Whittle Solution for Lignite Mining

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Abstract

India is endowed with many lignite deposits. However, the current commercially operating lignite projects are very few. In the Thar Desert region alone (forming western Rajasthan) several lignite deposits have been discovered with total estimated reserves of more than one billion tonnes. In spite of the above, no major lignite mining project has commenced operation in this region until recently. The above situation has arisen basically due to the lack of ascertaining the economic potentiality of the individual lignite deposits.

In this context, the individual deposit evaluation coupled with the application of Whittle software has become highly relevant for ascertaining economic viability. M/S Rajasthan State Mines and Minerals Ltd has undertaken the evaluation of Kasnau - Matasukh lignite deposits, Nagaur, and established the economic viability through the application of the Whittle software.

The steps involved include the generation of a mine resource model through the Datamine software. Subsequently, the mine resource model was subjected to the Whittle 4-D program. The cost parameters and slope design formed the main input for the Whittle program. Through its application, the optimal pit with economic valuation was generated. The Whittle program also helped in locating the IMC (Initial Mine Cut) and ascertaining the mine schedule and sequence.

Preamble

India, since its independence in 1947, has made rapid strides in industrial growth. Coupled with this, the power generation capacity has increased from a mere 1,362 MW to over 72,000 MW. Despite this growth, a gap still exists between demand and supply. As per current estimates over the next 5 years, this country needs an additional 43,000 MW capacity to meet the anticipated demands.

With such a scenario, the demands on commercial fuel are shown in Table 1.

	DEMAND ON COMMERCIAL FUEL (MILLION TONNES)	
Fuel	**2001-02**	**2006-07**
Coal	439.00	653.00
Petroleum	95.00	127.00
Natural Gas (oil equivalent)	32.30	54.60

Table 1: Estimated Demands of Commercial Fuels for 2001-02 and 2006-07

India has limited resources of natural oil and gas fields. Therefore, for the future generation of power, India is still largely dependent upon coal and lignite reserves. (Incidentally, India is the sixth largest producer of coal in the entire globe.) India's dependence on solid fuel as a primary source of energy will continue for several more decades.

The major coalfields of this country are restricted in occurrence to the NE, E and SE parts. The lignite fields occur in the southern, central west and western parts. The location of major coal and lignite fields of the country is as shown in Figure 1.

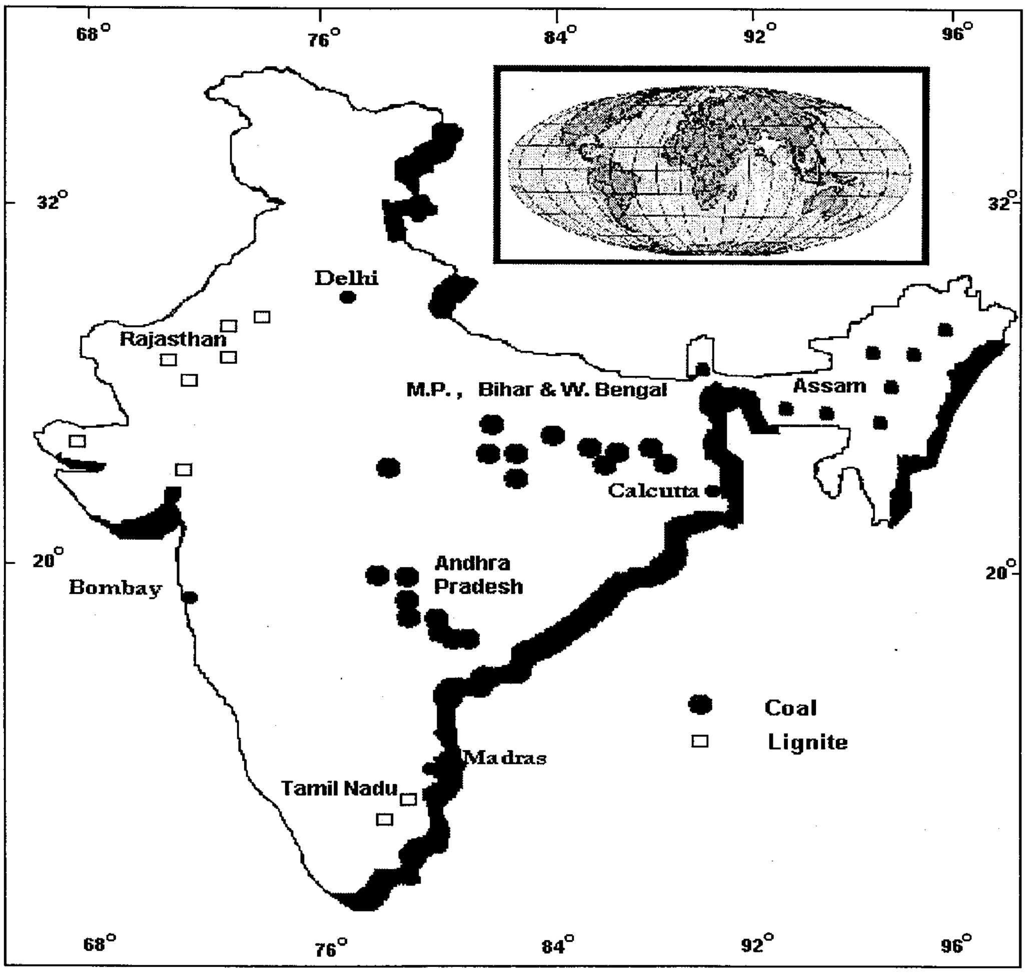

Figure 1: Coal & Lignite Fields in India

However, the development of coal projects is also beset with some logistic problems. The thermal projects located in the far west are dependent on coal supplies from the eastern side and need to haul supplies involving very high surface transport costs. Such a scenario necessitates the concurrent development of lignite fields, albeit of less calorific value. Presently, India has developed a few lignite based thermal projects in southern and central western parts. Some of the major lignite fields of the western side (Thar Desert region) still remain undeveloped and untapped. The total estimated lignite reserves of the western region (Thar Desert) runs to more than one billion tonnes. Appendix 1 presents the total estimated lignite reserves of the Thar Desert region and Figure 2 depicts the location of the same.

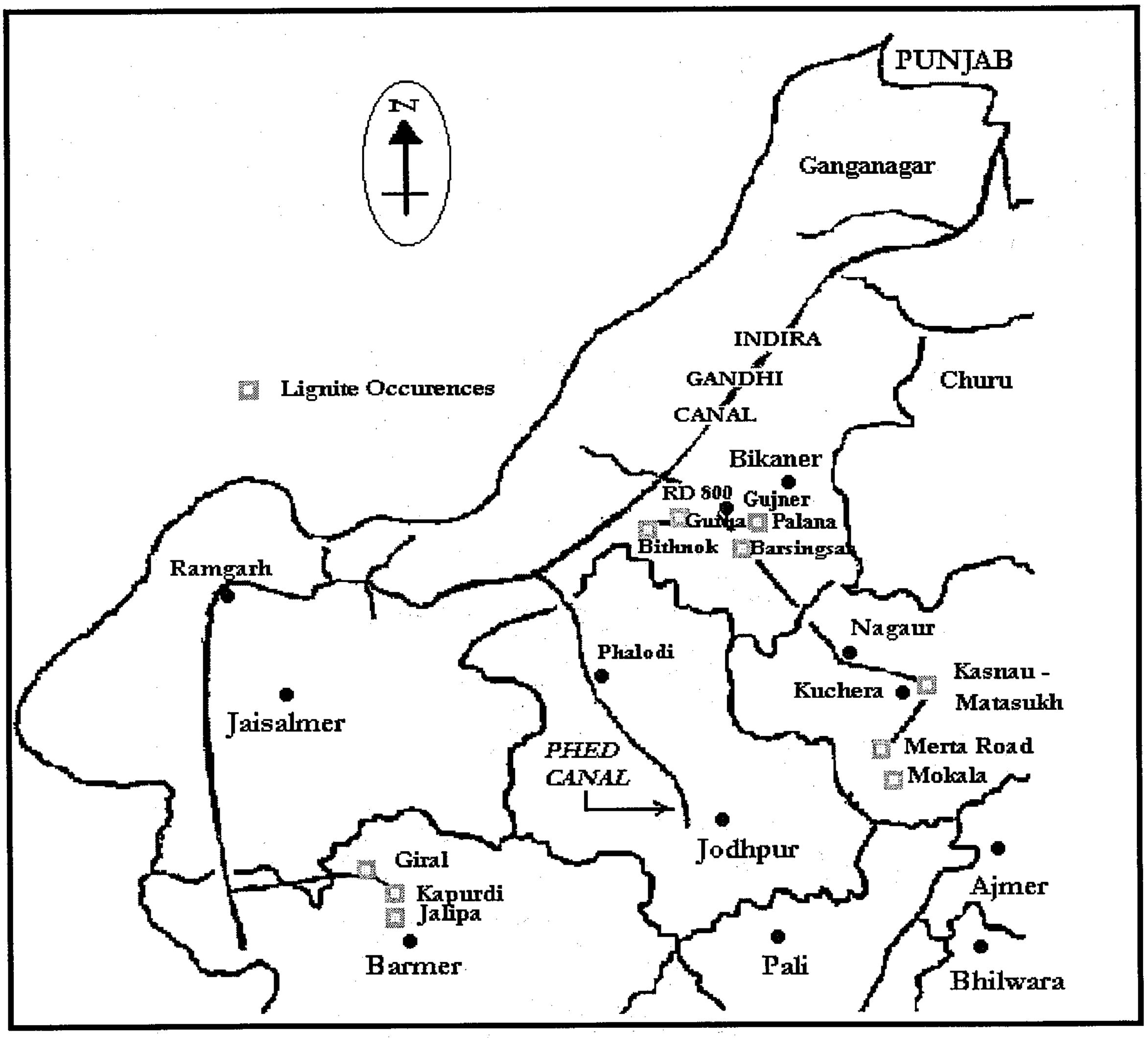

Figure 2: Lignite Depostis of Rajasthan

Three western districts - viz. Nagaur, Bikaner and Barmer of Rajasthan State contain all the lignite fields of the Thar Desert region. As already stated, to date none of the lignite deposits have been exploited except the Giral deposit. (Low key operations are continuing in this deposit.) The basic reason behind the non-exploitation of these lignite fields is due to lack of ascertaining their economic viability and potentiality. In this respect, the "Whittle Solutions" hold the key for ascertaining the economic viability of the lignite deposits subsequent to their evaluations.

M/S Rajasthan State Mines and Minerals Ltd, Udaipur, a Rajasthan Government Enterprise (a Federal Government under the Government of India) has carried out detailed exercises applying "Whittle Techniques" for evaluating the Kasnau-Matasukh lignite project in the Nagaur district of Rajasthan State and has established the deposits' economic viability. Based on these exercises, this lignite project is being implemented.

The present paper attempts to describe the "Whittle Techniques" applied on the Kasnau-Matasukh lignite deposits and the solutions obtained thereof.

General Information on Kasnau-Matasukh Lignite Deposits

Kasnau and Matasukh lignite deposits, spreading over an area of 7 sq. kms. occur as two separate lignite fields with an intervening distance of 3 kms. Motorable roads connect these lignite fields with Nagaur, the district headquarters, partly by State highway and partly by a fair weather road for a distance of 35 kms. The location of the lignite deposits is depicted in Figure 3.

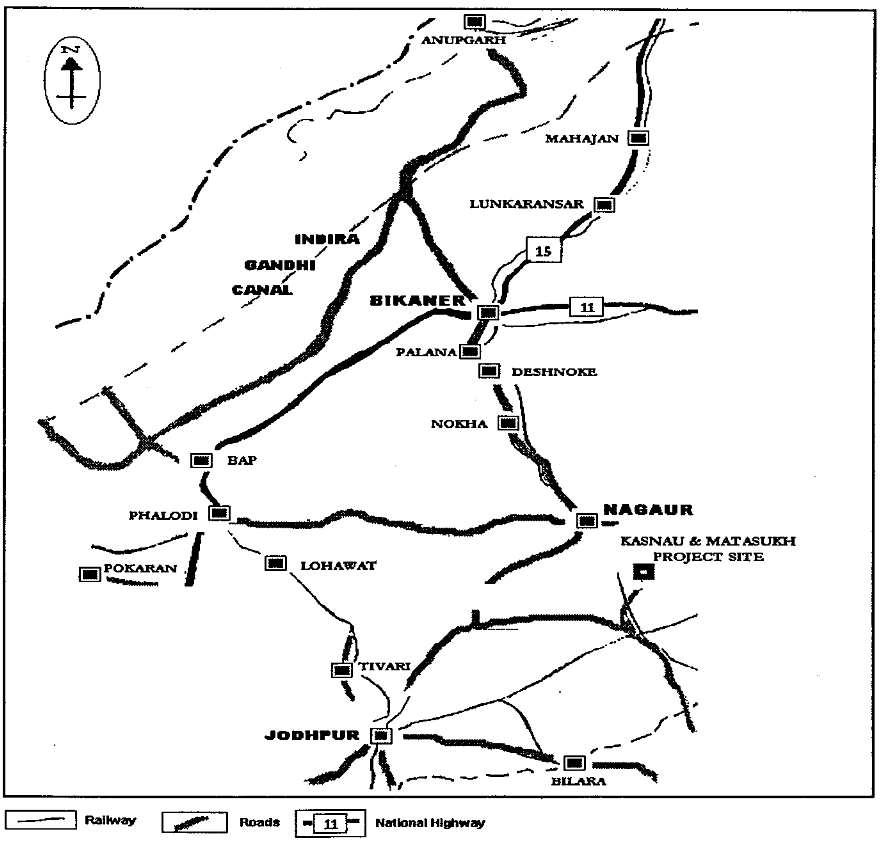

Figure 3: Location of Kasnau-Matasukh Lignite Project

A more or less flat terrain with thick alluvial cover characterizes this area. Generally, desert climatic conditions prevail in this region, with May and June months remaining hottest with temperatures ranging around 45°C, while December and January are the coldest months, in winter. Annual average rainfall is 300 mm.

Regional Geological Set Up

An extensive Westerly Basin encompassing the sediments from Cambrian to Tertiary periods characterizes the regional stratigraphy of the Thar Desert region. In fact, the Thar Desert region forms the SE extension of the Indus sedimentary basin. Through the earlier work of exploration agencies, several sedimentary basins have been identified which, along with their geological time scale, are as follows.

- Marwar Basin - Cambrian
- Bap Bhadura - Permian
- Latte Basin - Jurassic
- Jaisalmer Basin - Mesozoic & Tertiary
- Palana Ganganagar Shelf - Tertiary
- Barmer Basin - Cretaceous & Tertiary

A part of the regional geological set-up of the Thar Desert region highlighting the project site of the Kasnau-Matasukh lignite fields is depicted in Figure 4.

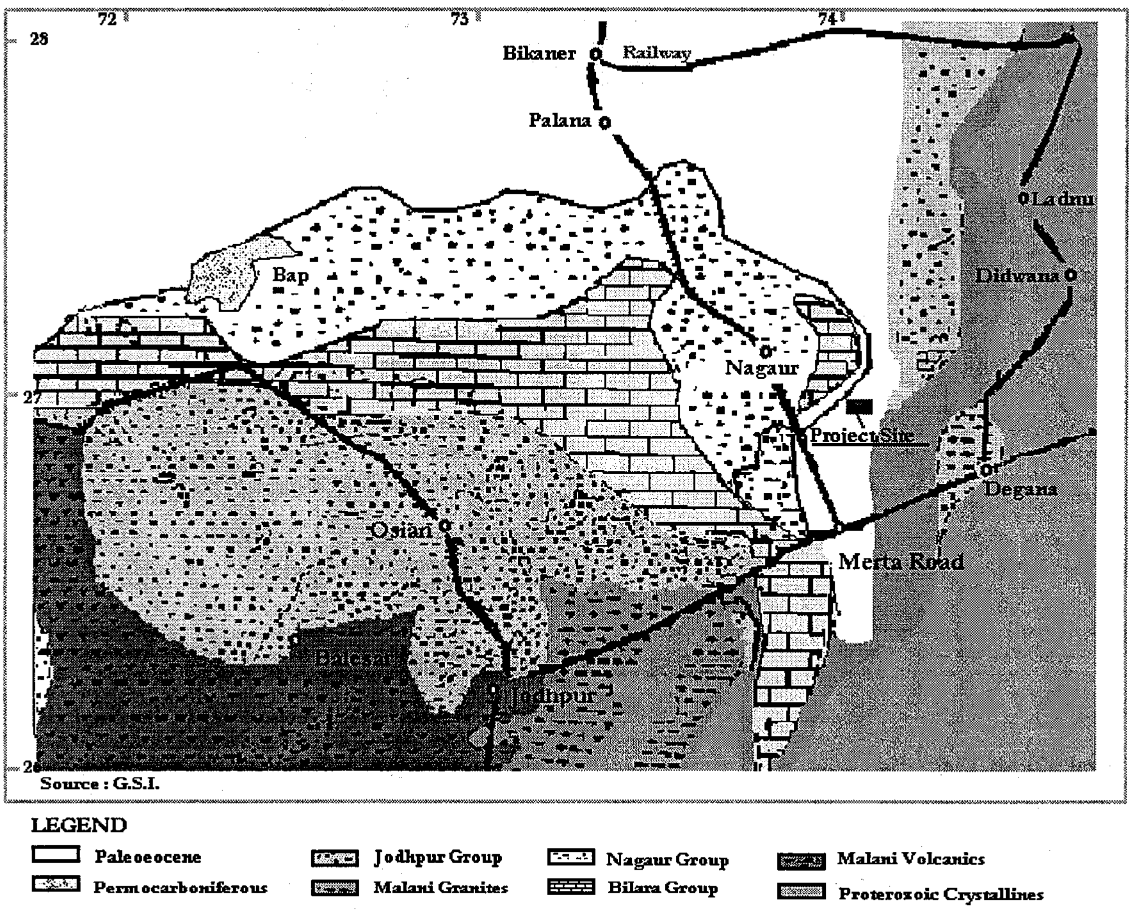

Figure 4: Regional Geological Map of Western Rajasthan

Local Geology

The Palana-Ganganagar shelf sedimentary basin containing the main lignite horizons of this area extends as a thin embayment in the southern directions.

Generally, the lithological units comprise alluvial cover/desert sand, followed by a lime concretionary bed, occasional fuller's earth, clay, friable sandstone, lignite horizon and sandy horizons. Although only one lignite horizon is identified, this horizon in some places splits into two or more bands interspersed with dirt. Figure 5 depicts the local stratigraphic succession of Kasnau and Matasukh lignite blocks.

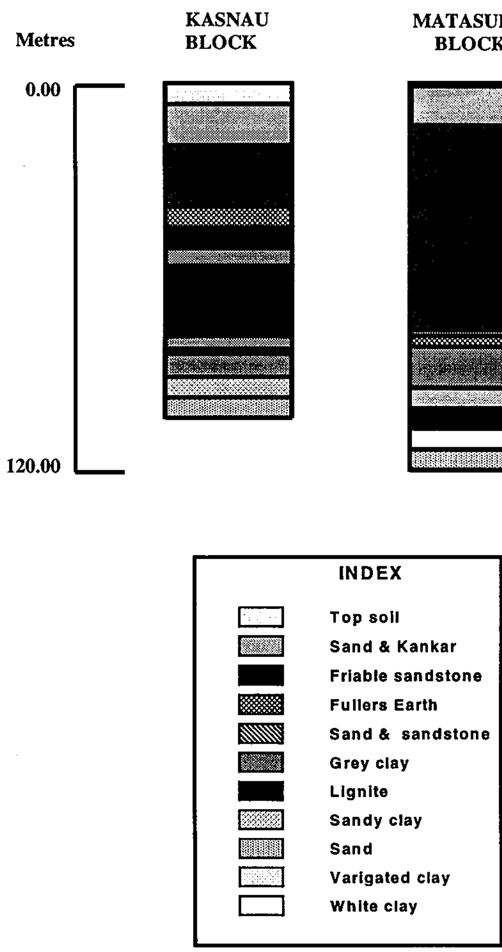

Figure 5: Stratigraphic Sequence

Exploration Details

The Directorate of Mines and Geology, Rajasthan, the federal government's exploration agency, undertook the regional and geological exploration over 19 sq. kms. in this area and has finally demarcated around 7 sq. kms. area as lignite bearing. Nearly 124 boreholes involving 15,920 metres of drilling were carried out in and around Kansa Block at a spacing of 400 x 400 metres, while, in the Matasukh block, 64 boreholes involving around 5000 metres of drilling were carried out at a spacing of 200 x 200 metres. The average depth of the boreholes is about 100 metres.

This exploration agency has undertaken a systematic sampling of boreholes and generated both approximate and ultimate analyses of lignite samples.

Figure 6 depicts the borehole distribution plan of both the deposits.

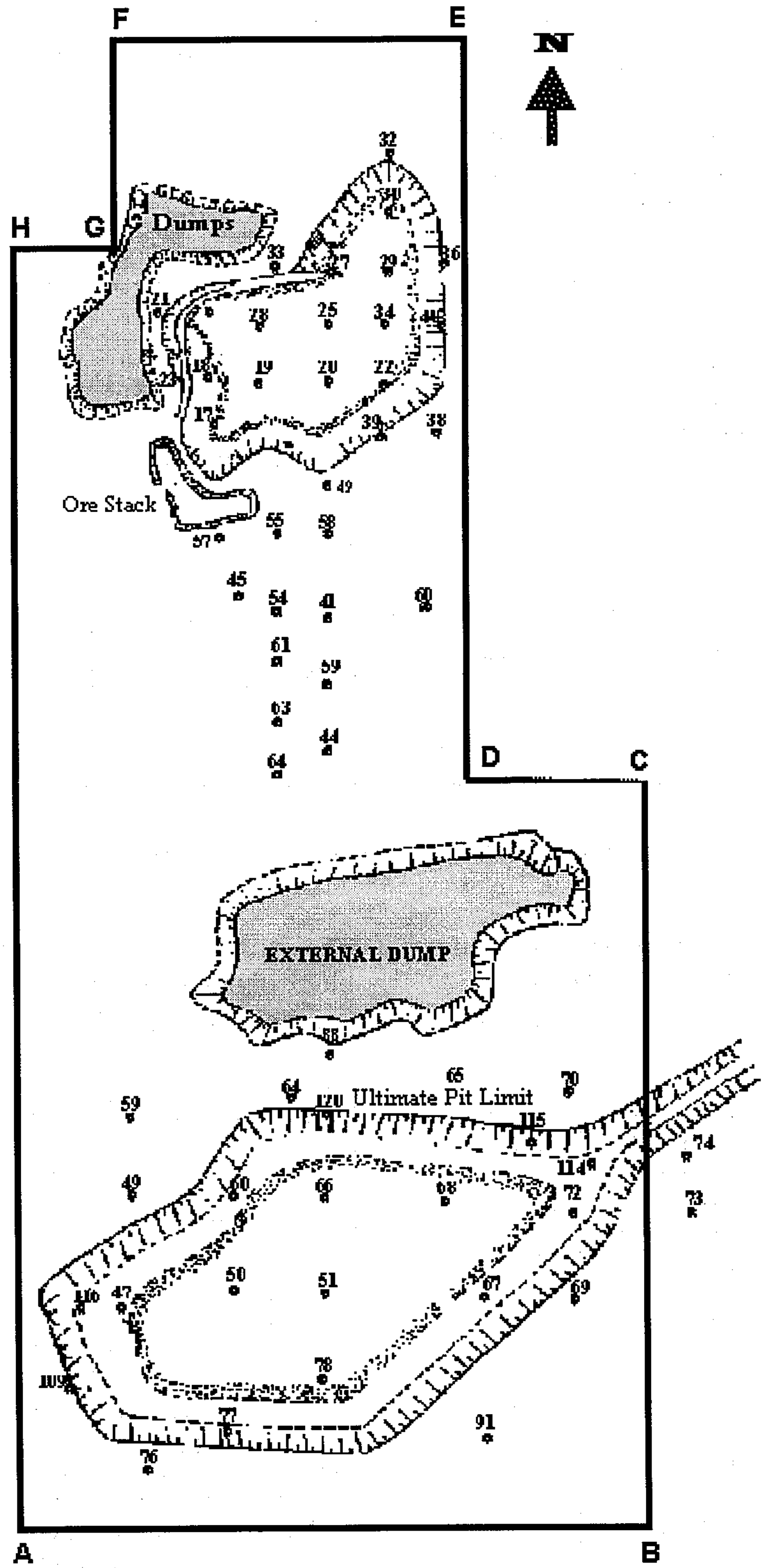

Figure 6: Borehole Location Plan of Kasnau & Matasukh Lignite Deposits

Lignite Horizons

On the basis of the above exploration programme, only one main lignite horizon comprising two seams has been identified. However, occasionally some local seams occurring below the main lignite horizon have also been deciphered. The intervening area of lignite bed is made up of dirt bands with carbonaceous clay compositions.

The study of lignite horizons of this area was done with the help of geological cross-sections prepared from the exploration data. A typical cross-section of Kasnau and Matasukh blocks are depicted in Figure 7.

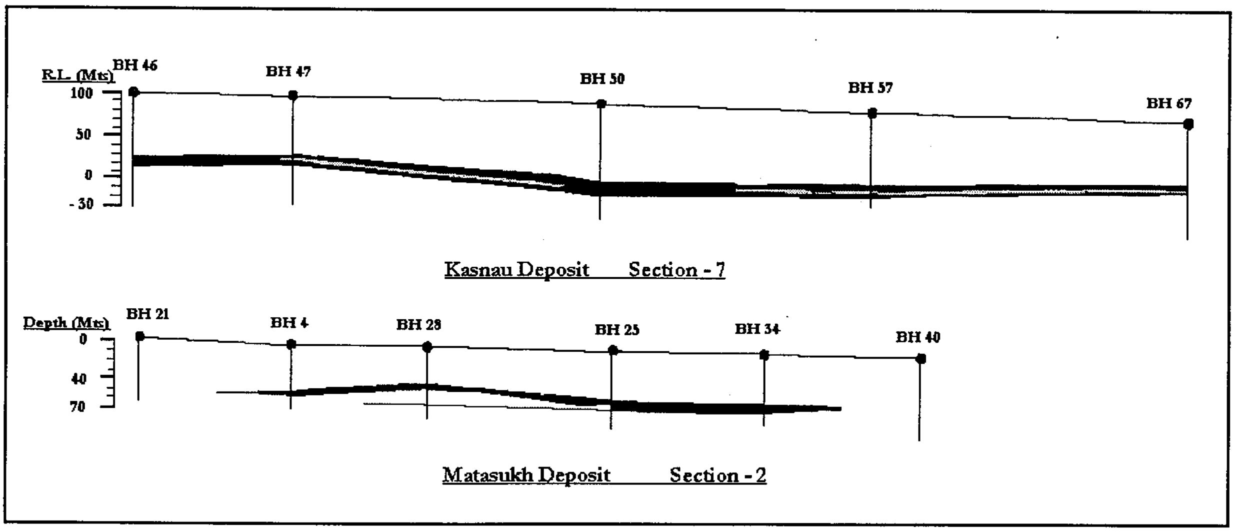

Figure 7: Typical Geological Cross-sections of the Kasnau-Matasukh Deposit

The following physical attributes of Kasnau and Matasukh blocks (shown in Table 2) were derived from these geological cross-sections.

PARAMETER	KASNAU BLOCK	MATASUKH BLOCK
1. No. of lignite intersections	19	39
2. Range of depth of roof (metres)	49 – 105	42.3 - 54
3. Range of thickness of lignite horizon (metres)	3.20 - 11.20	0.30 - 7.7
4. Mean thickness metres	7.37	7.64
5. Nature of dirt bands	Mostly carbonaceous clay	Grey clay

Table 2: Physical Attributes of Kasnau and Matasukh Blocks

The approximate parameters of Kasnau block obtained through the exploration data are shown in Table 3.

PARAMETERS	NATURE OF SAMPLE	RANGE (%)		MEAN %	STANDARD DEVIATION
		FROM	TO		
Ash	Ex-Band In-Band	7.8 7.8	16.43 17.02	12.47	2.86
Volatile Matter	Ex-band	20.63	26.02	24.22	1.28
Fixed Carbon	Ex-band	17.68	21.85	20.17	1.19
Calorific value (kcal/kg.)	Ex-band In-band	2480 2441	3063 3063	2782	1.86

Table 3: Approximate Parameters of Kasnau Block

Associated Lithology

The exploration data generated has also indicated the associated lithology of lignite horizons of this area. The associated lithology is mainly comprised of lime concretionary beds, friable sand stones, variants of clay bed and sandy horizons.

Statistical computation of the associated lithology are made from the borehole information. The distribution of litho units in terms of percentage in individual blocks (Kasnau and Matasukh) is depicted in Figure 8.

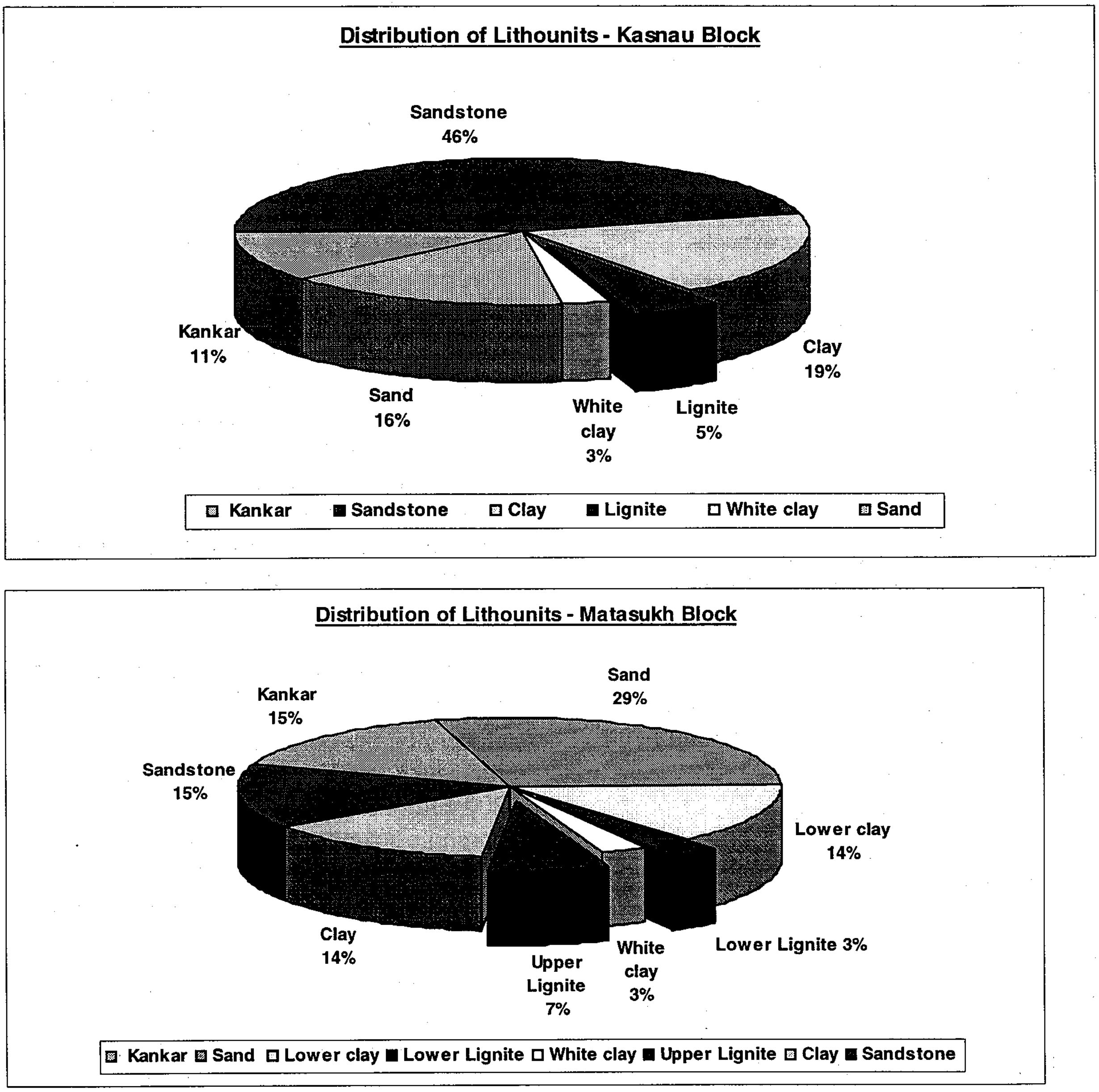

Figure 8: Distribution of Litho Units Kasnau & Matasukh Blocks

The closer study of the associated lithology has indicated that mining excavation is possible without resorting to any major blasting. This information forms the main input for deriving the mining excavation cost of lignite which, in turn, is utilised by "Whittle Techniques" for mine pit design.

Reserve Estimations

The earlier exploration agency had estimated a total geological reserve of 23.22 and 9.35 million tonnes of lignite in the Kasnau and Matasukh blocks respectively. However, RSMML, through an independent interpretation of borehole information, had estimated only 13.294 and 5.29 million tonnes of lignite reserves in the Kasnau and Matasukh blocks and these estimates, in turn, were utilized for further mine planning exercises.

The transformation of geological reserves into mineable reserves was done taking into consideration the following aspects:

- Calorific value of +2500 kcal/kg.
- Dilution factor of 10%
- Geological spread of lignite seam within the thickness ratio lignite vs. overburden of 1:15
- Minimum mineable cut off thickness of 0.5 metres.

With these parameters, the total mineable reserves were re-computed as 12.60 and 4.69 million tonnes of lignite for the Kasnau and Matasukh blocks respectively.

Mining Method

The selection of the mining method for this project was made considering the following salient parameters:

- Depths of lignite horizon
- The strata conditions of associated lithology
- Stripping ratio
- Mining losses and dilution
- Investment cost and gestation period of mine development
- Flexibility in mining operations
- Quality control
- Safety
- Total extraction of lignite resources throughout project life

In view of the above considerations, RSMML opted for the opencast mining method for the Kasnau-Matasukh lignite project.

Mine Planning Exercises

Ascertaining the mineable reserves and freezing the option on the mining method, mine planning exercises were to be conducted for establishing the various parameters such as Mine Phasing, Annual Production Schedule, Annual Waste Removal Scheme, Mine Sequencing etc. Prior commencement of these exercises, the economic viability of the project was to be evaluated. The "Whittle Techniques" were applied for the generation of the optimized pit and for establishing the economic viability of the project.

Application of the "Whittle Techniques"

The application of the "Whittle Techniques" was carried out through many logical steps. The first step involved the transformation the global mineable lignite reserves computed for the entire deposit into sub-block reserves. This was necessary to ascertain the individual economic value of sub-blocks in terms of their mineablity. This process is described below.

Transformation of Global Mineable Reserves into Sub-Blocks

Generally, the borehole spacing in Matasukh and Kasnau blocks was 200 x 200 and 400 x 400 metres. Adopting such borehole spacing, it was easier to generate many sub-blocks in the above sizes. Depth of the individual sub-blocks was uniformly at 10 metres.

Using the borehole information, the estimation of lignite reserves in individual sub-blocks was recomputed. The quality data, especially in respect of CV in kcal/kg. was assigned to the above sub-blocks. Since the size of individual sub-blocks roughly correspond to the borehole spacing, the above process could be completed without resorting to complicated calculations.

As stated earlier, lignite occurrences along the depth vary both in terms of thickness and number of splits. Taking the above aspects into consideration, quantity and quality determinations of individual sub-blocks were carried out. During the above process, due care was taken to avoid the inclusion of dirt bands (other than permissible) within lignite reserves. The mineable dirt band forming the interburden within a sub-block was estimated separately in terms of its volume.

Adopting similar processes, several sub-blocks for the two deposits were generated. These sub-blocks were indexed with estimated reserves and also the quality, especially in respect of calorific value. Mosaics of such lignite sub-blocks were created for the two deposits and maintained in a separate file for further utilization.

Volume of Over Burden Regimes

The second step of application involved was re-computation and re-distribution of the volume of overburden regime calculations in respect of various sub-blocks. Earlier, during the computation of mineable lignite reserves of the two deposits global OB regimes were computed and the stripping ratios were established. (The volume of interburden was also accounted in OB regimes.) The total waste of the Matasukh block was computed to be 33.274 million cubic metres, with an overall stripping ratio of 1:7.11 cubic metres. The same information for Kasnau was computed to be 116.00 million cubic metres, with an overall stripping ratio of 1:10.23 cubic metres.

Adopting a similar process as described under lignite estimations for various sub-blocks, the sub-blocks were generated corresponding to the borehole spacing of the two deposits. The OB volume regimes of individual sub-blocks were re-computed and assigned. A separate file of all OB calculations was maintained for further evaluation. A mosaic of sub-blocks with OB estimations was constructed.

Assigning PMV (Pit Mouth Value) For Generated Lignite Sub-Blocks

A logical step subsequently adopted during the application was to assign the total PMV of an individual sub-block. This was done through an indirect method, the principle of which is explained below.

Indian coals, both coking and non-coking, are generally classified into various grades as per CV (Calorific Value) expressed in kcal/kg. The grades available are from "A" to "G" in the non-coking variety, A grade representing highest CV and G grade representing the lowest CV. The pricing of coal grades at pit mouths is controlled through an administrative mechanism. Lignite with CV of around 2500 kcal/kg. is equated with F grade non-coking coal in terms of CV value and thereby becomes comparable in respect of pricing at the pit mouths as well. With such pricing data available, the landed price of lignite at a particular site is derived by adding the average rail transportation cost on PMV of "F" grade coal.

The above indirect method of establishing the price of lignite PMV was adopted at the Kasnau-Matasukh lignite project and the PMV price per tonne obtained was around Rs. 1000/(US$25 approx.). Accordingly, the total value of lignite in each sub-block was calculated and incorporated in the programme.

Assigning Mining Excavation Cost

As stated earlier, the overburden formations are mainly comprised of unconsolidated sediments necessitating no major blasting requirements for excavation. Accordingly, the mining excavation cost is anticipated to be relatively cheap as compared to the excavation cost of hard rock formation.

The mining excavation cost of this lignite project was basically derived from the Jhamarkotra Phosphate Project. (The

Jhamarkotra Project is the biggest mining project, presently being operated by M/S RSMML over the last three decades.) In this phosphate project, the cost of drilling and blasting operations together form roughly 60% of the excavation cost component. Thus, the mining excavation cost of the lignite project was assumed after due de-rating for these operations. The assumed mining excavation cost was Rs.50/ per cubic metre (Approx. US$1.2). Obtaining the above value of mining excavation cost, the total expenditure likely to be incurred on individual sub-blocks was calculated and incorporated.

Pit Slope Parameters

Another important parameter to be taken into consideration during application of the "Whittle Technique" is the pit slope of the proposed open pit, and this forms one of the main inputs while designing the optimized pit. The process adopted for defining the overall pit slope is described below.

The summarized litho log of two model boreholes, one of Kasnau and another of Matasukh blocks are presented in Tables 4a and 4b.

THICKNESS (METRES)		LITHOLOGY
From	To	
0.00	12.20	Clay with Lime Concretion
12.20	66.95	Friable Sand Stone
66.95	67.40	Variegated Clay
67.40	70.15	Fullers Earth
70.15	83.35	Greyish Clay
83.35	88.45	Black Shale
88.45	94.55	Lignite
94.55	97.60	White Clay
97.60	115.70	Sand

Table 4a: Summarized Litho Log of Kasnau Block

THICKNESS (METRES)		LITHOLOGY
From	To	
0.00	6.00	Top Soil
6.00	18.00	Sand and Kankar
18.00	36.00	Friable Sand Stone
36.00	42.00	Fullers Earth
42.00	48.00	Sand and Sand stone
48.00	52.90	Grey Clay
52.90	56.10	Lignite
56.10	57.10	Grey Clay
57.10	62.10	Lignite
62.10	63.00	Grey Clay
63.00	66.80	Lignite
66.80	70.00	Grey Clay
70.00	70.30	Lignite(local seam)
70.30	78.00	Grey Clay
78.00	84.00	Sandy Clay
84.00	120.00	Sand

Table 4b: Summarized Litho Log of Matasukh Block

A study of the lithological formations of the above two boreholes revealed that the overburden and interburden materials of these deposits are comprised of unconsolidated arnaceous and argillaceous sediments. The above lithology naturally indicates a gentler overall slope for the pit. Whilst, the geo-technical determination on borehole samples could have established this parameter in the absence of such studies, an assumption of the overall slope angle was made.

The overall pit slope angle assumed for the Kasnau pit was 34°, while for the Matasukh pit, the same was assumed to be 30°. The collection of information from similar lignite deposits having identical lithology to the neighbouring state had further corroborated the above assumptions.

Thus, the data on pit slope angles was incorporated into the system.

Operation of Software

Subsequent to defining all the inputs necessary for the software, the exercises on pit optimization were performed through the Whittle software. Many open pits were generated and the results, especially in terms of overall profitability, were compared. The optimized pit naturally indicated maximum profitability. However, while operating the software, certain limitations were observed.

Limitations

Indian mining laws for environmental control prescribe the "back-filling" of excavated areas and these measures have to be strictly adhered to during the operation of coal and lignite opencast mines. With such control measures, the optimized pit may not present the ideal solution. Hence, the optimized pit generated through the software may have to undergo further refinement and fine-tuning.

Final Optimized Pit

Undertaking the refinement process, the final optimized pits for the Kasnau and Matasukh blocks were generated. The optimized pits also helped in locating IMCs (Initial Mine Cut) of the respective blocks. Accordingly, the ramp systems were designed and located. The external dump areas were restricted to only 21 and 26 hectares for total waste quantities of 5 and 20 million cubic metres. The final optimized pits along with permanent ramp design of the two blocks are shown in Figure 9.

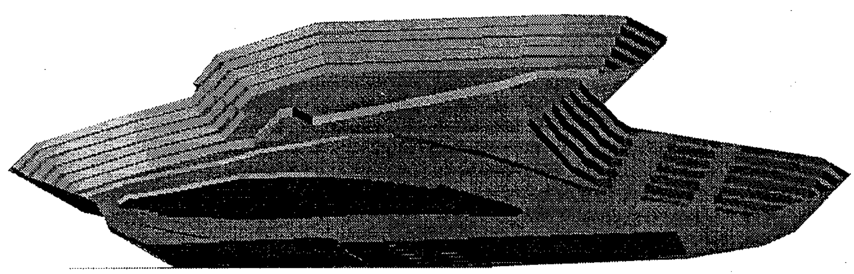

Figure 9: Optimised Pit of Matasukh Lignite Mine

The rest of the mine planning exercises such as mine sequencing and scheduling, were completed on the basis of final optimized pits. The equipment configurations for the proposed mine pits were crystallized. The final costs of production of lignite for the Matasukh and Kasnau pits were estimated and a ROE (Return on Equity) of 24% was estimated. The economic viability of the entire project was also established.

Based on the above studies, RSMML has now firmed up the financial investment decisions and implementation of the project. In fact, the pre-project activities, such as land acquisitions, creation of infrastructure etc. have already commenced.

Conclusions

Despite rapid strides in industrial growth, India's power scenario is not comfortable and over the next decade needs to augment its capacity in power generation by another 43,000 MW. Due to limited resources in oil and natural gas fields, India has to depend upon solid fuels such as coal and lignite for a few more decades. However owing to the logistic problems associated with the development of coal projects, concurrent development in lignite projects is necessary. Although some lignite projects were developed in some parts of the country in the past, many more lignite deposits especially in the Thar Desert region, still remain untapped. The basic reason for the above situation is the lack of ascertaining the economic potentiality of the individual deposit.

M/S Rajasthan State Mines and Minerals Ltd has undertaken such exercise through the application of "Whittle Techniques" on the Kasnau and Matasukh lignite deposits, occurring around 35 kms. SE of Nagaur, the district headquarters within the State of Rajasthan. With the available exploration data, these deposits have been evaluated and the geological and mineable reserves have been estimated. Subsequently, the mineable lignite reserves and OB regime estimations were distributed in sub-blocks. A mosaic of such sub-blocks was created and indexed as separate files. The PMV of individual lignite sub-blocks was ascertained and the mining excavation cost of OB sub-blocks was derived through indirect determination. Records of all sub-blocks were created. The pit slopes were assumed on the basis of experience of similar lignite deposits on the neighbouring state. The Whittle software was used to generate the optimized pits of the lignite deposits. However, in view of the environmental considerations of concurrent backfilling of excavated areas, the optimized pits were further refined and fine-tuned to generate the final open pit layouts. Subsequent mine planning exercises were concluded on the basis of the above final open pits.

The economic viability of the Kasnau-Matasukh lignite project has been established with 24% ROE , on the basis of which, M/S Rajasthan State Mines and Minerals Ltd, Udaipur is implementing this mining project. The pre-project activities such as land acquisitions, creation of infrastructures etc. has already commenced.

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Our sincere thanks to Dr. R. Choudhuri, Group General Manager (Projects) of M/S RSMML, for the valuable guidance and encouragement during the preparation of this technical paper.

Help and assistance received for preparing and finalizing the computer graphics of all drawings for this paper from Mr. Anil Bhatnagar, Manager (Geo.- Proj.) of M/S RSMML, is duly acknowledged.

Appendix 1

ESTIMATE OF LIGNITE RESERVES IN RAJASTHAN

DEPOSIT	RESERVES (M.T.)	QUALITY	PARAMETERS			
		Moisture (%)	Ash (%)	F.C.(%)	V.M.(%)	C.V. (Kcal/kg.)
BIKANER DISTRICT						
PALANA	23.57		3.56 - 04	21.25	20.8 - 35.6	3200-3500
BARSINGSAR	70.24		2.4 - 10.0	20.6-28.0	23.24	3000
GURHA GROUP	71.80		25.00	12.23	22.26	2000-3000
MANDAT CHARANAN	15.00		12.77	18.54	22.94	2667
BITHNOK	50.00	Under Exploration by MECL				
SUB TOTAL	**230.61**					
BARMER DISTRICT						
KAPURDI	150.40	40 - 60	5 - 20	13 - 26	21 - 25	2000-3800
JALIPA	350.00	35 - 50	5 - 20	15 - 25	20 - 30	2000-3500 (expl.contd.)
GIRAL	61.00	45.00	18.72	17.38	19.11	2414(do)
JOGESWART-ALA	34.52	-	-	-	-	2500 (Lignite horizons are deep seated)
BHADKA	9.46	-	-	-	-	2790
SUB TOTAL	**605.38**					
NAGAUR DISTRICT						
MERTA ROAD (MIRA NAGAR HANSIYAR)	83.20	45.00	14.63	17.75	24.63	2684
MOKALA	36.56	45.00	12.00	18.81	25.89	2837
INDAWAR	12.00	45.00	11.21	18.40	25.27	2770
KASNAU IGIYAR	64.90	45.00	12.00	20.13	23.75	2800
SUB TOTAL	**196.66**					
GRAND TOTAL	**1032.65**					

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