

GOVERNMENT OF RAJASTHAN



A STUDY

OF

THE PALANA LIGNITE FIELD IN RAJASTHAN

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A STUDY OF THE PALANA LIGNITE FIELD IN RAJASTHAN

INTRODUCTION

The lignite occurrence at Palana (27°51':73'19') near Bikaner City has been well known amongst the Tertiary coal deposits of India. It has been worked continuously over the past half a century and since the formation of Pakistan, it has been the only lignite mine of its kind in India. The mining operations are carried out by the Department of Mines and Geology of the Government of Rajasthan. With the reports of the lignite mining plans in Madras State, this operation also gains some importance particularly due to the fact that the Rajasthan State suffers as much if not more, from the fuel shortage as the Madras State and probably both the States have great future if their lignite deposits are successfully harnessed to produce power and the valuable by-products.

About 150 tons of coal have been produced at Palana per day to meet partially the fuel requirements of the Government owned Power-houses both at Bikaner and Shri Ganganagar. This coal field is situated about 14 miles southwest of Bikaner, the headquarters of the Division of the same name in the State of Rajasthan. The Palana railway station lies on the Bikaner-Jodhpur branch of the Northern Railway and is connected by a good motorable road with the Bikaner City.

LIGNITE DISCOVERY

It was in the year 1896 when the discovery of lignite was accidentally made here by some villagers who were sinking a well in the locality. The occurrence was noted at a depth of 200 feet from the surface, the ground water level being 150 feet further below the lignite horizon.

In place where fuel is so scarce and where coal from Bengal or Madhya Pradesh coal fields is not easily available or is quite costly, such a discovery proved to be a boon and attracted much interest. The State Government soon started further exploration and mining operations to prove and win the mineral. Many eminent mining engineers and geologists including La Touche ¹ Holland, Heron ² and Fox³ have visited this area and have expressed varying opinions about the method of mining which might be adopted to best suit the local conditions and the difficult nature of the deposit. The methods of mining chiefly consisted of sinking shafts for the purpose of proving coal and later to be used for raising in case of their meeting a workable thickness of coal seam. The reserves were ascertained almost from year to year and mining was so adopted as to produce sufficient coal to meet the requirement of the Power-houses to the maximum extent.

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1. La Touche, T. D. "Report on the occurrences of coal at Palana Village in Bikaner State", J. S. I. Records, Vol. XXX, 1897. P. 122.
 2. Heron, A. M. "The Mineral Resources of Rajputana", Trans. Min. Geol. Inst., Vol. XXXX, P. 4, 1935.
 3. Fox, C. S. "A Note on the occurrence, Recovery and Utilisation of the Lignite at Palana, Bikaner State, Rajputana," 1944 Unpublished.

GEOLOGY OF PALANA COAL FIELD

The coal field is situated in North Rajasthan practically in the heart of Thar Desert. There is a complete absence of exposures of any geological formations in the vicinity except the enveloping aeolian sands which cover varying thicknesses from 2-10 feet or even more at some places. Beneath this layer of sand, kankar beds have been found generally in association with ferruginous nodules and extend to depths of 0-70 feet. They are followed by weathered sandstones and clays of about 20-40 feet thickness. Below these, a hard, compact and buff coloured limestone is found, underlain in order of sequence by nummulitic limestones shales, impure ferruginous limestones, clays and about 50 feet thick fuller's earth bed. It is followed by a 10-30 feet thick incomplete section of bluish grey and pink shales, and a thin band of friable sandstone and lignite. Below the lignite seam there is an occurrence of 2-4 feet thick band of soft clay grading into a crumbling sandstone. This clay is peaty in appearance and is interstratified with sand at places. Tests conducted at the Central Glass and Ceramic Research Institute¹ indicate that it is quite a good fire-clay with a p. c. e. value of Orton Cone 31 i.e., 1680°C, and suitable for manufacturing even high grade refractorywares. Where lignite seam is not present the beds of fuller's earth and shales are directly underlain by coarse sand, locally called 'bajri'. The latter is generally followed by a stratum of black shale.

The mining operations in this region (Plate 1) have provided a volume of information, particularly about the geology, the nature and shape of the deposit and its extent.

1. Almost soon after the discovery of the lignite in this region, the first shaft marked '66' on the plan and located about 1800 feet north of the well, was sunk, but it proved only two feet thick lignite seam and so was abandoned.

This was the beginning of a series of shaft and pit sinking which in many cases were primarily intended for prospecting, but subsequently were equipped and used as raising shafts.

2. A new shaft 490 feet to the south of the water well was then sunk during the year 1900, which touched a 25 feet thick lignite seam at a depth of 211 feet from the surface. This was the first main coal raising shaft (P 26, S. I.)* in this field.

3. In order to prove further the extent of the deposit a bore-hole was drilled by Messrs Bird and Company, which were granted a mining lease here terminating in 1906. The strata found in this borehole near the shaft P 26 has been shown in Section I. This shaft continued to yield coal till 1912, when another pair of shafts P. 37; P 37 A of 11 feet diameter were sunk about 1500 feet west of it. Being located on the rise side they touched a 30 feet thick seam at a depth west of 175 feet only from the surface.

4. Soon afterwards an exploratory shaft (P. 44) was sunk 900 feet further to the west showing only 157.5 feet of over-burden and 50.5 feet thick seam. These shafts (P. 37; P. 44) were abandoned due to collapse of roof and fires in the year 1917.

1. Analysis Report No. CCT/25-52- of 15-1-53 of Central Glass and Ceramic Research Institute, Jadarpur, Calcutta.

• Abbreviation: P means Plan Position.
S means Section.

5. For months afterwards there was no shaft from which coal could be won. Another pair of shafts which were under sinking for some time, were completed during the year 1918. They were known as 'East' shafts and were located 1800 feet to the East of shaft P. 26. They met 18 feet thick seam, at a depth of 192 feet and 196 feet respectively (P. 13; P. 14, section II). The seam thinned out as the workings advanced towards the north and due to this, these pits had also to be abandoned in 1922.

6. In 1923, again two shafts (P. 16; P.17) were sunk about 2200 feet and 1900 feet respectively to the south-east of the shaft P. 26 and these proved a thickness of 25 feet and 43 feet of lignite at a depth of 155 feet and 137 feet respectively. Production was obtained from them for the next four years when they were abandoned due to falls and fire.

7. In 1927 the management was again confronted with the task of finding out further lignite bearing area. The advice of the Chief Inspector of Mines in India was sought for and two other pits (P. 39, P. 40, S IV and V) were sunk, which produced lignite for sometime. The shaft P. 40 was only 200 feet away towards the north of shaft P. 39 and the lignite was found in it at a much higher level due to a fault. It is estimated that it had an up-throw of about 40 feet. Fires and falls compelled the management to abandon these pits also in 1936. The presence of fault, crushed nature of the lignite and thinning out of the seam shortened the lift of these pits.

8. In 1929, however, a seven feet diameter shaft (P. 25) was completed in between the abandoned workings of the shaft P. 26 and the south-east shafts P. 16- and P. 17 to augment the out-put.

9. In 1931, while some production was on from P. 39, P. 40, P. 25, three more shafts (P. 11, P. 12, P. 15, S III) were then sunk. In these shafts the blue shade was seen well developed which is an indication for thicker lignite horizon and was welcomed by the management, a 36 feet seam of lignite was met. These shafts provided a steady out-put for a number of years, in fact the raisings exceeded the normal requirement and the production was slowed down by working for only four to five days a week.

10. When production from P. 11, P. 12 and P. 15 was coming, another shaft known as the "Silver shaft" (P. 9) was sunk at 1500 feet to the east of shaft P. 16 in the year 1937. A 40 feet thick lignite section was intersected at a depth of 131 feet from the ground level. This is the smallest section of overburden met so far in the Palana Coal Field. Within about 200 feet south of this shaft a big wash-out was met with which practically runs across the entire length of the coal field and so further development in this area from this shaft came to a close.

11. In order to continue further raisings, two seven feet diameter shafts (P. 7, P. 8) were sunk when the silver shaft P. 9 was about to be abandoned in 1939. Lignite section of 14 feet and 16 feet were met with at a depth of 210 and 213 feet respectively from the surface. The seam was found thinning out towards the north again and so the development was extended towards east, It had to be restricted, however, due to the main railway line passing over this area from Bikaner to Jodhpur.

12. Arrangements to swing this railway line to the east were made and completed in 1949. During this intervening period most of the development work in the south-eastern district was curtailed and only an exploratory shaft five feet in diameter was sunk in 950 to the east of the railway line (P. 3, S VI),

which touched a 20 feet thick seam, proving the continuity of the lignite bearing area in this direction. Another shaft P. 4 (Section VII) was also completed in this year. The shafts P. 3 and P. 4 yielded a steady out-put for about three years. Extensive wash-outs were encountered to the South of these pits and so they were abandoned towards the end of the year 1953.

13. The development operations though restricted to the south-east section, were continued with vigour in the north-west section of the field during the years 1945 to 1950. In 1945, three shafts (P. 49, P. 45, P. 41, S VIII) were sunk. The first two (P. 49, P. 45) continued yielding a steady out-put till 1949 but the third one (P.41) sunk on the basis of examination of the mine plan and meant to win the coal from several unworked 200 feet square pillars in the vicinity did not meet with success. When the galleries were driven from it, the pillars were found to be too small with badly rubbed sides and their surrounding galleries were practically choked with fallen debris of shale from the roof. It therefore, yielded very little lignite.

14. Another exploratory pit (P. 50, S IX) sunk in this area to explore lignite formation proved a thickness of about 14 feet of seam at 218 feet depth from the surface.

15. Attempts to prove further coal bearing area continued and exploratory (P. 38) shaft was sunk in the north in this area which conclusively revealed that the seam thinned out towards the north and only a thickness of 6 feet 9 inches seam was met at a depth of 257 feet from the ground level.

16. In 1948 two shafts (P. 54, P. 55) were sunk about 1000 feet south-west of P. 49. The pit P. 55 proved a thickness of 61 feet of lignite at a depth of 140 feet from the ground level which was the largest section of lignite seam intersected so far in any shaft or bore hole. The shaft P. 54 touched a thickness of 47 feet at a depth of 161 feet. These shafts were responsible for the maximum out-put attained by this colliery at any time during its history, viz, 72,000 tons in the year 1948. However, they had to be abandoned in 1949, owing to an extensive roof fall and fire.

17. The necessity of cheap lignite fuel for the power houses continued to provide urge for further exploration and development. Two new shafts P. 62, P. 63, S X) were sunk in 1948 at a distance of about 2000 feet to the north-west of the shaft P. 54. It proved a thickness of 17 feet of lignite at a depth of 183 feet. Unfortunately the galleries driven for a short distance of 150 feet from these shafts met extensive wash-out and clay pockets and had therefore to be abandoned.

18. With these attempts it was generally felt that there was no coal bearing area left for development and production in the north-west section. However, as a last attempt two shafts P.47, P. 48 were further sunk in the year 1950. They were intended to work a small triangular patch of coal left between the pits P. 50 and P. 55 sunk in 1945 and 1946 respectively and bounded by a big wash-out on one side. As a result of these difficulties, the out-put of lignite in 1950 contracted to about 25,000 tons and all attempts to increase the same did not meet with success.

19. A pit P. 60 (S. XI) sunk on the assumed axis of the field in the year 1949 also failed to strike the lignite formation and instead met another washout.

20 Two shafts (P. 31 and 32) were sunk in the year 1951. A chance was taken to find out if a workable thickness of seam in virgin area could be found out. This proved to be a success and the shafts proved 25 feet and 28 feet seam at a

depth of 226 feet and 221 feet respectively. These are the shafts which are the present lignite winning pits and a quantity of about 27,000 tons of lignite has so far been mined from these shafts. Another shaft (P. 33) to accommodate double cages has been sunk, equipped and kept ready for removing the shaft pillars of P. 32.

The tale of sinking shafts for the purposes of exploring and then employing them for lignite winning if a workable seam was encountered, and then abandoning them due to collapse of roof or fires has been repeated. The featureless surface of the field, the dull and repulsive look of the lignite, its high, moisture content and calorific value and comparatively cheaper cost of bituminous coal in the early stages from Bengal and Bihar coal-fields contributed to the slow exploration of this field. Its market was also limited to power-houses only because the chopping blast of the locomotives made this fuel unsuitable for them. Nevertheless its usefulness was fully recognised for raising steam from stationery boilers. The margin of profit in mining was very meagre and as such there was always reluctance in financing extensive prospecting and exploration programme.

This situation, however, has materially changed since World-War II, when the long distance of Bikaner from the Bihar coal-field and the high haulage cost, transport bottle neck, increased the dependence of the Power-houses on this fuel and it became necessary to consider, not only improved methods of mining aiming at higher extraction ratio of available lignite, but also for its intensive prospecting hydraulic stowing seemed inconceivable. The pneumatic stowing also could not be of much help because suitable stower and stowing material were not available and it was apprehended that clogging of pipes would rather be the rule than exception. The need for detailed prospecting further became imminent in 1949-50 when an exploratory shaft sunk on the assumed axis of the lignite bearing area indicated presence of large washouts.

With the procurement of a Hole Master rotary core drilling rig it has been possible to drill fifty four bore holes during a period of about four years (1952-54) and this method of prospecting has proved to be a boon to explore lignite in an area, where as already mentioned, the surface is a mere vast expanse of sand. These boreholes have helped to locate two virgin lignite bearing areas marked ABCD & PQRS about half a mile long and about 1200 feet wide indicating a thickness of lignite varying from 22 feet to 5 feet. The sections of the strata met at these bore-holes indicate the same nature of rock formations.

A study of the data from plan of the shafts and bore-holes of this coal-field clearly indicates that the lignite seam extends over a distance of about 3.5 miles in the north-west south-east direction and is about half a mile wide in NNW-SSE direction. It dips about 1 in 12 towards north-east. The seam is not regular and contains sporadic occurrences of clay pockets. These clay pockets or washouts present evidence of the erosion of the lignite formation by a stream after it had been deposited, and appears more or less wedge-shaped. With a maximum thickness of 61 feet as found in shaft P. 55, it gradually thins out towards the north in the dip direction and shows a thickness of 5 feet only in bore-hole. NW 17-52* and completely vanishes in about 25 feet distance further north from this bore-hole. It has been observed that the thickness of lignite seam approximately decreases by about a foot in every 50 feet distance travelled

* The abbreviation NW means North-West, first numeral 17 means serial number of bore-hole, and the last number 52 means the year when it was drilled.

laterally from south to north. The depth of the seam from the ground level has also been found to be varying from a minimum of 131 feet as seam at the 'Silver' shaft (P. 9) to a Maximum of 302 feet in the bore-hole N. W. 1-54.

ORIGIN OF THE DEPOSIT

The Palana lignite is believed to have been formed due to the accumulation of plant debris brought by the rivers and deposited in an estuary near the shores of a gulf in the Eocene times. Several deposits of almost the same age, though varying in their nature and quality, have been noted at Makarwal and Khost (Pakistan) and also in the State of Jammu and Kashmir. The washouts or clay pockets in the same horizon with lignite might have been formed as already mentioned by river action.

At the junction of the clay pockets and the lignite seam no evidence of faulting, drag or shattering has been noticed. The presence, however, of pebble beds as shown in some of the old shaft sections suggest 'drift' origin.

AGE OF THE DEPOSIT

The lignite occurs here associated with shale and fuller's earth lying below the nummulitic limestone possibly of the lower Kirthar series. The fuller's earth, shale and lignite are together grouped in the Laki facies of the Sind Tertiaries. There are further indications of coal in almost all the Laki formations which extend from Sind to Kashmir. For instance, lignite occurrences have been reported in the Thatta Taluka near Karachi and the anthracites near Jammu described by Middlemiss¹ are quite well known.

The argillaceous beds below the nummulitic limestone in those localities are evidently of the Laki age. Whenever the nummulitic limestone is absent as for example north of Barmer in the Jodhpur Division, the fuller's earth enclosing the fossil *Cibicides* "Nummulites" is said to belong to the Laki series, this fossil being a typical associate of the Laki beds. But in the absence of other fossil evidence excepting nummulitic limestone in the Palana area, generally the 'Laki' age can be assigned.

NATURE OF THE PALANA LIGNITE

Several opinions have been expressed about the Palana Lignite and its nomenclature. Roy² was of opinion that it should be regarded more as a peat than a lignite, Fox³ on the other hand suggested that an uplift of the area has resulted in the temporary exposure of the peat to the atmosphere thereby arresting further bacterial action, responsible for the conversion of the peat to lignite. He thus accounts for the incomplete transformation of the peat to lignite. In general appearances, however the Palana lignite is brown in colour as most lignites are and is highly resinous and in its chemical composition and calorific value it closely resembles lignite. In United States of America and United Kingdom the terms lignite and brown coal are used by some as synonymous. In Germany the term lignite (Lignit) is reserved for the wood or woody material of the coal as 'lignum' means 'wood'. The term "Brown Coal" (Braun Kohle) is generally used for coals which are brown in colour, and contain more than 30 per cent

1. Middlemiss.

2. Roy, S; unpublished report in old records of the Palana Colliery.

3. Fox, C. S.: op cit.

moisture. It embraces both the brown coal and lignite of the A. S. T. M. ¹ classification and all but the Glanz braun-kohle of the German classification. A typical analysis report ² of this lignite is given below:—

“The sample was in the form of dark brown dull lumps some what woody in appearance. Most of the lumps vary in size from 4 inches to 2 inches and showed cracks on the surface, breaking readily along certain directions when pressed with the fingers.

The results of the tests carried out on a representative portion of the sample are as follows:—

Moisture	36.14%
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PROXIMATE ANALYSIS ON THE DRIED SAMPLE

Volatile matter.	50.22%
Fixed Carbon.	41.96%
Ash.	...	...	...	7.82%
				<u>100.00%</u>

Nature of coke.	Non-caking.
Colour of ash.	Brown.

CALORIFIC VALUE ON THE DRIED SAMPLE

Calories per gramme.	...	...	6,674.
B. Th. U. per pound.	...	...	12,013.

The result of the ultimate analysis carried out on the dried sample is as follows:—

Carbon	...	...	...	67.37%
Hydrogen	...	...	...	5.03%
Nitrogen	...	...	...	0.90%
Sulphur (Volatile)	...	...	...	2.24%
Ash	...	...	...	8.10%
Oxygen (by difference)	...	...	...	16.36%
				<u>100.00%</u>
Total Sulphur	...	...	...	3.24%

Sulphur in ash calculated on the basis of ash:—13.01%”.

Results of analysis carried out by Fuel Research Institute, Jealgora, are also given below:—

“PROXIMATE ANALYSIS

	<u>Air dried</u>	<u>Dry basis</u>
Moisture.	26.7%	Nil.
Ash.	4.4%	6.0%
Volatiles	45.2%	61.7%
Fixed Carbon.	23.7%	32.3%
	<u>100.00%</u>	<u>100.00%</u>

Calorific Value in B. Th. U. per pound:—9,740

13,290.

1. 1902 Book of A. S. T. M. Standards, Part 5, P. 8:3 published by American Society for Testing Materials, Philadelphia, U. S. A.

2. Report Alipur Test House, Calcutta, No. MN/13/19 dated 5-4-1940 and No. MN/16/19 dated: 19.5-1940.

ULTIMATE ANALYSIS

	<i>Air dried</i>	<i>Dry basis</i>
Moisture.	26.7%	Nil
Mineral matter.	4.84%	6.60%
Carbon.	52.32%	71.29%
Hydrogen.	4.74%	6.47%
Sulphur.	1.68%	2.3%
Nitrogen.	0.91%	1.24%
Oxygen by difference.	8.81%	12.10%
	100.00%	100.00%

Extraction with P. E. and benzene mixture:—30:70.

P. C. extract on dry lignite. 16.5 about 25% which was wax insol in Ether.

Ash fusion range in mildly reducing atmosphere:—1120° to over 1300° C.

Sp. gr.— 1.213 at 40°/44° C".

Fuel ratio of lignite:—

$$\frac{\text{Fixed Carbon.}}{\text{Volatile matter.}} = \frac{41.06}{50.22} = 0.835 \left\{ \begin{array}{l} \text{As per analysis by Govt. Test House,} \\ \text{Alipur, Calcutta.} \end{array} \right.$$

The fuel ratio of Palana lignite is about double that of peat but slightly less than normal lignite. The comparative figures of fuel ratios are as follows:—

Peat—0.469 Palana lignite—0.835 Normal lignite—0.988

According to Hill's Law coals older in age generally carry less volatile matter and moisture content owing to deeper burial and the resulting high pressure.

Comparative merits and demerits of Palana lignite as against other brown coal deposits:—

"As a look into the comparative chart (Plate) giving analysis of important world deposits of lignites will show, the values of moisture and ash contents of the Palana Lignite are lower than some Australian and German brown coals, the ash content of Palana coal is almost equal to that of U. S. and Canadian brown coals,

The volatile matter of Palana lignite is higher than other world deposits. Therefore, in this respect the Palana Lignite does not fare better. But it has also higher percentage of fixed carbon and thus it fares better than other brown coal deposits.

The calorific value of Palana lignite is 7,384 calories per gram which is higher than that of German brown coals and South Arcot lignite but lower than Australian, U. S. and Canadian brown coals. The percentage of sulphur as shown by the ultimate analysis is higher in case of Palana lignite but it is not so bad, because some of the Australian brown coals contain a very high amount of sulphur, i.e., 5.6%. The Palana lignite though containing higher sulphur content than South Arcot lignite, fare much better in this respect than South Australian, Central German and Turkish brown coals.

It also contains higher amounts of Carbon and Hydrogen but lower Oxygen content. The Nitrogen content in the Palana lignite is 1.24 which is lower than that of South Dakota, Texas and Turkish brown coals but higher than Australian and North Dakota brown coals.

Palana lignite thus compares favourably with other lignite deposits as regards fixed Carbon and its calorific value though they are not very high can be considered satisfactory.

STRUCTURE OF THE DEPOSIT

The deposit is an irregular lense shaped one. There are evidences of small upthrow faults but no major faults have been located. It is considered that on the north-west side a strike fault is present because the lignite in this section is met with at a higher level on the dip-side, which may be due to the seam having been faulted and upthrown on the dip-side. On the whole item, however, be assumed that the area enjoyed comparative quiescence, even though there may be evidences of local faults, or displacements and minor folds.

METHOD OF WORKING

A glance at the underground plan (Plate) will show that to mine this lignite deposit, the room and pillar method has been adopted, shafts are sunk from time to time for winding the coal and raising and lowering men and material. Galleries six feet wide and six feet high are first driven in the virgin seam near the floor and are supported at intervals varying from 2 feet to 5 feet according to circumstances by timber (sal ballies) props of 4 to 6 inches in diameter. The soft nature of the lignite and also of the sandy shale above has made close timbering almost obligatory and recently on the main headings close skin to skin timbering has been adopted. Side walls with masonry bricks in line and arches have been tried to support the main roads, though this minimises the disintegration of coal to a certain extent but it cannot totally stop the drying up of the exposed lignite surfaces. It has been found that the disintegration goes on at the rate of about an inch of depth a month. After driving the main headings to a distance of about 1,000 feet from the shaft pillar extraction is generally started and as much roof coal as possible is taken out after proper timbering. The timber is then withdrawn and the roof allowed to fall. The pillar extraction is done right upto the shaft pillars. In a few cases even the shaft pillars had been attacked till any of the pair of shafts after taking out all the materials, fittings, equipment etc. Process of sinking new shafts continues where the depillaring is on, as soon as a pair of shaft is abandoned, the new ones which have been completed, are equipped and used for coal winning. This method has been in vogue since the very beginning of the mining operations at this Colliery.

As already described from the year 1895 till 1950 more than sixty shafts have been sunk and abandoned though some of them were meant chiefly for prospecting and exploration only. In the underground plan (Plate 2) the various areas, the abandoned shafts, and other features have been shown by different notations. It is abundantly clear from the same that the clay pockets, occurrence of spontaneous combustion, fires and roof falls have compelled the management to depart from the normal practice and approved plan of working and to adopt modifications to suit the conditions present.

In 1921 the 'Panel' system of working was tried, to meet the problem of spontaneous combustion. The area around the shaft (P. 13 and 14) was laid out in Panels. This helped to control the fires to some extent, but the collapse of the roof at the main junction and self-heating within a few weeks after the collapse made matters worse.

In the year 1927, the advice of Simpson¹ was sought for, he suggested driving main headings from the shaft in stone either above or below the seam, laying out the workings in panels and working the seam, by means of drifts from the stone headings. Unfortunately no stone with the required hardness was available reasonably near the seam itself and so the idea had to be dropped. Since then the headings are almost always driven in coal the galleries are kept

1, Simpson, R. R. Communication in old files of Palana Colliery.

staggered and the workings laid out in panels. As soon as development is finished in one district depillaring is started in that district without waiting for the completion of the development in other districts. As the stratum immediately above the seam consists of very soft sandy shale some roof coal has to be left for support and even then close timbering is necessary. On account of this, a minimum thickness of 9 feet of the seam is considered necessary for winning the lignite.

The difficulties in mining have been referred to visiting consultants from time to time and at one stage suggestions were received from Case ¹ that long wall method of mining with pneumatic stowing and mechanization may be adopted in modification of the existing method. The State Government purchased four electrically driven compressors of a total capacity of 4,000 Cft., per minute for pneumatic stowing, but the plan never went through and the compressors were not used for the purpose they were purchased. As early as 1939 it was revealed that the known reserves in this field have well nigh exhausted, though efforts to win small quantity of lignite by every available means and explorations of the adjoining areas have continued even to the present day.

VENTILATION

In the underground workings, the ventilation equipment used has been fairly adequate. The lignite contains much moisture near about 36% on an average. On being exposed to air particularly to the dry air of the desert region, it starts losing the moisture rapidly and consequently cracks start developing and spalling begins exposing fresh surfaces to the air. It has been observed that in about six months time nearly six inches thickness of the coal flakes off. Thus a gallery driven only six feet wide by six feet high becomes 7 feet wide and 6 feet 6 inches high in six months time, necessitating a replacement of the timber sets. If the air circulation is restricted this disintegration is comparatively less pronounced. Even then, due to the evaporation of moisture, the mine air soon becomes almost saturated. In order to minimise this effect by preventing much air circulation the working of most of the pits in the past depended on natural ventilation.

This was adequate in the early stages, but later, when greater out-put was brought out and more extensive area was opened, the natural ventilation was not only found to be inadequate, but also uncertain. The present mines (P. 31, 32, 33) are, therefore, now ventilated by a compressing fan with a capacity of about 50,000 Cft., of air per minute at pressure of 2 inches. An exhaust fan with a capacity of 30,000 Cft., of air per minute at a pressure of about one inch is also available for any future underground development work.

POWER

Formerly the Colliery was exclusively worked by steam power using lignite as fuel in its crude form and by burning it in vertical, Cornish and Lancashire boilers. The only change in the boiler fittings necessary to suit this fuel was to keep the spaces between the fire bars only 3/8" instead of the usual 1". As soon as the grate is charged with freshly mined lignite it acts as damper and once the moisture is driven out, the lignite burns with a good flame and forms a little clinkar. Cleaning the fire grates is less often necessary than in the case of other coals, the reason being that the ash content of lignite is lower than that of other coals. When it is burnt in vertical boilers the lignite consumption has been very high that is about 10% of the entire output, on the other hand with Lancashire type boilers the consumption is reduced to 3% of the total out-put. In the latter case, the shifting and installation has been very costly because of the frequent abandonment of

1. Case J. W. Report on the working of Bikaner State Colliery, Palana, 1939, unpublished.

raising shafts. Every fourth or fifth year, the boilers have to be removed and reinstalled at new sites. It is to avoid this recurring expenditure that the Colliery has arranged for its power supply from the Power House at Bikaner since 1942. The power is transmitted through high tension over head lines and brought at 6,600 volts, which is stopped down at three different points (1) by a 100 KVA transformer at shafts P. 32 to work the electric hoist fan and haulages (2) by a 50 KVA transformer at the Colliery water well to work the main pump (40 H.P.) against a lift of 350 feet and a surface pump used for distribution at various points (3) by a 50 KVA transformer for the workshop, equipped with lathe and drilling machine and for lighting.

It has been experienced that due to sand storms in summer months the current supply is interrupted though in winter this trouble is not there. The current failure can cause dislocation in air circulation within a few minutes and reversal of air current may also happen. To ensure freedom from such trouble it has been decided to work the main winder by steam and keep a steam engine as a stand by to work the fan. A new Lancashire boiler has been installed at the shaft P. 33 in 1953.

OPENCAST MINING.

The depleting reserves in Palana and the anxiety to recover all the lignite left underground as support of workings carried out during the last half a century for meeting the pressing demands for fuel for power houses and other industries prompted the State Government to consider alternative methods of working. They invited Mr. W. L. Opie¹, a Consulting Mining Engineer from England, in 1945, who suggested opencast mining methods after studying the area and its problems. His report which has not been published carries study on the various aspects. According to him the lignite area worked and proved till 1945, covered 17.7 Million Sq. Yards. Considering on an average the thickness of lignite to be 20 ft. this area is estimated to carry about 12.7 million tons. During the past fifty years, only about a quarter and a million tons was raised from this area. It can safely be assumed that about 10 million tons of lignite is lying in this area along. Since 1945 further areas have been developed, and the recent drilling operations have also indicated presence of nearly 3 million tons of lignite. The total available coal would very nearly be 15 million tons. Exercising all the safeguards it can be assumed to be nearly 12 million tons

The present system of mining has proved quite unsuitable for working lignite. The friable nature of the material and other characteristics have resulted in the collapse of galleries and other occurrences due to which the present workings do not leave any possible chance of there being re-entered on any but the smallest scale.

Whatever method of working may be used in the new deposits which may be found, it is quite certain that the opencast mining i.e. removal of over burden and open quarrying of the lignite is the only possible method of salvaging the lignite in the worked out areas.

The method of operation suggested by Mr. Opie is summarised below. The over burden to be removed has an average depth of about 210 ft. The thickness of deposit varies from 40 ft. to 15 ft. or less averaging about 20 ft.

Very briefly the method of operation is to open up the first exposure of lignite the most suitable position being ascertained and shown in Plate. 1 as bounded by the rectangle ABCD Obviously this 'first cut' will be mainly dealing with over-burden.

1. Opie, W. L. 'The development of the Palana- Opencast Colliery. The Planning Report', 1946.

In the complete stripping down to the lignite an approximate total of 2 million 80 thousand cubic yards of spill will be removed which would uncover 105 thousand tons of lignite.

The excavation referred to will be done partly by Tournapul, scrapers and partly by drag-line excavators. The first cut having been made, the amount of over burden to be removed would be dumped back into the areas from which lignite has already been excavated.

The plan was then estimated to cost a block capital of 21 lacs of rupees. Normal technical difficulties in launching opencast mining methods would be:—

- (i) A high ratio of over burden to the thickness of lignite will be about 9. 1 considering average thickness of lignite to be 20 feet.
- (ii) Possible loss of some lignite left unworked as support due to any fires or roof falls.
- (iii) Possibility of extensive reheating by spontaneous combustion of old fire zones due to the uncovering and exposure to air.
- (iv) Disposal of a minimum quantity of one thousand tons of lignite for industrial and other uses (this is considered to be the lowest daily production unit).

All the above points have generally been considered in preparation of this plan. It is true that if opencast mining is adopted it will be unique effort in the aim to win lignite for industrial and other requirements of fuel for this region. But its usefulness cannot be lost sight of. In fact the plan was accepted by the former Bikaner State Government and machinery worth about a million of rupees was purchased, but later on when it was known that electric power from Bhakra-Nangal Project would be available in a few years time, the State Government revised their previous decision and dropped further pursuance of the same and whatever equipment was obtained was put to alternative uses in the irrigation works. The computations made by Mr. Opie show cost of removal of debris and lignite as under:—

	Total Cost.	Cost per Ton	
		Sh.	d.
Plinth charges (writing of all plants in four years)	£87,636	1	11
Fuel charges.	£114,703	2	6
Supervision.	£32,092	0	7

Since this report had been submitted in 1946, considerable strides, have been made in the use of large earth excavating and transporting machinery in this country. The various irrigation and power supply schemes initiated under the First Five Year Plan have millions of rupees worth of equipment under operation. Characteristics and operative capacity of them is now a known feature. In the light of such available data and information the calculations made in 1946 can be reviewed but it is promptly felt that in view of the geographical position of the field and comparative high cost paid for Bengal and Madhya Pradesh coals and possibility of use of large tonnage of lignite daily for industrial uses, the opencast plan in fact becomes a more economic and sound proposition. In the present case an additional advantage can also be claimed because in the column of the over burden besides the lignite, fuller's earth limestone. kankar and clays are also available. The fuller's earth is considered an useful industrial mineral particularly

as a filler and for bleaching, clarifying or neutralising (some times combining, decolourizing and neutralizing) of mineral, vegetable and animal oils, fats that greases. Manufacture of petroleum products also requires its use, besides the textile and paper industry and a small quantity for medical purposes. Its demand though at present is about 15 thousand tons annually would increase as industrialization proceeds and activated and refined fuller's earth is available to the consumers. The typical analysis of fuller's earth obtained from this area is given below.

Chemical Analysis.

Hygroscopic moisture	8.80%
Water of combination	8.71%
Silica	56.58%
Lime	Traces
Iron Oxide & Alumina	17.15%
Magnesite	8.76%
Alkalies and loss	

Physical Analysis.

Talc	27.60%
Silica, iron etc,	72.40%

Microscopic Analysis.

Silvery white, translucent; good lustre
siliceous parts and slightly coloured.

The selling price of this fuller's earth is Rs. 40/- to Rs. 50/- per ton at pit's mouth.

Estimates indicate that for every 1000 tons of lignite production by opencast method, nearly 1400 tons of fuller's earth will be produced which would present a serious problem for disposal. It will require further research to find some more industrial uses of this mineral. Activated fuller's earth demand is also likely to strengthen with the development programme envisaged in the First and Second Five Year Plan.

The Palana Lignite as a fuel or as a source for valuable bye-products has considerable importance, and very favourably compares with the Bengal coal which after its long haul is certainly not as economic as the lignite i.e. in spite of high moisture content and weak physical nature it is reckoned that the relative values of the two fuels are in the ratio of 100:54 on a useful or net calorific value basis or in other words the lignite ought to be available in just a little over half the price of Bengal coal as far as the consumer can afford to pay upto Rs 21/6/- per ton for the lignite as excavated without bearing any loss. With large production of lignite by opencast method it would be necessary to briquet this soft friable mineral and make its transport possible to the consuming centres. Some experiments have been carried out on briquetting, which would be described later.

Since Opie's Report on this plan, considerable strides have been made in large dam construction and highway engineering in the Indian Union. The Bhakra-Nangal Irrigation and Hydro-power Project is on its way to fruition and canal waters will irrigate 523,000 acres of land in the North Rajasthan alone besides large acreage in West Punjab, P.E.P.S.U. and other adjoining areas. It will also supply 11,000 K.W. of electric power to Rajasthan. The consequent agricultural development would call for establishment of two to three scores of mandis (townships) which will stand in need of this fuel for lime and kankar burning and

other various uses. The Central Electricity Commission visualize electric power generation on thermal basis in South and Central Rajasthan, which would present persistent demand for cheap fuel and lignite produced by opencast mining would have no dearth for market. Recently much interest has been evinced in the possible Ammonium Sulphate Fertilizer Project based on gypsum mineral in Rajasthan. Experiments had been conducted in Germany as early as 1930 by the former Bikaner Government to investigate the gasification and low temperature carbonization of lignite.

The area marked ABCD in the plan has been considered by him (Mr. Opie) as best suited for initiating the opencast operation. The former Bikaner State at one stage accepted Mr. Opie's recommendations and obtained equipment worth nearly Rs. 8,00,000/- which included articles such as tournapulls bulldozers, rooters etc. The entire scheme according to Mr. Opie was to cost about Rs. 21,00,000/-. However, later in 1947-48 Government revised its previous decisions and dropped further pursuance of this project. The equipment was diverted to the Irrigation and Electrical and Mechanical Departments, where it has been used for several odd jobs, like repair of Ferozepur irrigation canals etc. Most of this equipment is now unserviceable.

FUTURE DEVELOPMENT

A case for opencast mining has been fully made out though due to change in prices of equipment it is necessary to reassess their value and examine the costs. The programme has been included by the State Government in their Second Five Year Plan. However, to keep continued production till opencast supplies are available for supplies to the local Power House, it is planned to develop areas ABCD and PQRS as shown in Plate 1 by underground methods. These are virgin coal bearing areas located by exploration with core drill. It is proposed to modify the mining method by instituting a long wall system of working.

PROSPECTING AND EXPLORATION

The State Department of Mines and Geology which is incharge of mining operations at present at the Palana Colliery have undertaken prospecting operations since 1950. The area was geologically examined and subsequently a grid plan was prepared to undertake core drilling operations. A rotary type core drill has been in use here since 1951. The exploratory drilling operations were carried out in the NW and SE extremities of the known lignite field. Seventyfive bore holes have since been drilled upto the end of June, 1957 and their core logs the plan showing the locations of the bore holes and a statement indicating lignite and overburden thickness is appended hereto.

It will be observed that the prospecting operations were successful in marking out lignite seams in fifty bore holes over 20.5 m. square feet area. An estimate of the virgin lignite reserve in this portion marked deep red on plan (Plate No 1) has been made at about 9 million tons. Prospecting operations are however, in progress. From the record of the bore holes the average thickness of lignite available calculates out to be 13'. The maximum thickness recorded was 29'. The exploratory drilling operations further suggested extension of the seam towards NE direction where drilling will be continued.

An examination of the underground plan has been carried out in order to estimate as accurately as possible, the lignite left underground in the areas where mining operations have been conducted since 1898. The reason for this coal

having been left underground has been low extraction due to bad roof conditions which did not permit an extraction of more than 15% of the available coal. These mined out areas have, therefore, been marked on the plan from 'A' to 'I' and the information about the Results has been tabulated below:—

<i>Year of work</i>	<i>Area</i>	<i>Tonnage</i>	<i>Tonnage Extracted.</i>	<i>Tonnage Left Behind</i>
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
1918—1923	E	14,26,704	92,800	13,33,904
1931—1936	D	16,18,675	2,11,700	14,06,975
1937—1939	C	4,82,342	1,06,800	3,75,542
1941—1943	B	10,20,728	1,33,229	8,87,499
1943—1945	F	4,10,093	92,511	3,17,582
1948	I	47,432	470	46,962
1945—1950	H	19,77,976	2,68,807	17,09,169
1950—1953	A	1,23,000	46,439	76,561
1951	G	6,56,993	67,826	5,89,167
1952—1956	G	5,63,745	1,63,746	4,00,000
		1,46,33,593	17,84,589	1,14,42,030
Less 10% allowed for mitti pockets.		14,63,359		
		1,31,70,234		

According to this the tonnage left behind in the worked out areas, therefore, calculates out at 1,14,42,030 tons i.e. say 11.5 million tons. Thus the total reserve now available at Palana lignite field works out to be 11.5 plus 9 i.e. 20.5 million tons. The position of reserve will, however improve if prospecting operations indicate further coal bearing area.

OTHER OCCURRENCE OF LIGNITE AND CARBONACEOUS SHALES AND THEIR FURTHER PROSPECTING.

Since the first lignite occurrence was discovered at Palana, Government was naturally interested in searching other similar deposits elsewhere in the State. As a result of preliminary investigations, sinking of prospecting shafts and bore holes etc. occurrences of lignite and carbonaceous shales have been noted at the following places:—

1. A lignite seam of three feet thickness was met with inside a well section in village Khari ($27^{\circ}58'45''$: $73^{\circ}57'$). The seam was found at a depth of 105 feet from the surface. The debris lying at the pit's bank, though weathered resemble those met within the Palana shafts.

2. Existence of lignite has been reported from Channeri ($27^{\circ}45'30''$: $72^{\circ}48'$) where also it has been encountered in a well. The extent of Channeri lignite is not known but the indicated thickness is 5 feet with signs of thickening of the seam in the easterly direction.

3. A three feet lignite seam has also been found at Ganga Sarowar ($27^{\circ}56'48''$ - $72^{\circ}54'6''$) at a depth of 220 feet. This lignite was analysed at the

Government Test House, Alipore and had the following analysis. It appears to be slightly inferior to the Palana Lignite:—

Loss on Drying at 110° 46.20%

APPROXIMATE ANALYSIS OF DRIED SAMPLE.

Volatile matter	45.15%
Fixed Carbon	48.45%
Ash.	6.40%
Nature of Coke	Non-cocking.
Colour of ash	Brown.
Calorific value of dried sample	
Calories per gramme	6.319
B. Th. U. per pound	11,374

4. A thin band of lignite of about 2 inches thickness, has been noted in a well at Mudh (27° 51' : 72° 58'), though no other occurrence has been reported from other wells situated in the locality.

5. A sudden collapse of small area near the village Napasar (27° 56' 43" : 73° 33' 40") occurred some years ago. It is believed to be due to the collapse of limestone caves below. Fox suggested that Fuller's Earth or Lignite might be found below.

6. Fuller's Earth occurrence has been reported in the village Kesardesar (27° 51' : 73° 29') but is not known whether any lignite was also intersected there.

7. A thin lignite seam has been found in a well at Gunga (26° 15' : 71° 11') in the Shiv District about 150 miles South-West of Channeri near Jodhpur-Jaisalmer border. Prospecting of this area with bore-holes has recently been started.

It is difficult to say that all the above occurrences promise to become potential sources but attention will be paid to all of them. There is another area at Bania village, east of Palana worth investigation, where a thick carbonaceous shale has been known to exist. Occurrence at this place which is north of Surpura (27° 42' : 73° 26') has been reported by M/s Bird and Company. A little further to the north is Napasar village, already mentioned above where according to Fermer further lignite formations may be possible to discover.

UTILIZATION

As already mentioned the opencast mining plan cannot be successful unless a minimum tonnage of about 20 to 30 thousands is produced every month. The local Power House consumption is not expected to exceed 7,000 to 8,000 tons a month. Therefore, a large quantity of lignite would be left as a surplus and can be used if a Thermal Station is located here or briquetted lignite is transported to other parts of Rajasthan and neighbouring provinces. It was also possible to use this mineral for the manufacture of a number of bye-products. The chart attached herewith describes some of the important uses of lignite.

The lignite is so friable that when it is burnt in boiler it is generally found that the chopping blast drives away incandescent coal particles through the chimney, resulting in the loss of heat causing, thereby loss of efficiency. When this physical weakness could be removed by briquetting it is possible to burn lignite successfully both in water tube and fire tube boilers

BRIQUETTING

Briquetting of lignite has been successfully carried out in several foreign countries. A number of experiments have also been carried out in the past with the Palana Lignite in order to determine its briquetting qualities at the Yeadon plant installed at the Nazira Coal Company Ltd's Colliery in Assam. The pitch was used as a binder for all the tests and was supplied by Shalimar Tar Products Co., Ltd., and had a melting point of 85°C.

The observation made during the briquetting tests showed that a ten tons wagon load sent from the Palana Colliery to Nuginimarea (Assam) weighed at destination, 8 tons 19 cwt. only suggesting thereby a loss of moisture of 1 ton 1 cwt., or 10.5% of the total weight during the transit.

As the percentage of pitch to make a satisfactory briquette with Nazira coal is about 7%, it was desired to test Palana lignite from a mixture of 8% pitch to the limit of successful briquetting. The first experiment showed that it was impossible to make briquettes without the use of water; therefore this was used in varying quantities in the latter tests. Eleven tests were carried out, details of which are given below:—

- 1st Test*:—92% coal, 8% pitch and no water. Briquettes were soft and unsatisfactory.
- 2nd Test*:—92% coal, 8% pitch and water. Briquettes were harder and more satisfactory than the first test, but not as hard as desired.
- 3rd Test*:—93% coal, 7% pitch and water. Much the same as the second one,
- 4th Test*:—94% coal, 6% pitch and less water than in the third test. Briquettes poor.
- 5th Test*:—95% coal, 5% pitch and sufficient water. Briquettes as satisfactory as those in the fourth test.
- 6th Test*:—95% coal, 5% pitch and sufficient water. Briquettes slightly softer than those in the fifth test
- 7th Test*:—96% coal, 4% pitch and sufficient water. Briquettes similar to those in sixth test.
- 8th Test*:—97% coal, 3% pitch and sufficient water. Briquettes softer than those in seventh test.
- 9th Test*:—95% coal, 2% pitch and 3% rice meal. Briquettes fairly good, though not hard enough.
- 10th Test*:—98% coal, 2% rice meal and sufficient water. Apparently as hard as in the previous case.
- 11th Test*:—No binder at all but with fairly large quantity of water. The briquettes fairly good but slightly softer than with 2% rice.

The briquettes never attained a hardness comparable to the briquettes made with Nazira coal.

Samples of all the briquettes were forwarded in a closed box by passenger train, but they did not travel very well, there being broken briquettes in each sample. The briquettes when knocked together had dull sound as compared with the sharp ringing sound of the Nazira briquettes and it appears that the pressure exerted by the roll may not be enough for this type of lignite. The most satisfactory briquettes seem to be those made in the test Nos. 8, 9 and 10 which rely as much on the dextrine content of the rice as on the pressure in the rolls. The

objection to this type of briquettes is that they are not waterproof and so are liable to disintegrate in the humid atmosphere. The use of starch also requires the introduction of some chemical to prevent fermentation of mould which tends to weaken the briquettes.

Present results show that the briquettes of a kind which can be made, are not completely satisfactory yet in view of the difficulties experienced in various countries in arriving at a suitable formula for making a satisfactory lignite briquette on a commercial scale, it is desirable to find as to how the present product can be improved upon. It is probable that with a pitch binder of 5% to 6% the briquettes can be made sufficiently hard to stand jerks during transportation. As to how briquettes would weather is a different matter. A suggestion has been made to use molasses as a binder instead of pitch. No experiments, however have so far been carried out with this material.

Tests were conducted in 1946 when opencast mining plan for Palana Colliery was under preparation and the following facts have been established. It should be taken that these facts are unable to give a first approximation to the specification of a good Palana briquette.

(1) *Size of material*:—The most favourable size of material from which to make the briquettes is to crush the raw lignite just sufficient to enable it all to pass through a $\frac{1}{2}$ inch screen, (or 4 mesh screen could be used, i.e. 4 holes to a linear inch). Smaller crushing gives a weaker product. Larger sizes also seem to give a weaker briquette but this is not yet entirely proved.

(2) *The mould*:—By grinding out and polishing (lapping) the inside of the mould an improved briquette was obtained. It was found that the moulds as being used were distinctly rough inside.

(3) *Lubrication*:—Greasing of the inside of the mould and the plunger gave much greater uniformity in the product.

(4) *Double pressure*:—It was found that by giving each briquette a second pressure a much more uniform hard briquette was obtained. The plunger is merely drawn back after the first pressure and then returned on to the briquette at full pressure for about a second.

(5) *Removing briquettes from the mould*:—It was noted that practically all the failures in the briquettes seemed due to the breakage while coming out of the mould across the briquette.

Observation showed vibration cracks and it appears certain that unless the mould is perfectly smooth inside, and better still both smooth and lubricated, the briquette sticks firmly in the mould. The use of the plunger to remove the briquette jars along the inside of the mould extruding it at the end in an already fractured and weakened state.

(6) *Present specification of Palana briquette*:—

Size of Feed.	...	Minus $\frac{1}{2}$ inch (unscreened)
Dimensions.	...	1 $\frac{1}{2}$ " diam, 2 $\frac{1}{2}$ " long finished
Mould.	...	Perfectly smooth inside and lubricated
Plunger.	...	Lubricated
Pressure.	...	Approximately 8 tons per sq. inch applied twice.

Briquettes made as above are hard and uniform and burn well. There is some sparking but all sparks are small and go out within three or four yards of the fire. All sparks are uniform in size and small.

Further tests on briquetting of this lignite were carried out at the Fuel Research Institute, Jealgora¹. The results of tests are given below.

Lignite samples fresh from the mine were sent in sealed drums. This was quickly crushed by hand to 2" size and later crushed in jaw crusher to $\frac{1}{2}$ " size. It was next coned and quartered and further crushed to pits 6 mesh (B. S. S.). A portion was crushed to pass through 72 mesh for proximate and ultimate analysis. For briquetting the sample was crushed to below 2 mm., with a majority of particles below 6 mm. Briquetting tests were carried out in a 50 ton hydraulic press and plunger type moulds were used. Briquettes with cylindrical shapes 1.5" dia. and about 2" in height were obtained. The following results on different tests on the briquettes are given:—

1. Compressive strength:—The optimum moisture for medium pressure briquettes (1 ton per sq. inch) is 18.5% while for higher pressure ranges it is 10.2% (at 17 ton per sq. inch).
2. Resistant to water emersion and weathering:—The briquettes usually disintegrate in a matter of few minutes in water. On exposure to weathering these briquettes developed cracks and fissures on storage and lost strength. This fact was more prominent in case of high moisture briquettes.
3. Combustion characteristic:—The briquettes were found to burn nicely. It gave good fire and percentage material combustion in ash was usually below 4%.

The result of proximate and ultimate analysis are given below:—

<i>Proximate analysis</i>	<i>Air dried</i>	<i>Dry</i>
Moisture.	13.5%	Nil.
Ash.	7.9%	9.133%
Volatile matter	43.8%	50.64%
Fixed Carbon.	34.8%	40.24%
Calorific Value/B. Th. U./lb.	10,200	11,800

Ultimate Analysis

Moisture.	13.5%	—
Mineral Matter.	—	—
Carbon.	54.41%	66.37%
Hydrogen.	4.11%	4.451%
Sulphur.	2.51%	2.904%
Nitrogen.	0.89%	1.0289%

The tests indicated that Palana lignite could be briquetted without the addition of a binder, simply with the application of pressure. It was found that moisture played a significant role in the strength of briquettes, the critical moisture being 18.5% for medium pressure and 10.3 for higher range of pressure.

Further research by designing a suitable pilot plant is being considered at present.

1. Report on Briquetting of Palana Lignite communicated by the Director, Fuel Research Institute, Jealgora, in May, 1955.

CARBONIZATION

During the year 1931 the former Bikaner State Government sent samples of this lignite to M/s Lurgi Gesellschaft Fur Warmetechnik, Frankfurt at Mainz, Germany, for a complete test for low temperature carbonization on Palana lignite to determine its amenability to carbonization with the Lurgi Process. The lignite was carbonized in a Lurgi Carbonizer and the products of carbonization were further tested by distilling the tar produced and by briquetting the semi-coke. It was found that the lignite from Palana could easily be carbonized in the Lurgi Carbonizer even with high through puts and the carbonization products (semi-coke and tar) are of good quality. The carbonizing analysis of lignite was as follows:—

Moisture.	25.0%
Aqueous distillate.	6.8%
Tar.	8.2%
Coke.	47.8%
Gas plus loss.	12.2%

The yields under practical working conditions were found as follows:—

Coke.	46.0% of the lignite.
Tar and Oils at a yield of 80%	6.5% of the lignite.
Crude Benzine.	2 gallons per ton of lignite.
Pitch	20% of the tar or 1.31% of the lignite.

The tar distillation tests indicated that the tar and oil obtained in the carbonizer plant can be used to produce a pitch suitable for briquetting process. It was suggested that in order to obtain suitable pitch from this lignite it will be necessary to distil the tar either under vacuum or by means of steam distillation. The yield of pitch will then amount to about 21% which would have a softening point of about 75 cm. (Kraemer-Sarnow), high ductility and penetration. The oil obtained in the scrubber was tested with regard to suitability for lighting purposes. It was found that by suitably distilling the tar, an oil could be obtained which would burn completely in a lamp.

Briquetting tests were carried out with the semi-coke obtained with the carbonizer. It was found that with 8% bituminous coal tar pitch as binder suitable briquettes having calorific value of 11,980 B. Th. U. per pound can be obtained.

Further carbonization tests were also carried out by Mr. Tozer of Battersea, London, who also opined that distillation plant called 'L. and N. Process' would be able to produce 200 tons of briquettes a day using about 450 tons of lignite and would simultaneously give 80 gallons of crude oil.

Since the above tests were carried out considerable research have taken place in Germany, and also in Australia and U. S. A. for pressure gassification and carbonization of lignite. Several important modifications in the process used in the tests described above have been since then made. It has, however, been established that the lignite from Palana can be used for the manufacture of briquettes as well as byproducts such as tar oil, benzine, etc., etc. The method of the treatment and a suitable plant can be devised only after further practical tests employing modern methods.

CONCLUSION.

It will be observed from the above that Palana lignite deposit has in the past been worked out of necessity in a wasteful manner. The chief idea then was

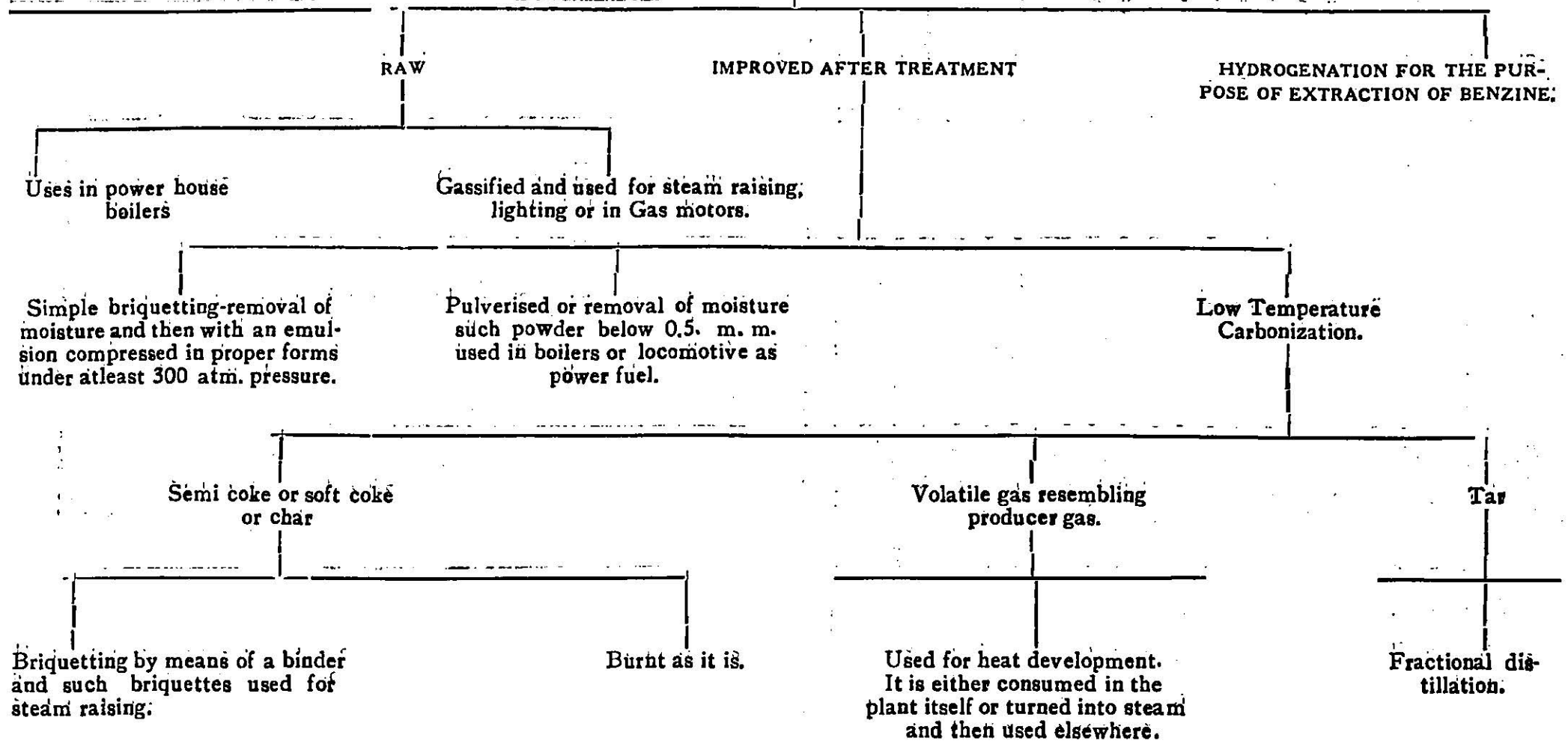
to make available supplies to the local power house at a cheap rate, but in the present context, with India at the threshold of industrialization, the unworked lignite left underground as support and the new discovered quantity of three million tons could not be allowed to remain unworked. It would easily make an important source of lignite production provided open-cast-mining method was adopted. The ratio of overburden of lignite no doubt appears to be high yet with the modern equipment the problem is not such as may not be solved.

The distance of North Rajasthan from other coal fields makes it imperative that this quantity of lignite should be won and utilised for industrial purposes. It is also well proved that Palana lignite can be briquetted and can be utilised as a good source of fuel and it can also be employed as an excellent raw material for carbonization and production of other important distillation products. The discovery of more coal bearing area in the extension of the coal field and indications of coal horizon at half a dozen other places in Bikaner and Jodhpur Divisions show that probably more lignite formations could be found besides this deposit and, therefore, an intensive prospecting programme for them by drilling is proposed.

In writing this article the chief aim had been to give an up-to-date information which the department possesses in respect of this colliery in a concise form and in writing the same the authors are grateful for the assistance which has been given by Mr. A. Roy, Assistant Mining Engineer, in seeing through the draft preparation of maps and statistical data. Assistance of other Officers of the Department of Mines and Geology and of the Palana Colliery is also acknowledged. The authors also wish to express their thanks to Dr. M. S. Krishnan, Director Geological Survey of India for his valuable suggestions in connection with this article.

UTILIZATION OF LIGNITE

LIGNITE



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ANALYSES OF IMPORTANT WORLD BROWN COAL DEPOSITS

	Australian Brown Coal						German Brown Coal			Turkish Brown Coal	U. S. Brown Coal			Canadian Brown Coal	Indian Brown Coal Palana (Rajasthan)		South Arcot Madras
	Victorian			South Australian			Lower Rhine	Central German	Neide Lausitz		North Dakota	South Dakota	Texas		Analysis by Alipore Test House	Analysis by Fuel Research Institute	
	1	2	3	1	2	3											
PROXIMATE Moisture	66.3	60.0	33.4	52.0	51.7	48.7	60.0	51.5	57.6	43.0	39.7	38.5	34.5	50.0	36.14 (Dry basis)	43.3 (Dry basis)	15.08
Ash	0.7	2.7	1.6	13.9	8.3	11.7	2.3	6.8	3.2	15.0	4.1	5.8	9.5	6.3	7.82	6.0	3.20
Volatiles	17.7	20.8	26.8	19.6	24.5	24.2	20.6	23.7	21.7	21.6	27.2	26.9	26.3	21.3	50.22	61.7	44.78
Fixed Carbon	15.5	16.5	38.2	12.5	15.5	15.4	17.1	18.0	17.5	20.4	20.0	28.8	29.7	22.3	41.96	32.3	36.94
DRY AS FREE BASIS Volatiles	53.4	55.7	41.2	60.9	61.25	61.1	54.6	56.8	55.3	51.4	48.5	48.3	47.0	48.9	—	65.4	—
CALORIFIC VALUE BTU/Lb. Cal/Gm	11,125	10,780	12,535	12,370	—	—	6,200	6,894	6,245	—	12,010	12,230	12,820	11,650	12,013 6,874	13,290 7,384	9,500
ULTIMATE Carbon	67.4	67.7	72.0	69.2	69.3	—	68.9	61.1	62.5	70.8	71.1	72.0	73.0	—	—	76.32	—
Hydrogen	4.7	4.7	4.7	5.7	4.8	—	5.3	4.8	5.2	4.7	5.0	4.8	6.2	—	—	6.92	—
Sulphur	0.3	2.5	0.5	5.4	3.9	5.6	0.3	2.0	0.8	2.8	0.4	0.7	1.8	—	—	1.87	1.16
Nitrogen	0.5	0.5	1.0	0.5	0.7	—	—	—	—	2.2	1.1	1.4	1.5	—	—	1.33	—
Oxygen	27.1	24.2	21.8	19.4	21.3	—	25.5	19.0	23.2	19.5	22.4	21.1	18.1	—	—	13.56	—
Ash	—	—	—	—	—	—	—	12.0 On dry	8.3 basis	—	—	—	—	—	—	—	—

Statement showing Borehole Data

No. S	Number of borehole	Thickness of Overburden	Thickness of coal seam	Remarks.
1	2	3	4	5
1	S. E. 2	251'	9'	The 48 boreholes a total lignite thick- ness of 618' was met with, thus average thickness of lignite seam is 618/48 or 13'.
2	S. E. 1	137½'	23'	
3	S. E. 3	205'	4½'	
4	S. E. 4	199'	No. Coal	
5	N.W. 52-2 F	179'	3'	
6	1 F	216'	23'	
7	3 F		No coal	
8	5 F		No coal	
9	4 F		No coal	
10	6 F	232'	27'	
11	8 F	285'	No coal	
12	7 F	203'	29'	
13	9 F	250'	21'	
14	11 F	32'	12'	
15	10 F	259'	11'	
16	12 F		No Coal	
17	14 F		No Coal	
18	13 F		No Coal	
19	15 F	240'	12'	
20	17 F	200'	5'	
21	16 F	235'	13'	
22	18 F	195'	7'	
23	20 F	263'	12'	
24	19 F	200'	4'	
25	21 F	190'	6'	
26	22 F		No Coal	
27	24 F	235'	3'	
28	23 F	282'	13'	
29	25 F	238'	10'	
30	N.W. 54-3	260'	5'	
31	54-2		No Coal	
32	N.W. 53-1	290'	10'	
33	N.W. 54-5	295'	10'	
34	54-6	220'	15'	
35	54-7	235'	10'	
36	54-10		No Coal	
37	54-6	190'	15'	
38	54-9	175'	13'	

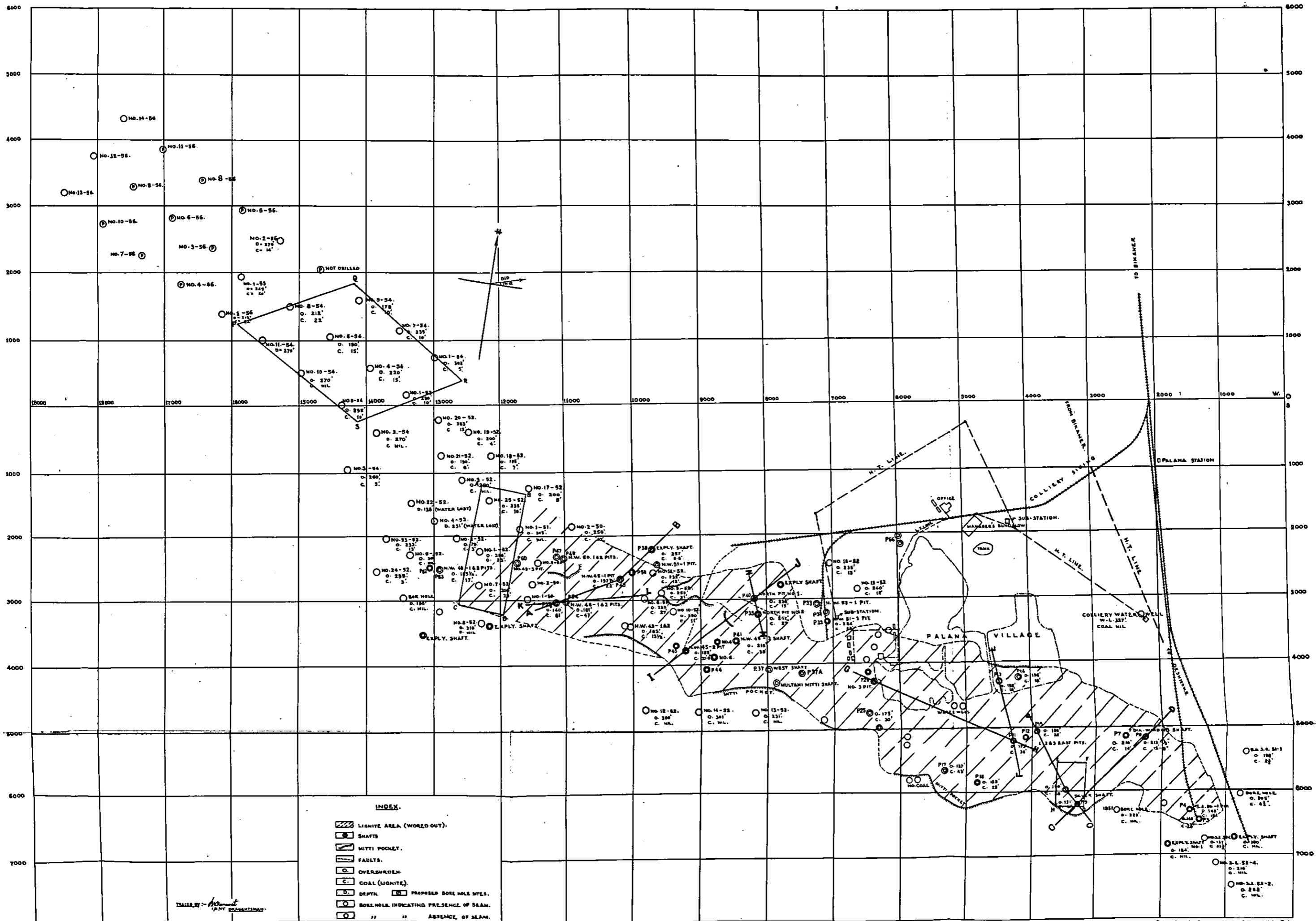
1	2	3	4	5
39	54—11		No Coal	
40	54—8	212'	22'	
41	N.W. 56—1	212'	22'	
42	N.W. 55—1	245'	20'	
43	N.W. 56—2	270'	10'	
44	56—3	260'	8'	
45	56—4	221'	17'	
46	56—5	285'	7'	
47	54—6	296'	8½'	
48	56—7	252'	18'	
49	56—8	270'	6'	
50	56—9	265'	10'	
51	56—10	245'	24'	
52	56—11	256'	5'	
53	56—12	215'	16'	
54	56—13	184'	26'	
55	56—14	208'	20'	
56	56—15	209'	12'	
57	56—16	199'	20'	
58	56—17		No Coal	
59	56—18	265'	8'	
60	57—1		No Coal	
61	57—2	255'	7'	
62	57—3		No Coal	
63	57—8		No Coal	
64	57—9		No Coal	
65	57—10		No Coal	
66	57—11		No Coal	
67	57—12		No Coal	
68	57—13		No Coal	
69	57—14		No Coal	
70	57—15		No Coal	
71	57—16		No Coal	
72	57—17		No Coal	
73	57—18		No Coal	
74	57—19		No Coal	
75	57—20		No Coal	
76	57—21	243'	4'	
77	57—22		No Coal	
78	57—23		No Coal	
79	57—24		No Coal	
80	57—25		No Coal	

1	2	3	4	5
81	57—26	201'	5'	
82	58—1	246'	2'	
83	58—2	235'	6'	
84	58—3		No Coal	
85	58—4	185'	15'	
86	58—5	257'	3'	
87	58—6	275'	8'	
88	58—7	190'	16'	
89	58—8	235'	5'	
90	58—9		No Coal	
91	58—10		No Coal	
92	58—11	195'	12'	
93	58—12		No Coal	

SURFACE PLAN OF PALANA COLLIERY

SCALE 600=1"

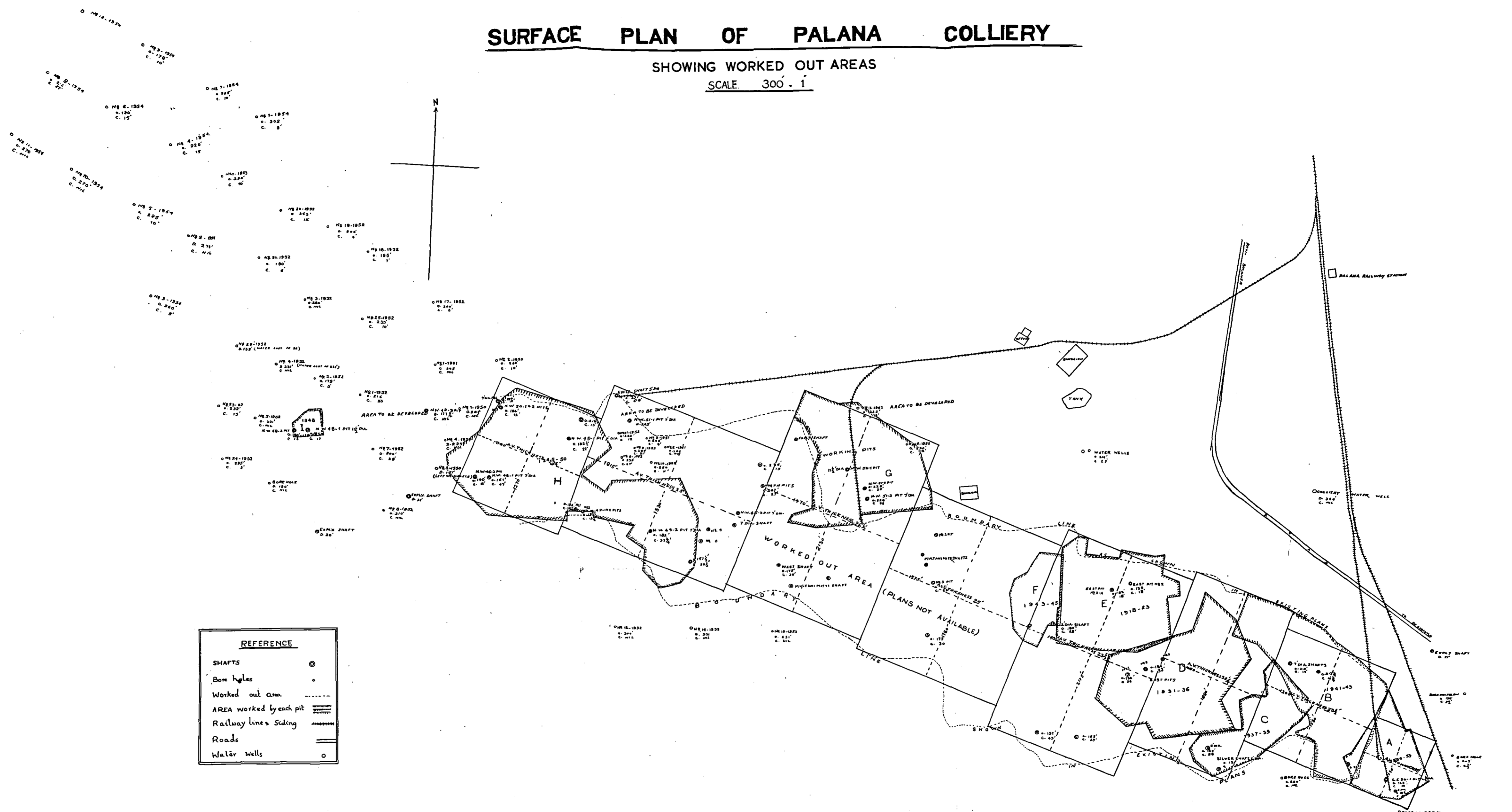
PLATE 1.



SURFACE PLAN OF PALANA COLLIERY

SHOWING WORKED OUT AREAS

SCALE 300 = 1



REFERENCE	
SHAFTS	⊙
Bore holes	○
Worked out area	-----
AREA worked by each pit	=====
Railway lines Siding	=====
Roads	=====
Water wells	○

YEAR OF WORKING	AREA	TOTAL TONNAGE	TONNAGE EXTRACTED	TONNAGE LEFT BEHIND	PERCENTAGE OF EXTRACTION	OCCURRENCE OF FIRE	CAUSE OF ABANDONMENT OF MINE	REMARKS
1950 - 1953	A	123,000	46,439	76,561	37.76	SEVERAL FIRES	MINE WORKED OUT ACCORDING TO PREVALENT PRACTICE.	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1941 - 1943	B	102,072	1,33,229	88,749	13.05	NO RECORD OF OCCURRENCE OF FIRES	REASONS FOR OCCURRENCE OF FIRES: (1) RAILWAY LINE HAS BEEN SHUT DOWN SINCE 1943 (2) DAMAGE TO SUPPORTS CAUSED BY COLLAPSE OF C IN NEAREST AREA CAUSED 1943-44	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1937 - 1939	C	48,542	10,680	37,862	22.40	YES	FIRE AND COLLAPSE	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1931 - 1936	D	1,61,675	2,11,700	14,687	13.00	TWO FIRES AFFECTED AREA	FIRE	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1918 - 1923	E	1,42,670	92,800	1,33,870	6.50	FIRE AT SHAFT BOTTOM	(1) COLLAPSE OF ROAD WAY (2) SUBSIDENCE OF VILLAGE ON SURFACE	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1913 - 1915	F	4,10,933	92,517	3,17,416	22.50	NO RECORD OF OCCURRENCE OF FIRES	FIRE OCCURRED AT SHAFT BOTTOM	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1911 (DURHAM WORKING)	G	5,46,993	67,020	5,89,167	10.30 (100% = 86)	FIRE OCCURRED AT SHAFT BOTTOM	FIRE OCCURRED AT SHAFT BOTTOM	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1945 - 1950	H	1,77,976	2,68,807	17,091	15.60	FIRE OCCURRED AT SHAFT BOTTOM	ENCOUNTERING PITTS & ROCKS	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
1948	I	47,432	470	46,962	0.99	FIRE OCCURRED AT SHAFT BOTTOM	ENCOUNTERING PITTS & ROCKS	(1) SH. ONLY PRESENT (2) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE (3) SEVERAL SH. ONLY PRESENT & ABOVE 100 YDS. NOT BEING DEVELOPED UNLESS POSSIBLE
		14,03,841	1,45,252	12,58,589	12.80			
		1,45,252	1,45,252	0	100.00			
		16,20,833	1,60,504	15,04,329	9.89			

Map No. 4008 ME57-251.

Revised to full from the original supplied by the Director of Mines and Geology, Jaipur.