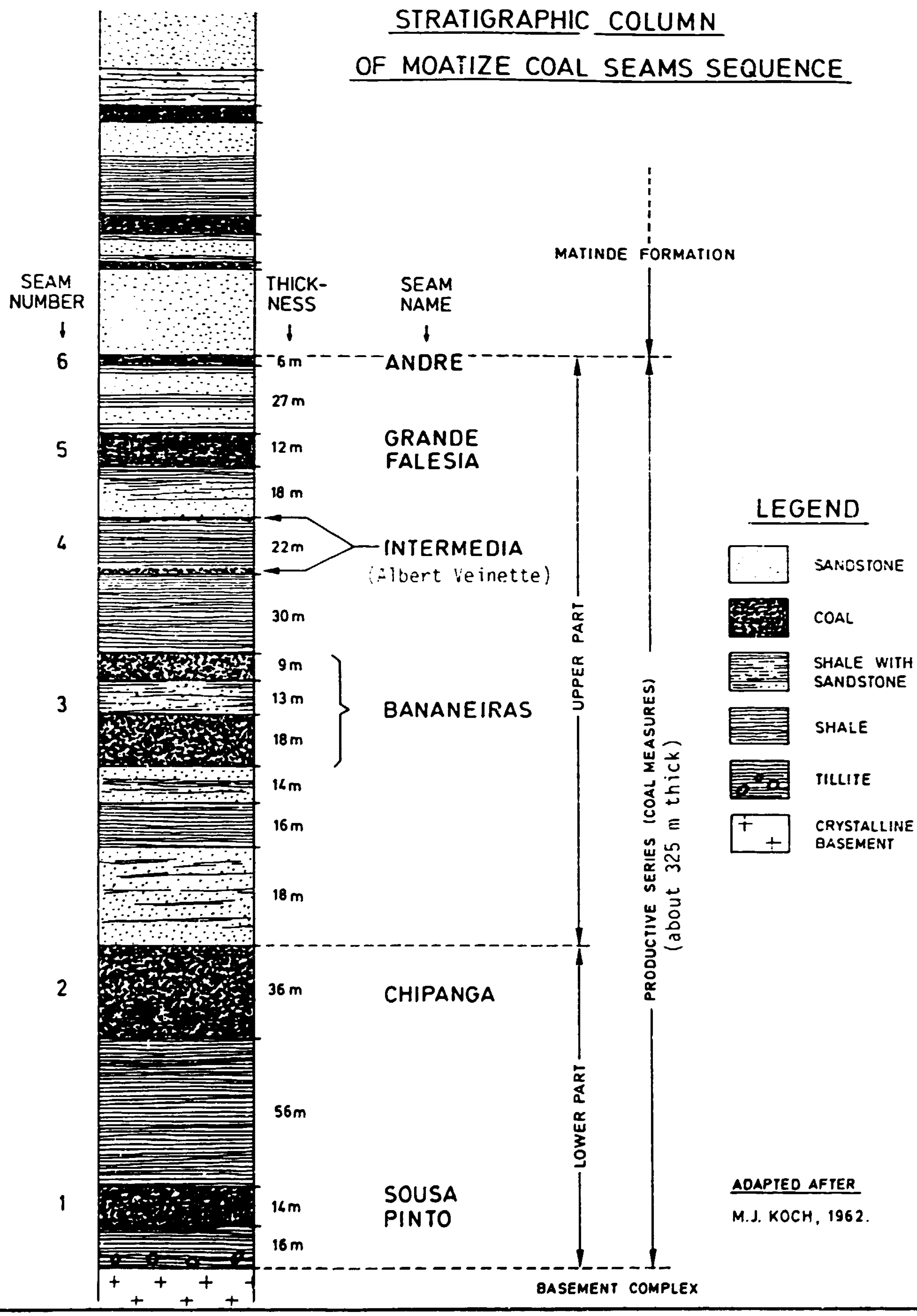
Annex 10	Action Plan - Scenarios A + B Development of Surface Plants on each mine: Activities' List	500,000 t.p.a. 1,000,000 t.p.a.
Annex 11	Action Plan - Scenarios A + B Central Surface Plant Facilities: Activities' List	500,000 t.p.a. 1,000,000 t.p.a.
Annex 12	Action Plan - Scenario A: Activities' Time Schedule	500,000 t.p.a.
Annex 13	Estimate of Equipment Investment Costs for Realization of Action Plan Scenario A and Action Plan Scenario B	
Annex 14	Action Plan - Scenario B: Production Development Schedule	1,000,000 t.p.a.
Annex 15	Action Plan - Scenario B: Activities' Time Schedule	1,000,000 t.p.a.

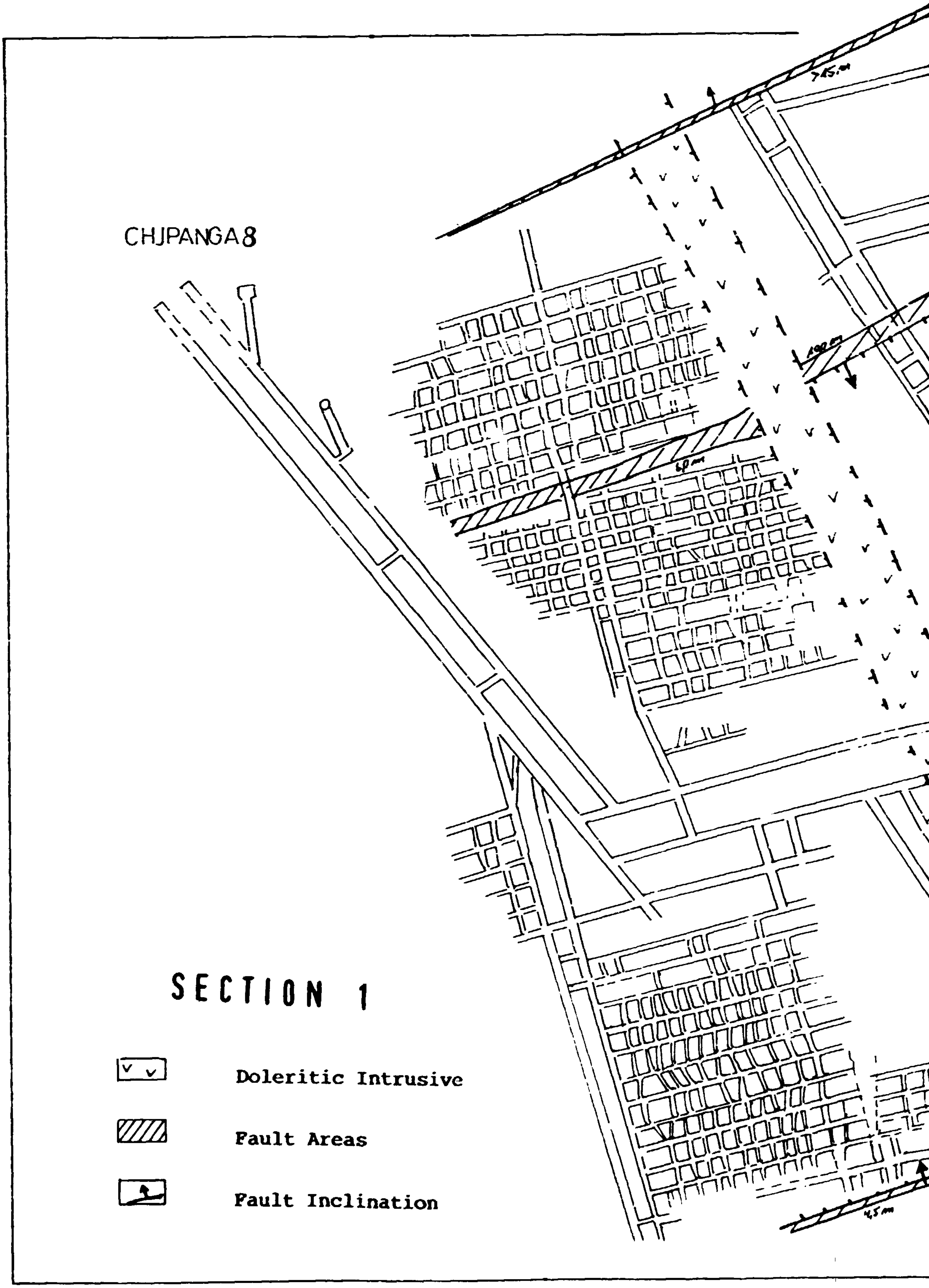

REGIAO DE REVUBUE
SECCAO 3
CHIPANGA XI
Bloco 1
SECCAO CENT
SEC
Sul
MO
SECCAO 3
Bloco 2-4
SE
Parte
Ocidental
TÊTE
Rio Revubue
8222
8216
8212
Km N
BENGA
SECTION 1
ESCALA: 1 : 50.
1 0 1 2
566 Km E
570
574

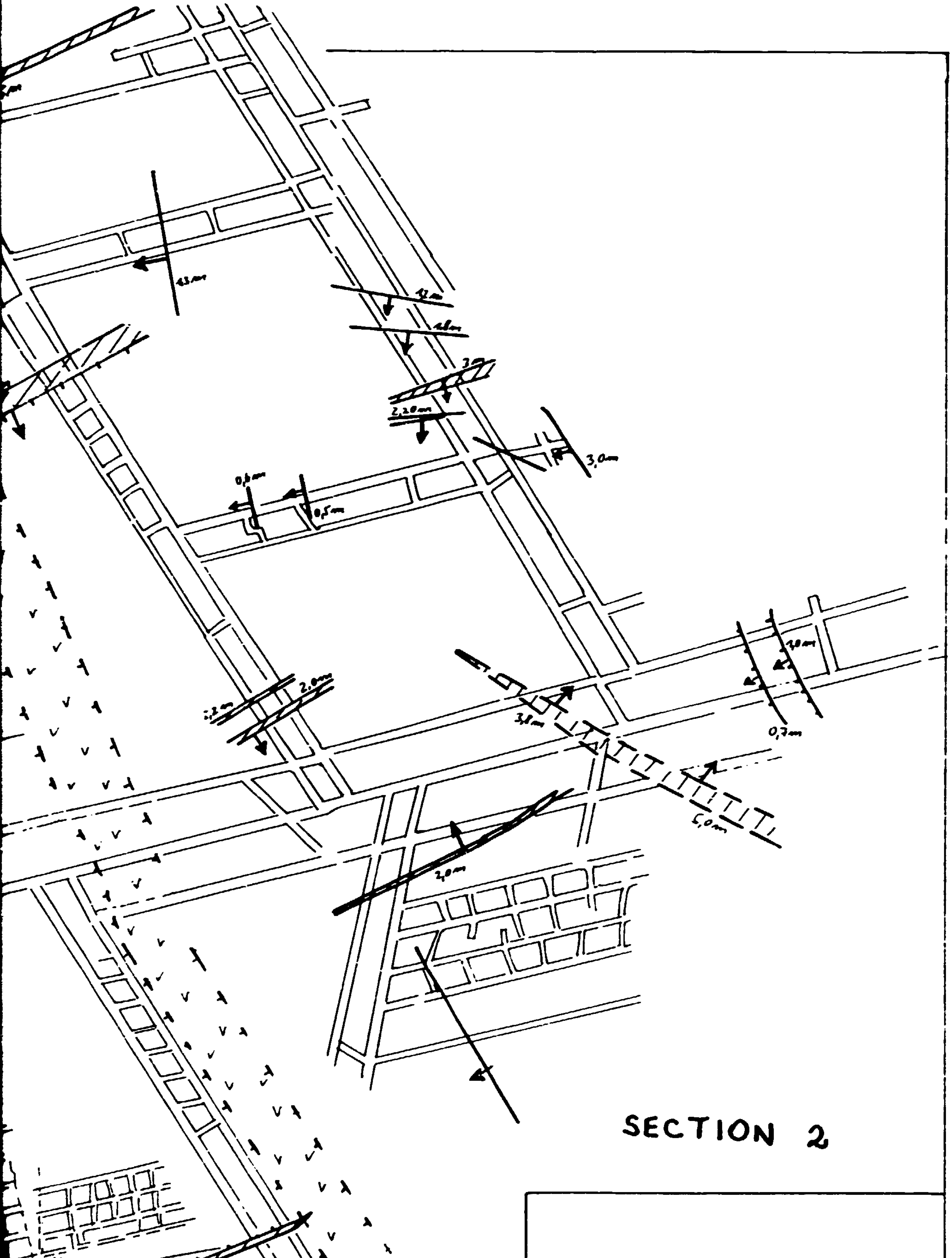
Annex 1



General map showing the boundaries of the existing mines and of the exploration sections of the Moatize coal basin


STRATIGRAPHIC COLUMN
OF MOATIZE COAL SEAMS SEQUENCE
SEAM NUMBER
THICK-NESS
SEAM NAME
MATINDE FORMATION
6
6 m
ANDRE
27 m
5
12 m
GRANDE FALESIA
18 m
4
22 m
INTERMEDIA
(Albert Veinette)
30 m
9 m
3
13 m
BANANEIRAS
18 m
14 m
16 m
18 m
2
36 m
CHIPANGA
56m
1
14m
SOUSA PINTO
16 m
UPPER PART
LOWER PART
PRODUCTIVE SERIES (COAL MEASURES)
(about 325 m thick)
BASEMENT COMPLEX
LEGEND
SANDSTONE
COAL
SHALE WITH SANDSTONE
SHALE
TILLITE
CRYSTALLINE BASEMENT
ADAPTED AFTER
M.J. KOCH, 1962.

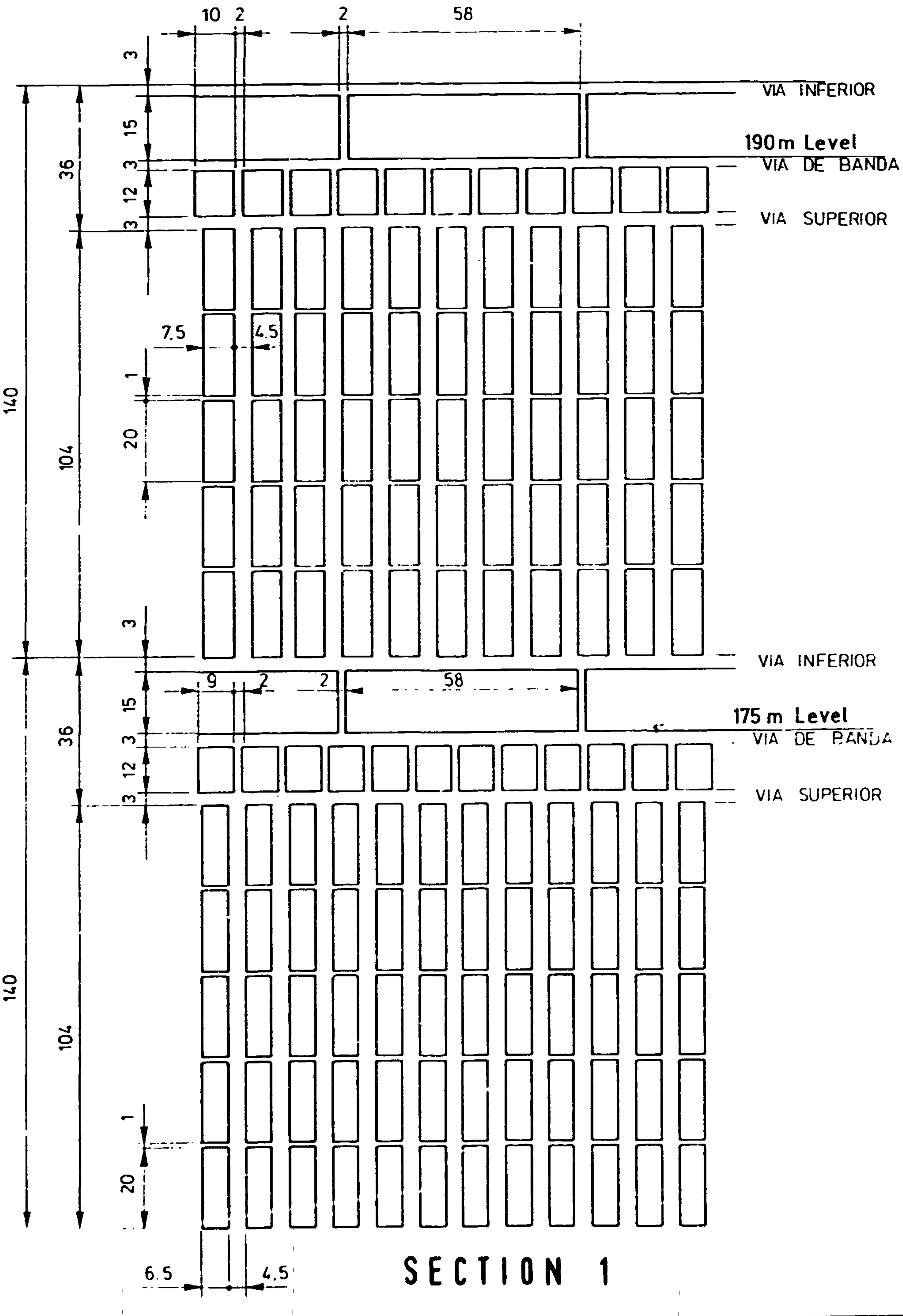

CHJPANGA 8
SECTION 1
Doleritic Intrusive
Fault Areas
Fault Inclination



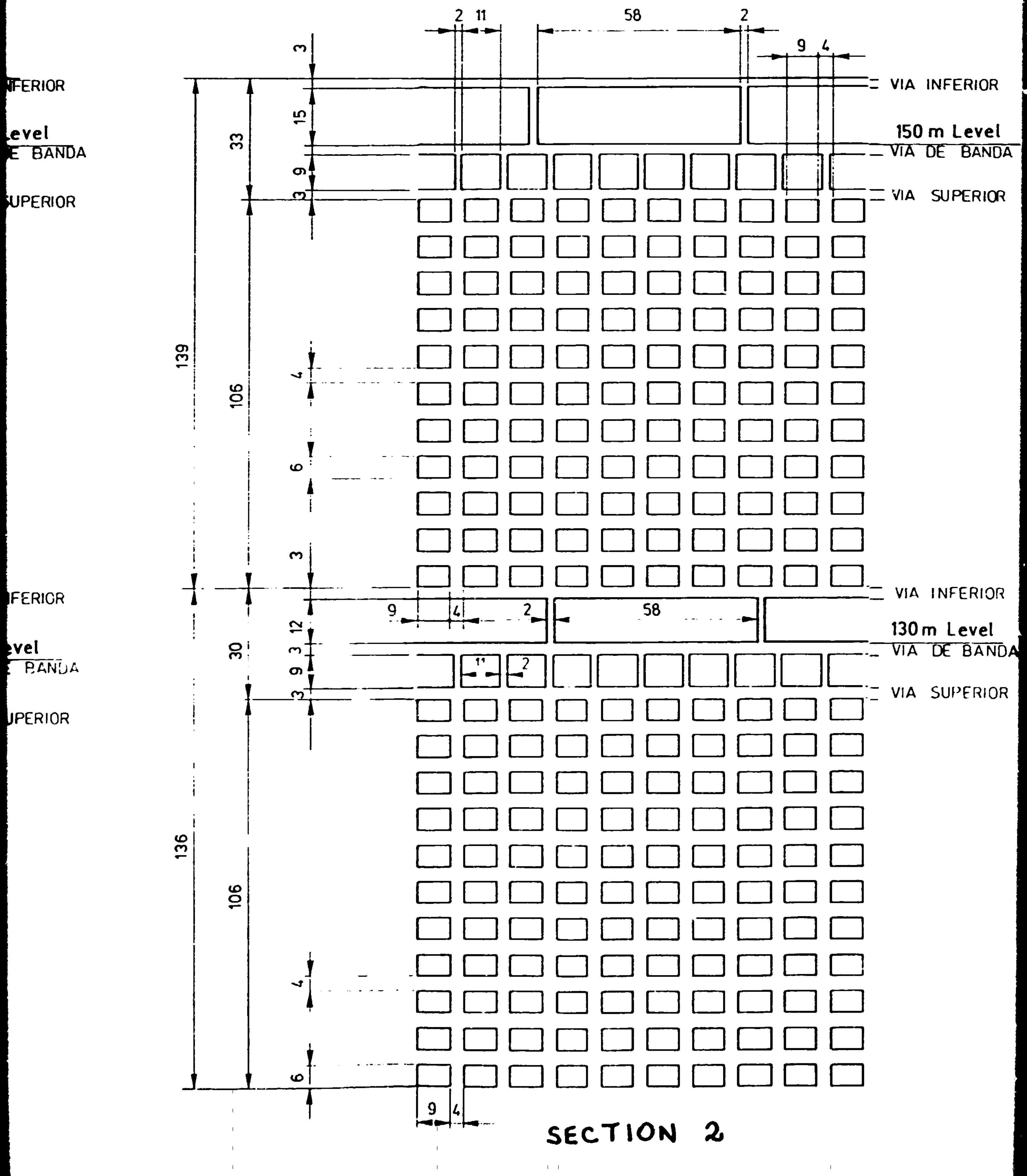
Sketch of Chipanga VIII mine showing fault occurrence

Depths of mining (m)	< 40	40-75	75-105	105-150	150-175	175-200	> 200
Reserve losses (%)	31	35	44	51	62	65	79
Geological reserves t/m^2							
3.62	2.50	2.36	2.03	1.78	1.38	1.27	0.76
4.35	3.00	2.83	2.44	2.13	1.65	1.52	0.92
5.08	3.50	3.30	2.84	2.48	1.93	1.78	1.07
5.80	4.00	3.77	3.24	2.84	2.20	2.03	1.21
6.52	4.50	4.24	3.65	3.20	2.48	2.28	1.37
7.25	5.00	4.71	4.06	3.55	2.76	2.54	1.52
7.98	5.50	5.18	4.47	3.90	3.03	2.79	1.68

Recovery rate of reserves as function of depth of mining and seam thickness $\rho = 1.45\ t/m^3$

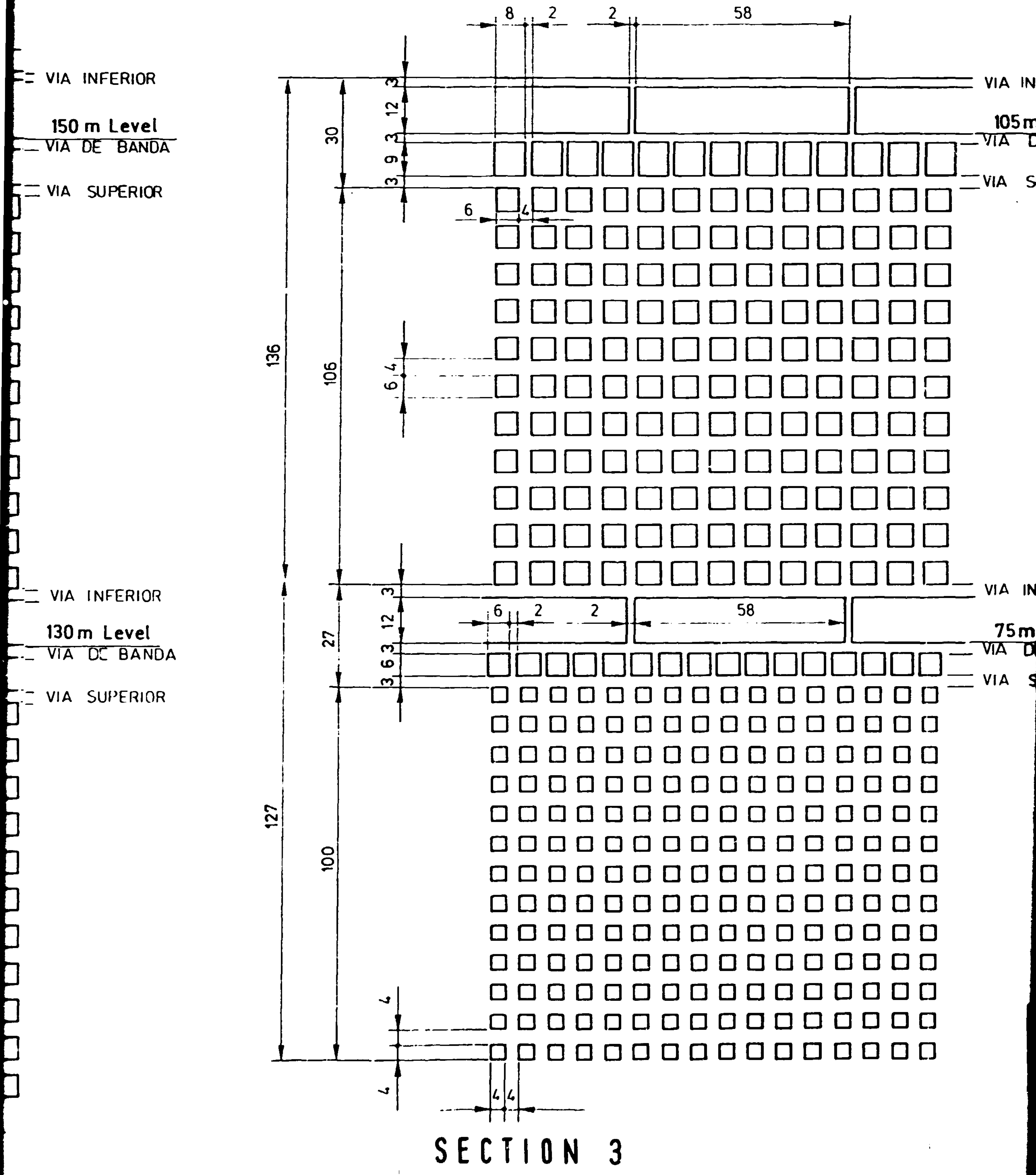

VIA INFERIOR
190m Level
VIA DE BANDA
VIA SUPERIOR
VIA INFERIOR
175 m Level
VIA DE BANDA
VIA SUPERIOR
10
2
2
58
3
15
3
12
3
36
140
104
7.5
4.5
1
20
9
6.5

SECTION 1

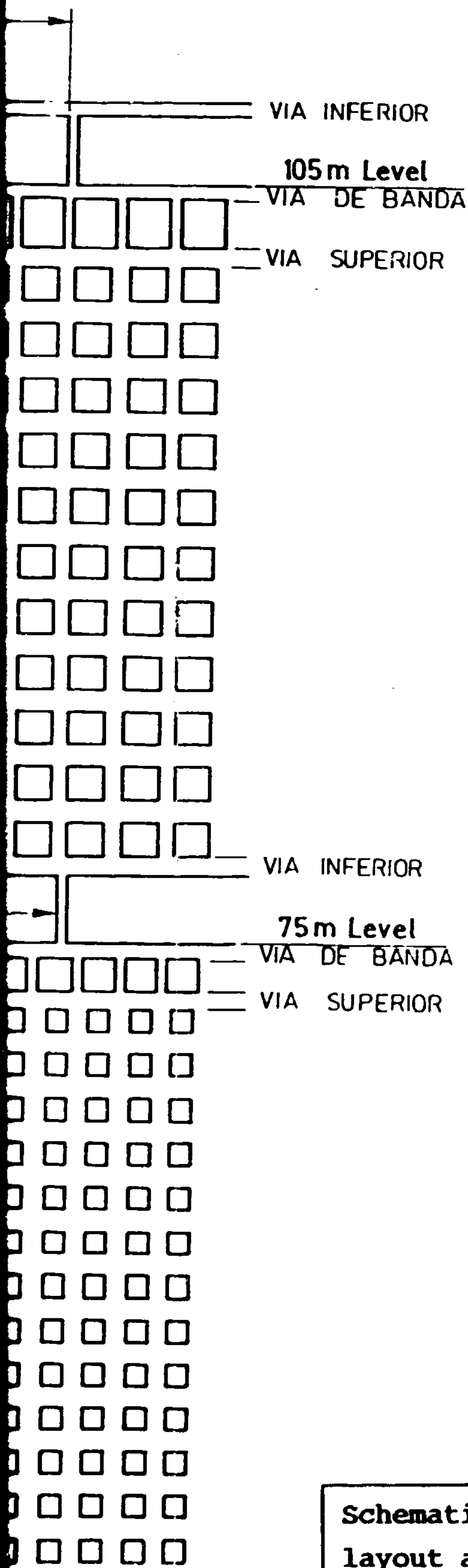


2
11
58
2
9
4
3
15
33
9
3
VIA INFERIOR
150 m Level
VIA DE BANDA
VIA SUPERIOR
139
106
4
6
3
VIA INFERIOR
9
4
2
58
130 m Level
12
30
3
9
3
VIA DE BANDA
VIA SUPERIOR
136
106
4
6
9
4

SECTION 2

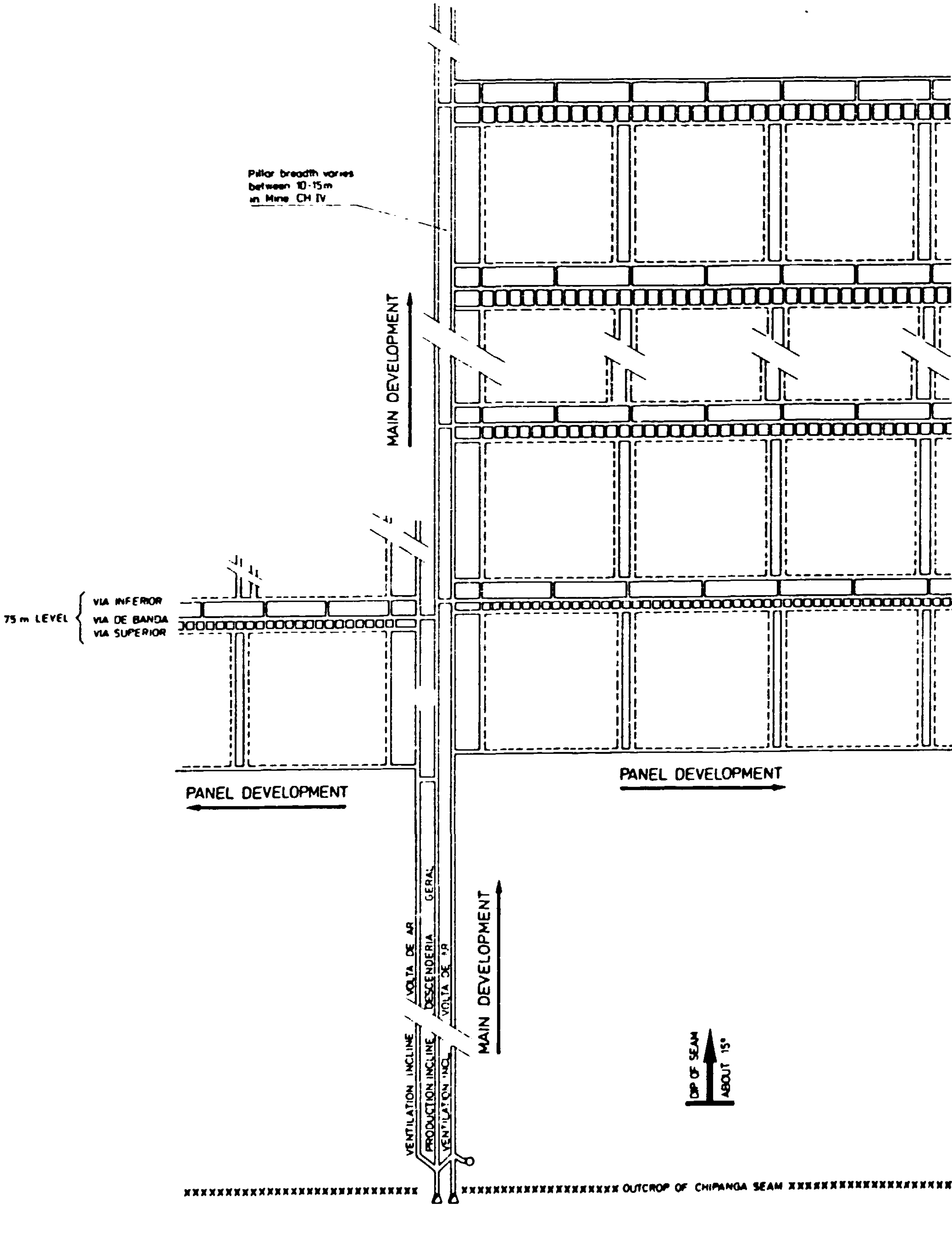

VIA INFERIOR
150 m Level
VIA DE BANDA
VIA SUPERIOR
VIA INFERIOR
130 m Level
VIA DE BANDA
VIA SUPERIOR
105m
75m
8
2
2
58
3
12
3
9
3
30
136
106
6
4
27
6
2
2
58
127
100
4
4
4
4

SECTION 3



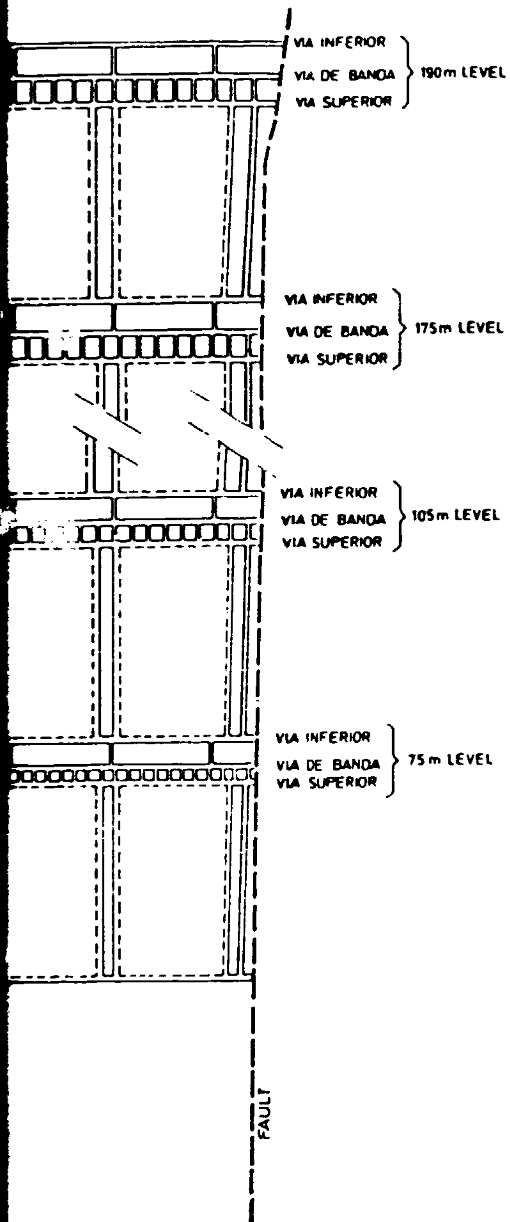
SECTION 4

Schematic plan of room and pillar mining layout as applied in CARBOMOC's min



Pillar breadth varies between 10-15m in Mine CH IV
MAIN DEVELOPMENT
75 m LEVEL
VIA INFERIOR
VIA DE BANDA
VIA SUPERIOR
PANEL DEVELOPMENT
PANEL DEVELOPMENT
MAIN DEVELOPMENT
VOLTA DE AR
DESCENDERIA
GERAL
VOLTA DE AR
VENTILATION INCLINE
PRODUCTION INCLINE
DIP OF SEAM
ABOUT 15°
OUTCROP OF CHIPANGA SEAM

SECTION 1



LEGEND:

(FOR PANEL DEVELOPMENT ONLY)

VIA INFERIOR • LOWER GANGWAY
VIA DE BANDA • GENERAL HAULAGE GANGWAY
VIA SUPERIOR • UPPER GANGWAY

SECTION 2

Drawing No.	AM - 85 / 44	AUSTROMINERAL
Date	JANUARY 1985	
Draft	RUTHNER	
Approved	HONIG	
1 : 2,500		SCHEMATIC PLAN OF MAIN AND PANEL DEVELOPMENT
Reduction - 60 %		TECHNOLOGICAL CONCEPT ON DEVELOPMENT OF MOATIZE COAL MINES — FIG 3 - 2

Production Record Moatize Coal Mines

1972 - 1989 in 1,000 t_{rom}

Chipanga Mines							
Year	III	IV	VII	VIII	XI	(V+VI)	Total
1972	13.5	-	opened up			322.8	336.3
1973	37.1	-				357.1	394.2
1974	74.6	0.2	6.8			344.3	425.9
1975	128.3	82.3	85.1			279.1	574.8
1976	157.9	181.1	138.4	opened up		81.5	552.9
1977	108.7	143.7	33.4	2.5		-	288.3
1978	47.3	165.4	-	23.5		-	236.2
1979	95.3	153.2	-	71.1		-	319.6
1980	110.1	148.7	18.1	131.8	opened up	-	408.7
1981	121.1	164.0	94.7	154.8	-	-	534.6
1982	18.9	11.0	25.7	5.4	5.6	-	66.6
1983	17.4	40.7	0.6	-	-	-	58.7
1984	33.4	33.5	-	-	-	-	66.9
1985	1.2	19.2	-	-	-	-	20.4
1986	3.2	0.7	-	-	-	-	3.9
1987	22.5	18.5	-	2.3	-	-	43.3
1988	3.7	13.8	-	6.4	-	-	23.9
1989*	21.5	27.0	-	12.5	-	-	61.0
		accumulated :	402.8	410.3	5.6		

* : estimated

ACTION PLAN - SCENARIO A 500,000 t.p.a. Production Development Schedule - 1,000 t_{rom} p.a. -																				
Chipanga Mines	**Period**																			
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
III	22	22	28	28	*	*														
IV	34	34	34	34	34	34	34	22	*	*										
VIII	14	44	118	160	160	160	160	160	160	160	160	160	160	160	160	4	*	*		
VII	-	-	25	100	160	160	160	160	160	160	160	160	160	160	160	160	160	160	135	*
XI	-	-	25	55	90	90	90	90	90	90	90	90	90	90	90	90	90	50	*	
Total	**70**	**100**	**230**	**377**	**444**	**444**	**444**	**432**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**254**	**250**	**210**	**135**	-

* : depleted

ACTION PLAN - SCENARIOS A + B 500,000 t.p.a.
1,000,000 t.p.a.

Development of Underground Operations : Activities

	Mines in operation			Inundated Mines		Section 5		Central Section	
	Chipanga Mines					Bloc N	Bloc S	Bloc 1	Bloc 2
	III	IV	VIII	VII	XI				
Additional Design Criteria									
- additional exploration	0	0	0	0	0	1	1	1	1
- specific data: pillar dimensioning	1	1	1	1	1	1	1	1	1
- determination of gas content	1	1	1	1	1	1	1	1	1
Design									
- mine access	0	0	0	1	1	1	1	1	1
- mine layout	0	0	0	2	2	1	1	1	1
- winning procedure	0	0	2	1	1	1	1	1	1
- coal haulage	0	0	2	1	1	1	1	1	1
- material transports	0	0	2	1	1	1	1	1	1
- energy (power, compr. air)	2	2	2	1	1	1	1	1	1
- ventilation	2	2	2	1	1	1	1	1	1
- water: supply and drainage	2	2	2	1	1	1	1	1	1
- communication	1	1	1	1	1	1	1	1	1
- operational media	0	0	1	1	1	1	1	1	1
- spare parts	1	1	1	1	1	1	1	1	1
- supports	3	3	3	1	1	1	1	1	1
- specs, bill of quantities	1	1	1	1	1	1	1	1	1
- preliminary time/cost schedule	1	1	1	1	1	1	1	1	1
Financing	1	1	1	1	1	1	1	1	1
Supplies and Work Performance									
- tendering	1	1	1	1	1	1	1	1	1
- review of offers	1	1	1	1	1	1	1	1	1
- contracting	1	1	1	1	1	1	1	1	1
- final time/cost schedule	1	1	1	1	1	1	1	1	1
Construction and Assembling	2	2	1	1	1	1	1	1	1
Personnel Training	1	1	1	1	1	1	1	1	1
Development of Operations	1	1	1	1	1	1	1	1	1

0 : no action required
1 : comprehensive action necessary
2 : improvement and/or substitution
3 : due to operational conditions

ACTION PLAN - SCENARIOS A + B 500,000 t.p.a.
1,000,000 t.p.a.

Development of Surface Plants on Each Mine: Activities

	Mines in operation			Inundated Mines		Section 5		Central Section	
	Chipanga Mines								
	III	IV	VIII	VII	XI	Bloc N	Bloc S	Bloc 1	Bloc 2
Collection of Design Criteria									
- personnel facilities	0	0	1	1	1	1	1	1	1
- material facilities	0	0	1	1	1	1	1	1	1
- product facilities	2	2	1	1	1	1	1	1	1
- safety aspects	1	1	1	1	1	1	1	1	1
- infrastructure	2	2	1	1	1	1	1	1	1
Design									
Personnel facilities									
- change + sanitary facilities	2	2	1	1	1	1	1	1	1
- work cloth: store and distribution	2	2	1	1	1	1	1	1	1
- lamp room and distribution	2	2	1	1	1	1	1	1	1
- CO rescue devices and distribution	2	2	1	1	1	1	1	1	1
- tools, consumables and distribution	2	2	1	1	1	1	1	1	1
- shift monitoring	2	2	1	1	1	1	1	1	1
- office: mine manager	2	2	1	1	1	1	1	1	1
- office: supervisor	2	2	1	1	1	1	1	1	1
Safety Aspects									
- communication	1	1	1	1	1	1	1	1	1
- mine control	1	1	1	1	1	1	1	1	1
- first aid	1	1	1	1	1	1	1	1	1
Infrastructure									
- power (feeder, transformer and distributor)	2	2	1	1	1	1	1	1	1
- compressed air	1	1	1	1	1	1	1	1	1
- mine ventilation	2	2	1	1	1	1	1	1	1
- mine water reservoir	1	1	1	1	1	1	1	1	1
Product									
- bunker (intermediate storage)	2	2	1	1	1	1	1	1	1
- transport	2	2	1	1	1	1	1	1	1
Specs, bill of quantities	1	1	1	1	1	1	1	1	1
Preliminary time/cost schedule	1	1	1	1	1	1	1	1	1
Financing	1	1	1	1	1	1	1	1	1
Supplies and Work Performance									
- tendering	1	1	1	1	1	1	1	1	1
- review of offers	1	1	1	1	1	1	1	1	1
- contracting	1	1	1	1	1	1	1	1	1
- final time/cost schedule	1	1	1	1	1	1	1	1	1
Construction and Assembling	1	1	1	1	1	1	1	1	1
Personnel Training	1	1	1	1	1	1	1	1	1
Development of Operations	2	2	1	1	1	1	1	1	1

0 : No action required
1 : comprehensive action necessary
2 : improvement and/or substitution
3 : due to operational conditions

ACTION PLAN - SCENARIOS A + B 500,000 t.p.a.
1,000,000 t.p.a.

Central Surface Plant Facilities : Activities

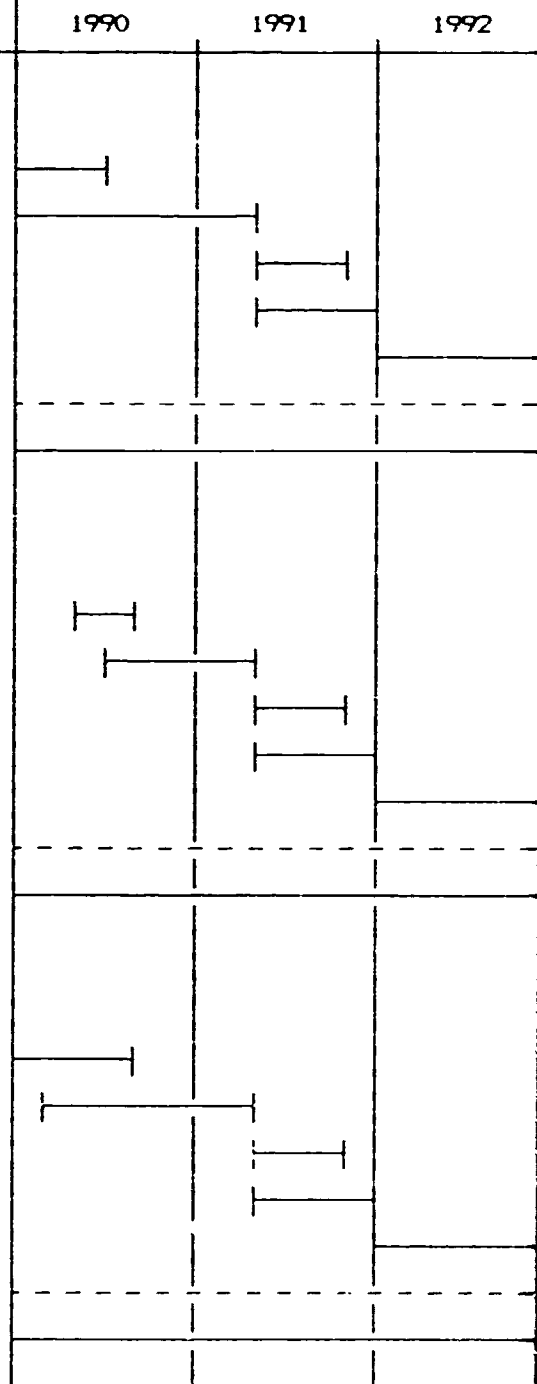
Collection of Design Criteria	
- personnel facilities	1
- material facilities	1
- product facilities	1
- safety aspects	1
- infrastructure	1
Design	
Personnel facilities	
- administration (technical, commercial and legal)	2
- health services	2
- welfare	1
- education and training	1
Safety aspects	
- mine rescue	2
- fire brigade	1
- central alarm system	1
Infrastructure	
- energy (feeder, distribution, metering)	2
- media (supply- and discharge lines)	2
- transports	2
- communication	1
Products	
- homogenisation stockpile	1
- coal washery	1
- final products' bunkers	1
- tailings handling	1
Material	
- Central store : mechanical equipment	2
- " " : electrical "	2
- " " : control- and monitoring equipment	1
- " " : tools	1
- " " : consumables	1
- " " : operational media (P.O.L.)	1
- Central workshops : mechanical equipment	1
- " " : electrical "	1
- " " : electronic "	1
- " " : vehicles "	1
Specs., Bill of Quantities	1
Preliminary Time/Cost Schedule	1
Financing	1
Supplies and Work Performance	
- tendering	1
- review of offers	1
- contracting	1
- final time/cost schedule	1
Construction and Assembling	1
Personnel Training	1
Development of Operations	1

0 : no action required
1 : comprehensive action necessary
2 : improvement and/or substitution
3 : due to operational conditions

ACTION PLAN

Scenario A
500,000 tpa

ACTIVITI



Undergound

- additional design criteria
- design
- financing
- supplies & work performance
- construction & assembling
- personnel training
- development of operations

Surface plants minewise

- collection of design criteria
- design
- financing
- supplies & work performance
- construction & assembling
- personnel training
- development of operations

Central surface plant

- collection of design criteria
- design
- financing
- supplies & work performance
- construction & assembling
- personnel training
- development of operations

Preliminary devel

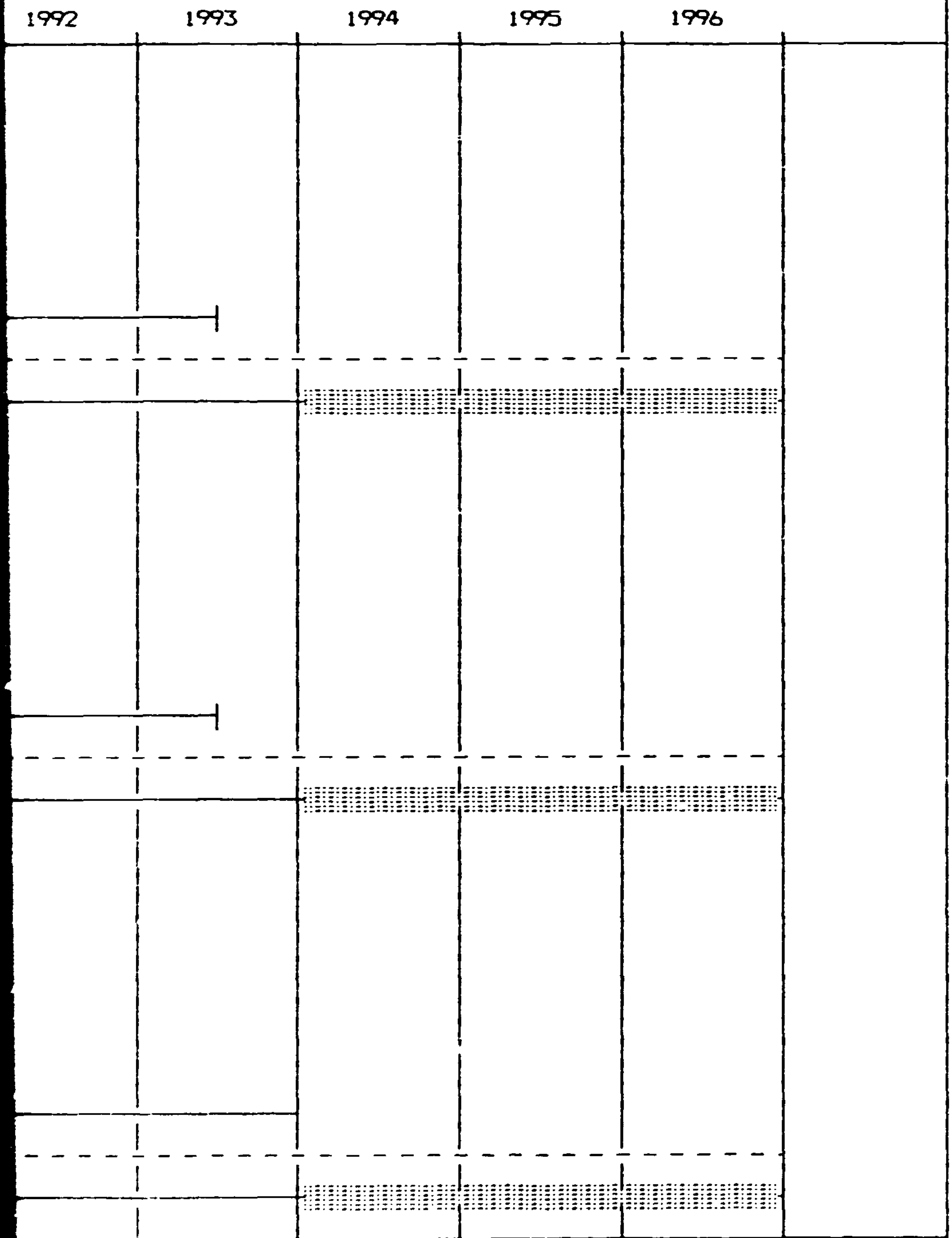
Operation of Chipanga
Rehabilitation of Chipa
Tete Coal Mine Operati

SECTION 1

ANNEX 12

VITIES TIME SCHEDULE

Years



y development — Full development

nga III, IV, VIII Mines
hipanga VII, XI Mines
rations Mozambique

December 1989

SECTION 2

Estimate of Equipment Investment Costs for Realization of Action Plan Scenario A and Action Plan Scenario B

This is a first exercise attempting to figure out the necessary investment costs for budgetary purposes, in case the Scenarios A and B are realized.

The major portion of the necessary items will probably have to be imported.

The cost estimates in this Annex are, therefore, based on quotations of the European manufacturers/suppliers of the coal mining industry.

1. Basic Data for an Investment Estimate

In Scenario A, three mines are necessary to achieve the annual production of 410,000 tons:

Chipanga VIII	160,000 t_{rom}
Chipanga VII	160,000 t_{rom}
Chipanga XI	90,000 t_{rom}
	410,000 t_{rom}

In Scenario B, four additional mines will be necessary to achieve the annual production of 890,000 t:

Chipanga VIII	160,000 t_{rom}
Chipanga VII	160,000 t_{rom}
Chipanga XI	90,000 t_{rom}
Section 5, Bloc N	120,000 t_{rom}
Section 5, Bloc S	120,000 t_{rom}
Central Section, Bloc 1	120,000 t_{rom}
Central Section, Bloc 2	120,000 t_{rom}
	890,000 t_{rom}

The maximum annual production of one mine is about 160,000 t_{rom}, whereupon the following assessment of the equipment is based.

With an average annual working period of <u>280</u> days, the daily production of the mine approximates 580 t/d.

For the estimate of the necessary mining and developing faces, the following performance data are adopted from the actual operational statistics of Moatize:

			t/d
Mining	Double-road heading	Avanço	32
Mining	Double-road heading	Realça	60
Development	Double-road heading	Descenderia Geral Volta de Ar	40
Development	Double-road heading	Descenderia	32
Preparatory Works	Double-road heading	Via superior Via de banda	38
Preparatory Works	Double-road heading	Montagem	32

In order to calculate the number of working faces underground, it is necessary to assume a typical working point distribution underground according to the expected mining conditions. Based on the above figures, the following distribution is assumed:

Mining		t/d
4 double-road headings	Avanço	128
4 " " "	Realça	240
Development and Preparatory Works		**t/d**
1 double-road heading	Descenderia Geral	40
1 " " "	Descenderia	32
2 " " headings	Via de banda	76
2 " " "	Montagem	64
total 28 working faces/14 teams		580

The above listed working point distribution leads to the overall production breakdown:

Mining	63 %
Development	13 %
Preparatory Works	24 %

This distribution corresponds to the actual production distribution in Moatize.

2. Equipment Requirements

2.1 Mining and Development Equipment

The following assumptions refer to the previous proposals.

Each working point should be equipped with

- compressed driven drilling machines (2 per face)
- blasting machine with circuit measuring device
- scraper winches
- chain conveyors
- pick-hammers
- compressed air driven hoists
- auxiliary fans

Haulage and material transport equipment will be dealt with in the next chapter.

2.2 Coal Haulage and Material Transport Equipment

In general belt conveyors are used for coal haulage in both the main incline and the main gateroads; their average length: ~ 400 m

	Belt width	Number of units
Main Incline (Descenderia geral)	800 mm	4
Main Gateroads (Via de Banda)	630 mm	6

It is proposed to transport material by winch and car in the main incline and by suspension monorail systems in the main gateroads.

Total length of monorail system is estimated to be 3,000 m per mine;
number of trains (incl. drive station): 6.

2.3 Pumps and Pipes

A mine's pumping capacities should be able to cope with the water influx at any time possible. The water influx is estimated according to the actual capacities of the mines. For an average water influx of about 100 m^3/h, it is assumed to have 6 stationary pumps (55KW) and 15 compressed air driven pumps installed in places where influx rates require it.

It is proposed to have three pipe systems installed underground: for clean water, mine water and compressed air.

2.4 Electrical and Communication Equipment (Surface and Underground)

It is proposed to install the following electrical equipment at the surface also to provide high voltage energy underground:

- high voltage switches
- high voltage transformer 33/6 KV
- medium voltage transformer 6/0,5 KV
- medium voltage switches and relays
- cables and distribution
- emergency power generator

In order to guarantee the electrical power supply underground, a second high voltage cable should be installed in the supply incline.

The electrical equipment underground has to be of flameproof design. The communication equipment should be intrinsically safe.

The electrical equipment underground comprises transformer stations (6,6 KV/550 V, 630 KVA), high voltage switches, contactors, relays, cables and electric motors.

For the communication underground a telephone system is proposed. Illumination should be provided by a spiral transformer and underground lighting systems.

2.5 Equipment for underground infrastructure services

For the underground infrastructure additional equipment is taken into consideration such as:

- drilling equipment for underground exploration,
- concrete and mortar-, mixing- and pumping systems,
- ventilation, monitoring- and telemetering system,
- portable mine air measuring devices,
- self-rescue devices against CO-gas,
- fire extinguishers,
- high-pressure water pumps (e.g. for dust suppression, coal injections, hydraulic purposes).

Material of domestic origin, such as rails, construction material, supports and similar are not included.

2.6 Mine Surface Equipment (except for electrical equipment)

The necessary surface equipment includes mine fan, winding machine, compressed air compressor station, loading bin for coal haulage and lamp room.

Not included are the spare part store house, the supervisor office and the changing room as these items represent civil works.

3. Investment Cost Estimates

3.1 Investment List for a typical mine of 160,000 t.p.a.

Cost estimates are given in Deutsche Mark (DM) fob as of 1989

Heading Equipment	1,000 DM
Drilling machines	126
Blasting machines including circuit measuring device	23
Scraper winches	2,240
Pick hammers	62
Hoists	126
Drills	26
Chain conveyors	3,360
Auxiliary fans including ducts	299
Total	6,262 =====

Haulage and Material Transport Equipment	1,000 DM
Belt conveyor systems 800 mm width	940
Belt conveyor systems 630 mm width	1,230
Monorail track incl. suspension	570
Monorail transport units	390
Monorail drive stations	990
Containers	300
Roof bolting machine	40
Total	4,460 =====

Pumps and Pipes	1,000 DM
Stationary pumps for mine water drainage	120
Portable pumps for secondary water drainage	225
Clean water pipes	80
Mine water pipes	100
Compressed air pipes	120
Total	645 ===

Electrical Equipment and Communication Systems	1,000 DM
Transformers (630 KVA)	540
High voltage switch and distribution	240
Contactors, motor relays	800
Cables	500
Electric motors	720
Accessories	150
Telephone system	40
Illumination u/g	64
Total	3,054 =====

Underground Infrastructure	1,000 DM
Drilling equipment/exploration	170
Concrete mixing and pumping equipment	60
Ventilation monitoring system	40
Portable mine air measuring device	33
Self-rescue devices	260
Fire extinguishers	9
High pressure water pumps	300
Miscellaneous	16
Total	888 ===

Surface Equipment	1,000 DM
Mine fan including reserve fan	700
Winding machine	1,100
Compressor station	400
Coal bin	50
Lamp room including charging units	82
Cap-Lamps	208
Measuring devices charging units	10
Electrical equipment	2,070
Total	4,620 =====

Total Equipment Investment

	1,000 DM
Mining and Development Equipment	6,262
Haulage and Transport Equipment	4,460
Pumps and Pipes	645
Electrical Equipment and Communication	3,054
Infrastructure Equipment	888
Surface Equipment	4,620
Sub-total	19,929
Allowance for spare parts (15 %)	2,989
Physical contingencies (5 %)	1,145
Total	24,063 ======

To the sub-total are added contingencies and a global extra 15 % for spare parts.

3.1 Specific Investment Costs per ton_{rom}

Given the annual production rate of 160,000 tons, the specific investment costs amount to 150 DM/yearly ton, equivalent to approx. 80 US$/yearly ton.

3.2 Investment List for Central Surface Equipment Scenario B

Central Surface Equipment	1,000 DM
Coal washery plant	25,000
Coal handling	2,000
Central work shops and stores	2,900
10 km belt conveyor systems to feed raw coal from mines	6,900
Train loading facilities	0,400
Wash transport and process water	0,700
Central rescue and fire brigade	0,400
Communication systems	0,100
Fresh water supply	1,100
Ancillary equipment	3,000
Total	42,500 ======

4. Estimate of Equipment Investment Costs for Scenario A and Scenario B

For Scenario A, it is necessary to provide Chipanga VII, VIII and XI mines with new equipment. The annual production of these three mines is scheduled for 410,000 t_{rom} (see production schedule). According to the above listed specific costs of 150 DM/yearly ton, the overall equipment investment costs for Scenario A can be estimated at 61,5 million DM, equivalent to approx. 32 million US$.

For Scenario B seven mines with new equipment are necessary to achieve the envisaged production of 890,000 t_{rom} p.a. Based on the above investment ratio of 150 DM/yearly ton, the overall equipment investment costs can be estimated at

133.5 million DM, equivalent to
some 70 million US$ as per 1989.

To this amount must be added

42.5 million DM or
22.5 million US$ respectively

for the central surface installations which are required in the case of Scenario B.

This overall equipment investment cost as per 1989 arrives at

176 million DM fob or
92.5 million US$ fob

It must be emphasized that the above figures do not include capital requirements for mine development civil works, expenditures for equipment installation or pre-production capital expenditures and only refer to the mine sites.

Attention is drawn to the assumption that the above estimated amounts most probably require foreign currency.

ACTION PLAN - SCENARIO B 1,000,000 t.p.a.
Production Development Schedule
- 1,000 t_{rom} p.a. -

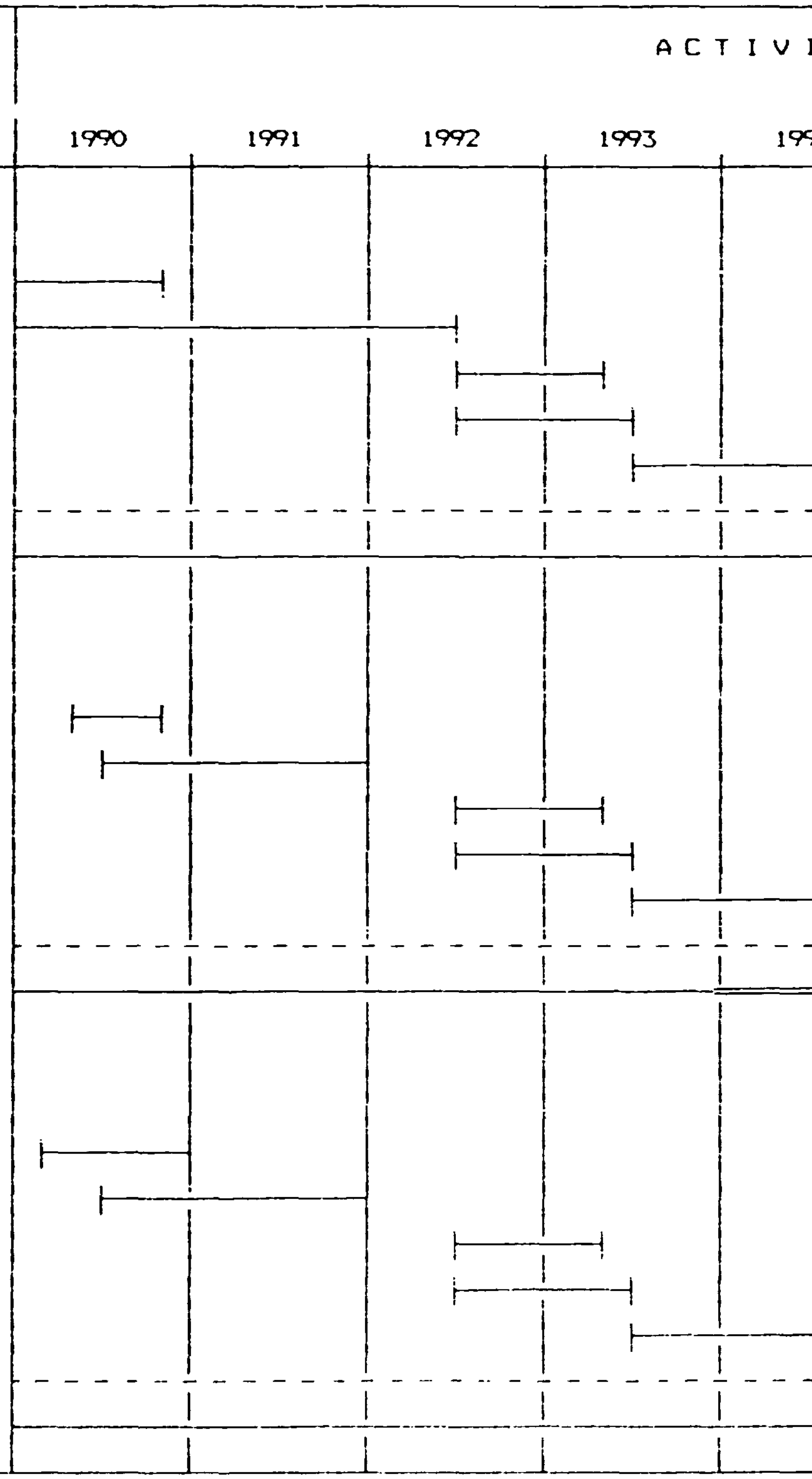
Mine	Period																			
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Chipanga																				
III	22	22	28	28	*	*														
IV	34	34	34	34	34	34	34	22	*	*										
VIII	14	44	118	160	160	160	160	160	160	160	160	160	160	160	160	4	*	*		
VII	-	-	25	100	160	160	160	160	160	160	160	160	160	160	160	160	160	160	135	*
XI	-	-	25	55	90	90	90	90	90	90	90	90	90	90	90	90	90	50	*	*
Total Scen. A	**70**	**100**	**230**	**377**	**444**	**444**	**444**	**432**	**410**	**410**	**410**	**410**	**410**	**410**	**410**	**254**	**250**	**210**	**135**	
Section 5 Bloc N	-	-	-	-	-	10	20	60	120	120	120	120	120	120	120	120	120	120	120	120
Section 5 Bloc S	-	-	-	-	-	10	20	60	120	120	120	120	120	120	120	120	120	120	120	120
Central Section Bloc 1	-	-	-	-	-	-	-	10	20	60	120	120	120	120	120	120	120	120	120	120
Central Section Bloc 2	-	-	-	-	-	-	-	10	20	60	120	120	120	120	120	120	120	120	120	120
Total Scen. B	**70**	**100**	**230**	**377**	**444**	**464**	**484**	**572**	**690**	**770**	**890**	**890**	**890**	**890**	**890**	**734**	**730**	**690**	**615**	**480**

* : depleted

Annex 14

A C T I O N   P L A N

Scenario B
1,000,000 tpa



Undergound

- additional design criteria
- design
- financing
- supplies & work performance
- construction & assembling
- personnel training
- development of operations

Surface plants minewise

- collection of design criteria
- design
- financing
- supplies & work performance
- construction & assembling
- personnel training
- development of operations

Central surface plant

- collection of design criteria
- design
- financing
- supplies & work performance
- construction & assembling
- personnel training
- development of operations

Preliminary development

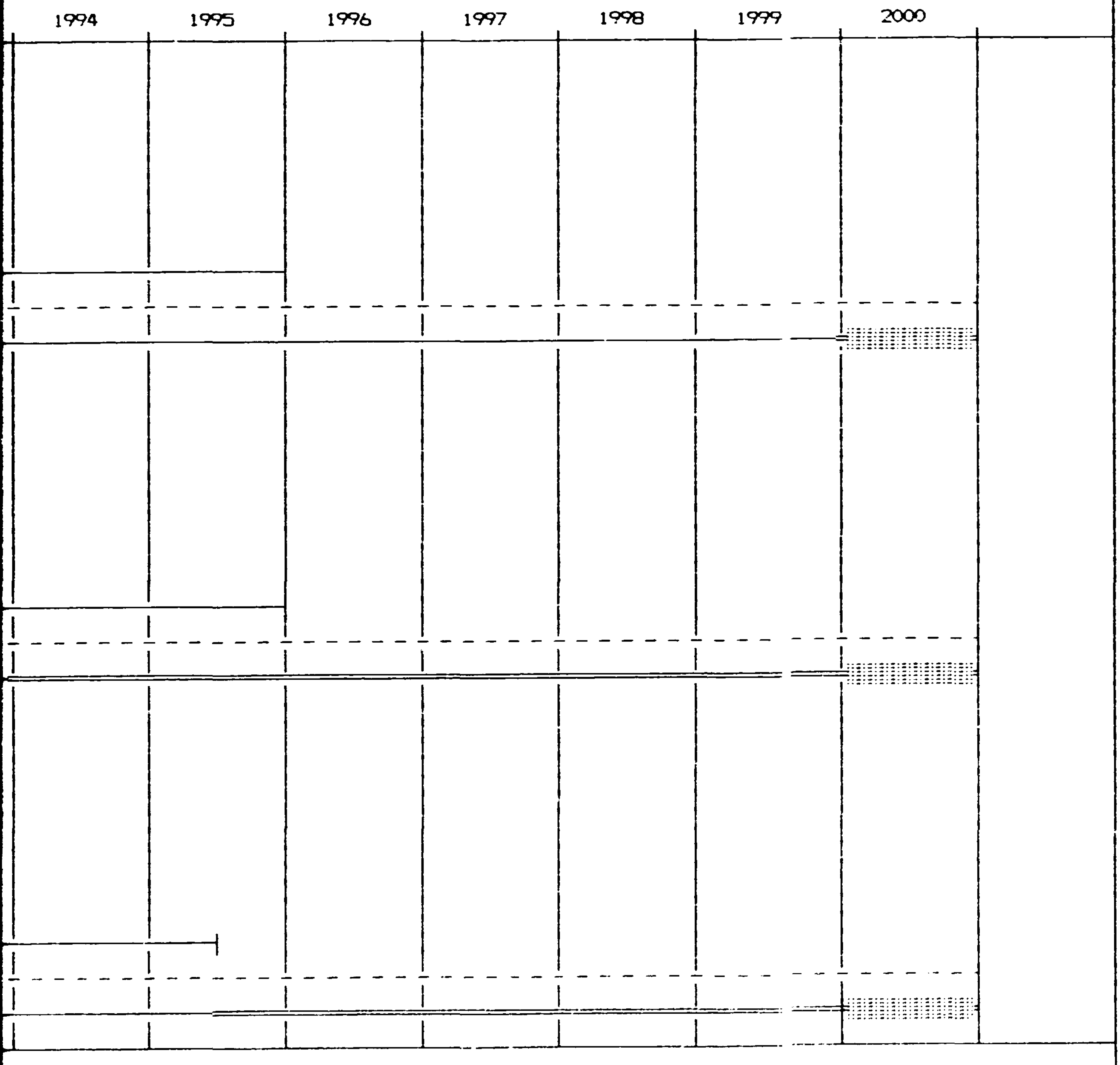
O p e r a t i o n   o f   C h i p a n g
R e h a b i l i t a t i o n   o f   C h i
Development of 4 new Mines: Section 5 / Block N,I
T e t e   C o a l   M i n e   O p e r a

SECTION 1

ANNEX 15

TIVITIES TIME SCHEDULE

Years



Advanced development

Full development

panga III, IV, VIII Mines
Chipanga VII, XI Mines
lock N,Block S & Central Section Block 1, Block2
perations Mozambique

December 1989

SECTION 2