

GOVERNMENT OF RAJASTHAN.
DEPARTMENT OF MINES & GEOLOGY, UDAIPUR.



A REPORT ON THE INVESTIGATIONS
FOR
LIMESTONE AT CHITTORGARH

BY

M. L. SETHI
AND
A. C. MITTER

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**REPORT ON THE INVESTIGATION OF LIMESTONE
DEPOSITS OF CHITTORGARH.**

INTRODUCTION.

A detailed study of the limestone deposit near Chittorgarh for ascertaining their reserve and quality was undertaken by the Department of Mines and Geology, Government of Rajasthan. The work started in December, 1954 and consisted of mapping, core drilling, collection of representative samples and their analyses. The former Rajasthan State had entrusted this study to a private prospecting agency in 1948. Though it reported⁽¹⁾ existence of a large limestone deposit in the area but could not carry out detailed work owing to non-availability of any drilling equipment and facilities for detailed sampling and analytical work. This area has also later been reported upon by a geologist of the Geological Survey of India.⁽²⁾

The departmental prospecting operations, therefore, consisted of checking through the geological map prepared on a scale of 1000' : 1" by the prospecting agency referred above and on the basis of a study of surface geology sites for drill holes were selected by a field party. During 1955-56 only three drill holes could be completed to a depth of 105', 60' and 30' respectively. The drills employed were calyx type, worn out and old so could not attain much speed. Later two diamond core drills were acquired and engaged for this purpose and since July, 1956, thirteen drill holes as shown in the map have been completed. Almost all of them have given from 85% to 90% core recovery.

The limestone bearing area is located between the latitudes 24°45' to 24°55' and the longitudes 74°35' to 74°45' and covers nearly 17 square miles. The formations continue beyond this trip in the tehsil of Nimbahera also. It is approached conveniently from the Chittorgarh railway station on the Ratlam-Ajmer Section of the Western Railway. A metalled road connecting Ajmer-Ratlam passes through this area.

(1) By late Shri M. M. Dhar "Report on Preliminary Examination of limestone Deposits of Chittor area, Mewar State, Rajputana and possibilities of manufacturing Cement therefrom (unpublished).

(2) By Shri C. Karuna Karan "Investigation of limestone near Chittorgarh, Udaipur State, Rajasthan".

CHAPTER I

Physical Features :

The country side around Chittorgarh presents an undulating stretch of plains with no eminence of magnitude and is confined within the contour level of 1300' to 1400' above the sea-level, there being a gradual rise of level from the west and south towards east and the north. The historic Chittorgarh fort stands up prominently as a bold and solitary hill mass 500' above the country at its base and 1950' above sea level. From the north to the south it covers nearly $3\frac{1}{2}$ square miles. Close to it separated by a saddle 150 yards in length a small round hillock known as Chittori (a diminutive of Chittorgarh) is present towards the south. It is about 150' lower in elevation than the main Chittorgarh hill. About three miles east wards the view is arrested by a long and lofty range of hills and valleys stretching as far as the Chambal river.

Drainage :

The rivers Gambhiri and Berach with their tributaries provide the main drainage of the area, although in its north-easterly course the Berach ultimately absorbs the river Gambhiri, their confluence point being about a mile north of the Chittorgarh hill. The river Gambhiri with her northerly flow maintains its separate existence over this short distance and forms the main drainage of the country lying on the south and the east of Chittorgarh. These rivers are shallow in most places and during the cold and dry months they are fordable but during rains their voluminous flow with high embankments presents a different sight. An earthen dam has been constructed across the Gambhiri river about 12 miles south of Chittorgarh near Mothan and Arnia villages. The storage capacity of the reservoir at full tank level is 3850 million cubic feet. Average depth of water in the same is 17'. It is expected to irrigate about 34000 acres of land which would consume about 3400 million cubic feet of water. Allowing for the dead storage below sluice level for 390 million cubic feet nearly 112 million cubic feet will be available for industrial purposes. Two canals 20 miles in length have already been completed, one of them is passing close to Senthil village. The canal water supply would readily be available to the cement industry or any other industry located near Chittorgarh railway station.

Forest and Vegetation :

On the slopes and the base of the Chittorgarh hill and from Chittorgarh to Shambhupura a thin forest of 'babul' (*Acacia arabica*) and 'palas' (*Beautea frondosa*) is observed mostly in places which are not far from the Gambhiri river. Sharipha (*Annona squamosa*) almost grows wild on the fort. Uncultivated soil covered lands support a very scrubby growth besides cactus bushes, spear grasses etc. Where the soil mantle is thick usually good cultivation is carried out by well irrigation. Millets, pulses, oil seeds, cotton, wheat and barley are generally grown there.

Rainfall and Climate :

This part of the country receives a fair amount of rainfall averaging about 40" annually, mostly from the south-western monsoon during the months of July to September.

The climate of the locality is dry and extreme. Drinking water obtained from wells is generally good.

Inhabitants and Labour :

Existence of numerous stone quarries in the area has helped to produce a fairly large community of quarry workers. As far as unskilled labour is concerned it is available in plenty. The people are hardy and intelligent and are well adapted to hard manual work. The Bhils residing in the hilly areas would form good source for labour supply.

CHAPTER II

Geology, Mode of occurrence & Description of Deposits :

General geology of this region has been mapped and studied by Dr. A.M.Heron (1) of the Geological Survey of India. The geological formations have been classified by him and have been further studied in detail. The sequence of the geological formations as indicated here is given below :—

Kaimur Sandstone	}	Vindhyan system.
Suket Shales		
Nimbahera Limestone		
Nimbahera Shales		
<hr/>		
Bundelkhand Gneiss		

The limestone formation around Chittorgarh, therefore, is of the Vindhyan age and belongs to the Nimbahera stage. It rests conformably on the Nimbahera shales and assumes an average thickness of about 500' in the locality. The limestone is generally seen outcropping though it does not rise more than a few feet above the plain. Narrow anticlinal and synclinal foldings are observed in this formation with dips varying from practically horizontal to as high as 82° angle, the average being between 30° to 40° with a general N.NE.-S.SW. to N.S. strike.

The limestone rock is usually pale bluish to greenish gray in colour with occasional layers of brown, pink, and red. It is fine grained and non-crystalline and is hard, smooth and compact, and fairly thick bedded, the layers generally being a foot or two in thickness. Their jointing is regular. The joint planes generally run N-20° W and N-80°-E. It is this feature of the limestone which has helped in the establishment of flagstone quarries near Bhenra, Manpura, Senthil and Sawa. It is possible to obtain in many places slabs 2 to 3 yards square and about 9" or less in thickness (photo No.1 and 2). At Bhenra, there are 45 working quarries varying in length from 25' to 100'. Their depth vary from 20' to 50' (photo No. 3). Similarly there are 39, 46, 15 and 6 working quarries at Manpura, Senthil, Sawa and Sagwa respectively. Limestone as a flagstone has been quarried here for more than a century and both roofing slabs and floor tiles are supplied to the building industry. These quarries are located at a distance of about 5 to 6 miles from the Chittorgarh railway station and can be approached by a cart track only (photo 4, 5, 6).

The overlying Suket shales are seen exposed close to the Nimbahera limestone, They rest conformably on the same. A gradual upward passage from the limestone to the shale is marked by the calcareous nature of the lower shale beds. They are usually hard, siliceous, and micaceous and yield pinkish flagstones. The upper beds of the shale are soft, fissile and fragile of varying colours-purple, grey, buff, greenish blue, chocolate to almost black. Ripple marking is commonly present along with a well developed jointing running north-south and east-west direction. These Suket shales appear to have formed elongated narrow syncline in the limestone. The dip of these beds as observed is generally low striking north-south.

Overlying the Suket shales is the Kaimur sandstone, the passage being without discordance. It is a hard and weather resistant rock which gives rise to bold topography. It is this formation on which the Chittorgarh fort stands prominently. Boulders from the same are strewn all over covering the outcrops of the Suket shales.

No exposure of older formations viz. the Aravallis, Raialos etc., is seen in the locality. The succession of development in this region is as follows :—

Kaimur Sandstone	100;250'	
Suket Shales :—		
Fawn	}	400'
Purple		
Greenish-Blue		

(1) Memoir Volume LXVIII Pt. I by Dr. A M. Heron of G.S.I.

Nimbahera grey limestone	450'
Nimbahera purple limestone	30'
Nimbahera shales(purple)	150'

On the north-western corner of the locality beyond the western bank of the Berach river, Bundelkhand gneiss can however, be seen. This abuts directly against the Vindhyan formation due to the presence of the great "boundary fault" running north-east south-west. These gneisses are usually soft and crumbling and are buried under a thick mantle of soil mostly derived from the disintegration of the gneiss itself.

Structure & Tectonics:

Excepting some local disturbances, the shales, limestone and the sandstone strata belonging to the Vindhyan series, show very little major structural displacement or disturbance of their primaevial characters. The rocks show no evidence of metamorphism, as is expected from their age, beyond induration or compacting. The shales have not developed cleavage nor have the limestones undergone any degree of crystallisation.

The marked minor structural disturbances are mostly seen on the northern most area, where the Vindhyan strata have been affected by folding and minor faulting due probably to the great boundary fault to the west and north-west of the area. All the strata are folded in the same way, in narrow synclines and anticlines with more or less north and south axis. Variation of dips, both in amount and direction, and the well marked dragging effect of the strata, as can be seen in geological map of area No.1, are probably due to faults for which no other evidence could be noticed in the field. Though generally the dips of all the strata are found to be low, varying from 30° to almost horizontal, in certain localities they are found to dip at a very high angle, almost vertically, probably due to local faults.

Probable Origin of the Deposit:

As described above the rocks, therefore, are of sedimentary origin and were deposited during the Vindhyan times. The Vindhyan system of the Indian geology is developed principally in the central Indian high lands which form the dividing ridge between north India and the Deccan and is known as the Vindhyan mountains. They represent a vast stratified formation of sandstone, shales, limestones. Almost from Sasaram to Rohtas in western Bihar right upto Chittorgarh in Rajasthan they occupy a large extent of the country covering more than 40,000 square miles with the exception of a central tract in Bundelkhand. The formations have their maximum breadth between Agra and Neemuch.

CHAPTER III

Details about the departmental prospecting operations.

A detailed study of the surface geology was carried out with the help of a 1000' to 1" scale map. The bore hole sites were then selected by the department's field party near the following villages :—

1. Manpura 2. Bhoikhera 3. Kirkhera 4. Near Chittorgarh fort 5. Bhilonka-khera 6. Chamthia-khera I 7. Chamthia-khera II 8. Segwa I 9. Segwa II 10. Senth.

These bore holes were completed to a depth of 100' each. The location of the bore holes is indicated on the plan (appendix 1 & 2). It was considered that drilling up to 100' depth would be sufficient to indicate both the quality and the reserves of the limestone. It does not, however, mean that the extent of limestone is just 100' in depth.

but in all the holes the limestone formation continues further deeper. Core recovery hole by hole is indicated in appendix 3 and for the purposes of these investigations it is considered to be very good. The cores obtained were sampled at every foot interval. Where marked homogeneity was noted, the representative sample was drawn on a 10' interval. Complete analyses of about 500 samples have been carried out in the department's laboratory and check analyses numbering about 100 have also been carried out with independent firms of analysts. The results obtained are appended (Appendix 4).

The lime content of limestone (calcium oxide) generally varies between 42.25% to 47.16%. The magnesia content is fairly low. Similarly the silica, iron and alumina contents as reported are also within the limits laid down for cement grade limestone.

Three bore holes were specially located to determine the extent of the limestone towards the fringe of the deposit where it merges with the shale formation.

Extent:

On the basis of the work done the limestone zone near Chittorgarh can be divided into three areas :—

1. Comprising of area close to Manpura, Bhenra, Bhoikhera and Kirkhera, measuring 5.76 square miles.
2. Comprising of area close to Senth, Segwa, Ochri, Chamthia-khera, Bhilonka-khera and near Chittorgarh fort, measuring 3.3 sq.miles.
3. Shambhupura area measuring 8 square miles i.e. a total of 17.06 square miles.

In the north, the limestone band extends upto Baldarkha village, six miles NNE of Bhenra village and towards the south it continues upto Kesarpura railway station in the State of Madhya Pradesh. On the east the formation passes close to Damdama, Manpura, Chittorgarh railway station. On the west it passes close to Bhenra, Bhoikhera, and the Chittorgarh Dak Bungalow.

Areas numbering 1 and 2 above, where core drilling has been done are near to the main railway station. The analyses of the average surface sample show comparatively a high calcium content and the quantity as estimated, on the basis of the drilling data, appears to be inexhaustable. They can supply a large size cement plant for decades to come.

As a result of these investigations it was found unnecessary to take up further detailed work in Shambhupura area which is rather away from Chittorgarh railway station.

Reserve of Limesone:

Area No.1 Three bore holes close to villages Manpura, Bhenra, Bhoikhera were placed to indicate their quality and extent.

(a) Near Manpura-Bhenra villages which are three to four miles north-east of Chittorgarh railway station the limestone bands have been found exposed over 3500' in breadth and almost the same distance along the length. The bore hole which was placed in this area to a depth of 110' gave a core recovery of 85%. Considering about 15 cubic feet of limestone equivalent to a ton, reserves estimated here amount to 80 million tons with an average calcium oxide content of 44.51%.

(b) Close to Bhoikhera which is about 2½ miles north-east of Chittorgarh railway station, the second bore hole was located. Here the area of exposed limestone measures 2500'x800'. The bore hole drilled to a depth of 100' gave a very high core recovery of 95% with an average calcium oxide content of 47.16%. Reserves on calculation in the area amount to 15 million tons.

(c) Close to Kirkhera, about $1\frac{1}{2}$ miles north-east of Chittorgarh railway station where the third bore hole was located, exposed limestone is marked over $1000' \times 1000'$ stretch with the bore hole depth of 100'. With 95% of core recovery it shows about 8 million tons of reserve with an average CaO content of about 42.25%.

Thus nearly 103 million tons of good quality limestone is available in area No.1 described above.

Area No.2. The reserves of this area likewise have also been calculated.

The four bore holes located in this area near fort (Chittorgarh), Bhilon-ka-khera and Chamthiakhera indicate a total of about 100 million tons of reserves. The core recovery in the first hole close to the fort being 90% the average calcium oxide content was analysed to be 46.69%. It was measured that limestone exposures in this area extend over a length of nearly 11000' and continue further southwards beyond the zone of the present study. The width exposed averages 1500'. Towards the west of this limestone band separated by a 6000' stretch of Suket Shales another parallel band of limestone appears close to Senth and Segwa villages where three bore holes were located. Here 42.25% calcium oxide was indicated in the hole close to Senth village giving nearly 85% core recovery and two bore holes close to Segwa village gave nearly 90% core recovery with about 42% calcium oxide content. This area, therefore, also carries more than 140 million tons.

The three bore holes near Ochri, Mitharamji-ka-khera and near Triveni indicated that the limestone bands slowly pass into Suket shales.

CHAPTER IV

Considerations for Cement Manufacture.

Considering the large reserves of limestone available at Chittorgarh of a requisite quality, this place appears to be suitable for establishing a cement manufacturing industry. Portland cement is a product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicate to which no additions have been made subsequent to calcination other than gypsum or water or both. It derives its name from the fact that it resembles in colour to a stone that is obtained from Portland, England. The Portland cements are made by calcining to vitrification an intimate mixture of calcareous and argillaceous minerals i.e. $\text{CaO} + \text{Al}_2\text{O}_3 + \text{SiO}_2$. The resulting product does not slake when water is added. After calcination it is ground and the resulting powder hydrates to form a hard mass in presence of water. The Portland cement according to A.S.T.M.C-150-52 is of five types:—

- Type I. For use in general concrete construction where the special properties of other types are not required.
- Type II. For use in general concrete construction exposed to moderate sulphate action on where moderate heat of hydration is required.
- Type III. For use when high early strength is required.
- Type IV. For use when a low heat of hydration is required.
- Type V. For use when high sulphate resistance is required.

In Portland cements there is a mixture of compounds viz. dicalcium silicate, tricalcium silicate, tricalcium aluminate and tetra calcium aluminoferrite are present in amounts partly dependent on the degree of attainment of equilibrium conditions during

calcination. MgO if present is in free state. The most important of these compounds is tricalcium silicate and the more of this if present would be better although other compounds also have hydraulic value. Given below are analyses of various types of portland cements.

		<i>Cement Regular</i>	<i>High early strength</i>	<i>Low heat of setting.</i>
CaO	Min.	61.17	62.7	59.3
	Max.	66.92	67.5	61.5
	Ave.	63.85	64.6	60.2
SiO ₂	Min.	18.58	18.0	21.9
	Max.	23.26	22.9	26.4
	Ave.	21.08	19.9	23.8
Al ₂ O ₃	Min.	3.86	4.1	3.3
	Max.	7.44	7.5	5.4
	Ave.	5.79	6.0	4.9
Fe ₂ O ₃	Min.	1.53	1.7	1.9
	Max.	6.18	4.2	5.7
	Ave.	2.86	2.6	4.9
MgO	Min.	0.60	..	..
	Max.	5.24	..	..
	Ave.	2.47	..	..

In the regular Portland cement there is on average 51.7% tricalcium silicate, 21.4 % dicalcium silicate, 10.5% tricalcium aluminate, 8.7% tetra calcium aluminoferrite, 2.9% calcium sulphate and 2.47% MgO. High early strength cement contains larger amount of tricalcium silicate while low heat of setting cement is high in dicalcium silicate and tetra calcium aluminoferrite but low in tricalcium silicate and tricalcium aluminate.

Raw meal for Portland cement contains about 75% CaCO₃, 20% SiO₂+Al₂O₃+Fe₂O₃ and remaining 5% impurities such as magnesia and alkalis, Raw meal of limestone containing higher percentage of CaCO₃ but with low contents of silica and alumina needs the addition of shale or clay in the mixture to approximate to the composition given above.

I. S. Specification for ordinary, rapid hardening and low heat Portland cement (I.S.269-/951) lays down certain chemical requirements which are summarised below :-

(1) Cementation Index

$$\frac{\text{CaO}}{2.8 \text{ SiO}_2 + 1.2 \text{ Al}_2\text{O}_3 + 0.65 \text{ Fe}_2\text{O}_3}$$

should not be less than 0.66 nor greater than 1.02.

2. Iron modulus $\frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3}$ should not be less than 0.66.
3. Magnesia content 5% (maximum).
4. Sulphur content SO₃ not to exceed 2.75%
5. Loss in Ignition 4% (maximum).

The requirements enumerated above relate to the final product, i.e. cement which is prepared by calcination of calcareous and argillaceous materials. Chittorgarh limestone when properly mixed with argillaceous material i.e. clay or shale on calcination will yield a product which will meet these specifications.

Given below are the results of chemical analysis of limestone deposits at Phalodi in Sawai Madhopur district and at Lakheri in Bundi district along with that of one typical sample of Chittorgarh limestone deposit:—

Phalodi limestone		Lakheri limestone	Chittorgarh limestone (Manpura)
SiO ₂	9.34	15.96	9.82
Fe ₂ O ₃	1.03	3.50	1.98
Al ₂ O ₃	2.01		
CaO	45.35	42.89	47.88
MgO	3.02	1.56	0.22
Loss on Ignition	38.77	35.28	38.76

Thus it will be seen that Chittorgarh limestone fares very well and is eminently suitable for use in cement manufacture.

At Chittorgarh the Nimbahera Shale which is occurring at about 3/4th of a mile distance will be suitable to use as an argillaceous material. These shales are more aluminous than the sukhet shales and so their mixing in the raw meal would be preferable. It would obviously displace use of bauxite to some extent for this purpose. It can be easily obtained by removing the thin soil overburden. Near Sawa village there is another good occurrence of highly aluminous clay about 1½ miles north of the village. Analysis of the same carried out by the Geological Survey of India laboratory ⁽¹⁾ is given below:—

SiO ₂	40.50
Al ₂ O ₃	35.69
Fe ₂ O ₃	1.02
TiO ₂	7.41
H ₂ O (combined)	13.34
Moisture	2.66
MgO	Nil
CaO	Nil
TOTAL	100.62

Nimbahera shales constitute the lowest shales of the Vindhyan system of the area and according to Dr. Heron they assume a thickness of about 150' in this locality. They give rise to no surface feature and mostly underlie a thick mantle of soil.

From the cement manufacture's point of view the selection of a site for cement factory requires many considerations. At Chittorgarh any site lying between Chittorgarh railway station and the Gambhiri river would meet many of these demands. This place will have easy accessibility to raw materials. From the point of view of topography, climate, labour and transport facilities it appears to be an ideally located. This area would also have access to hydro-electric power supply at the end of the Second Five Year Plan period. Further a canal linking the Gambhiri Dam with several villages around is just passing, very close to the railway station and sufficient water for industrial purposes is ensured. With regard to gypsum supply already Rajasthan is one of the biggest producers of this mineral in the States of India and no difficulty with regard to its supply is anticipated. As regards coal like other cement factories located at Sawai Madhopur and at Lakheri the same will have to be obtained from Bihar coal fields.

(1) Memoir G. S. I. Vol. LXVIII Part 1 Page 115.

Conclusion:

The present investigations lead to the following conclusions:--

- A.(i) In the Chittorgarh limestone zone three distinct areas exist from the view point of suitable reserves for quality material for cement making. The first area is the one located close to Manpura, Bhera Bhokhera and Kirkhera. It carries a reserve of 103 million tons and extends further to several miles in length beyond the present zone of study. It shows an average grade of limestone carrying nearly 44.5% to 47% calcium oxide.
- (ii) The second area is the one lying close to the Chittorgarh fort, Bhilon-ka Khera and Chamthikhera, which carries a reserve of nearly 100 million tons. The average grade of limestone reported here varies from 43.11% to 46.69% calcium oxide.
- (iii) The third area is near Senth and Segwa, carrying nearly 140 million tons of limestone reserve. Average lime content reported here is 42%.

B. Obviously the area numbering 1 and 2 carry a huge reserve of high grade limestone which can supply all the demand for any cement industry.

C. These areas are suitable also because they are located quite close to Chittorgarh railway station being only about 3 to 4 miles away.

D. The limestone bands can be quarried by opencast mining methods. Their physical characteristic would lend to easy drilling, blasting and loading by shovels for a large scale output.

E. From the market point of view this place enjoys an unique position as there is no other cement plant within a 300 miles radius.

F. The area would have access to plentiful supply of labour.

G. It will be possible to obtain the required quantity of industrial water supply from the Gambhiri river dam through its canal which passes close to Senth village.

H. The Chambal Hydro-electric grid line of 132 K.V. from Gandhi Sagar Dam would be passing through Neemuch within the Second Five Year Plan and, therefore, cheaper electric power supply can be available in this region within the next five years.

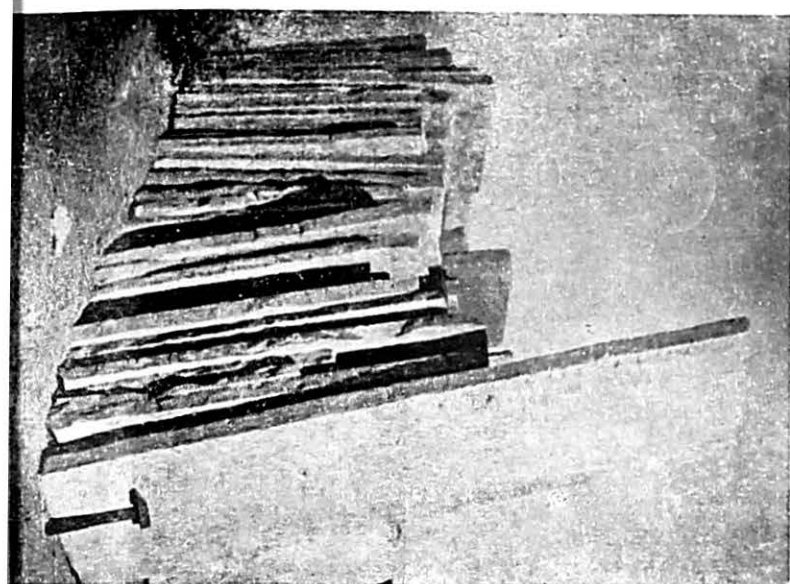
The area is suitable thus from the view point of raw material supply, industrial water and power supply and from the point of view of transportation and market demand it appears to be an ideal one.

Acknowledgment:

Authors are thankful for assistance received from the various members of the staff particularly Shri P.D. Swami, Chemist-cum-Ceramic Technologist, Shri Y. N. Dave Senior Geologist, Shri O.L. Joshi Mining Engineer, Udaipur; Shri A. Roy the then Asstt. Mining Engineer (Headquarters), and Mines Foreman, Chittorgarh; for their co-operation in the execution of the work. Thanks are also due to Shri Bhagwan Dass, Superintending Engineer, Water Works, Udaipur, for providing information with regard to dam and water supply possibility from its canals.

Authors feel that the initial work carried out by late Shri M.M. Dhar has been valuable in conducting the present investigation at Chittorgarh.

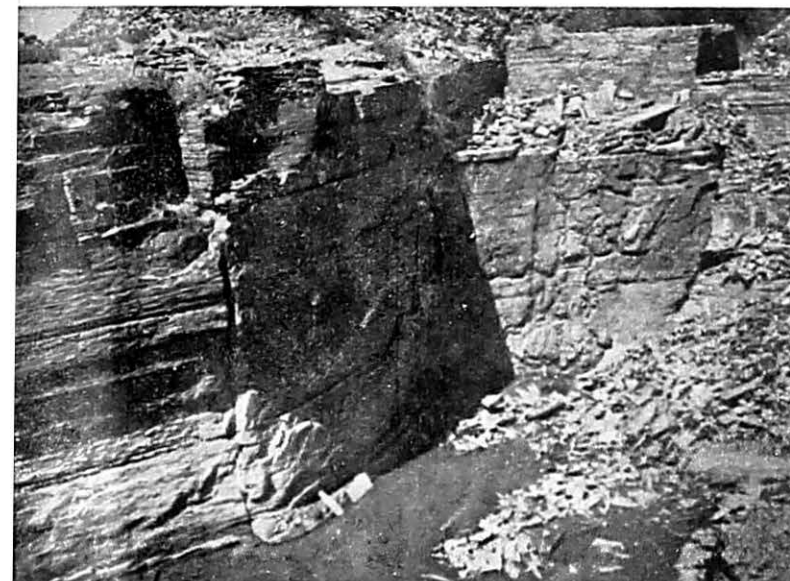
APPENDIX I



Large slabs of Chittorgarh limestone.



Large and thick slabs moved by crowbars.



A quarry showing its depth and thickness of strata



Method of cutting limestone slabs.



Separating cut slabs from a quarry.



Carting limestone from the quarry.

APPENDIX (i)

TABLE SHOWING BORE HOLE DETAILS.

<i>Bore hole No.</i>	<i>Name</i>	<i>Co-ordinate.</i>	<i>Description</i>	<i>Depth of drill hole.</i>	<i>Core recovery.</i>	<i>Average CaO content.</i>
Area No. 1.						
1.	Manpura.	(38, 25)	It is situated at a distance of 1500 ft. NE of Manpura quarries	100'	85%	44.51%
2.	Bhoikheda	(25, 25)	It is located about 500' west of Bhoikhera	100'	95%	47.16%
3.	Kirkhera	(16, 18)	It is situated 500' SW of Kirkhera village	133'-5"	95%	42.25%
Area No. 2.						
4.	Near Chittorgarh fort.	(21.5,31)	It is located about 2500' SSW of Chittorgarh Town	100'	90%	46.69%
5.	Bhilon-ka-Kheda	(22, 26)	It is located at about 4000' ESE of Chittorgarh Rly. Stn.	100'	80%	40.95%
6.	Chamthia-ka-Khera I	(21, 17)	It is located at a distance of about 1000' SE of Chamthia-ka-Khera village	100'	80%	43.56%
7.	Chamthia-ka-Khera II	(21, 12)	It is located at a distance of about 3300' SSE of Chamthia-ka-Khera village and 2500' south of Chamthia-ka-Khera No. 1	100'	80%	42.66%
8.	Segwa I	(4, 9)	It is situated 3300' NNE of Segwa village	100'	90%	43.37%
9.	Segwa II	(4, 15)	It is situated at a distance of 3000' north of Segwa No. 1 and 3000' SSW of Senthii village	100'	80%	40.31%
10.	Senthii	(5, 20)	It is situated at a distance of 500' SW of Senthii village	100'	85%	42.25%

APPENDIX (ii)

ANALYTICAL RESULTS.

BORE HOLE NO. I.

Manpura.

Depth	SiO ₂	Al ₂ O ₃ Ti O ₂	Fe ₂ O ₃	CaO	MgO	L. I.	Ca CO ₃	Mg CO ₃
1 ft.	..	..	..	50.12	..	..	89.53	..
2 ft.	..	..	..	49.29	..	..	88.02	..
3 ft.	..	..	..	49.56	..	..	88.52	..
4 ft.	..	..	..	49.84	..	..	89.02	..
5 ft.	..	..	..	49.43	..	..	88.26	..
6 ft.	..	..	..	45.92	..	..	82.01	..
7 ft.	..	..	..	45.51	..	..	81.20	..
8 ft.	..	..	..	44.24	..	..	80.25	..
10 ft.	9.82	1.98	..	47.88	0.22	38.76	..	..
12 ft.	..	..	..	50.40	..	..	90.02	..
13 ft.	..	..	..	47.88	..	..	85.51	..
14 ft.	..	..	..	46.90	..	..	82.51	..
15 ft.	..	..	..	46.48	..	..	81.02	..
16 ft.	..	..	..	45.36	..	..	81.01	..
17 ft.	..	..	..	40.88	..	..	72.98	..
18 ft.	..	..	..	40.60	..	..	74.46	..
19 ft.	..	..	..	41.72	..	..	74.51	..
20 ft.	9.62	1.76	..	43.32	1.02	39.78	..	..
21 ft.	..	..	..	51.52	..	..	91.97	..
22 ft.	..	..	..	50.96	..	..	91.01	..
23 ft.	..	..	..	50.28	..	..	90.52	..
24 ft.	..	..	..	46.76	..	..	83.51	..
25 ft.	..	..	..	46.88	..	..	83.76	..
27 ft.	..	..	..	42.04	..	..	74.02	..
28 ft.	..	..	..	50.96	..	..	91.01	..
29 ft.	..	..	..	48.44	..	..	86.52	..
30 ft.	11.32	0.92	..	48.44	0.41	38.86	86.52	0.86
31 ft.	..	..	..	48.16	..	..	86.02	..
32 ft.	..	..	..	42.16	..	..	74.26	..
40 ft.	13.48	0.96	..	47.04	0.39	37.66	84.04	0.82
60 ft.	17.46	0.96	..	44.24	0.33	35.98	79.05	0.69
70 ft.	10.64	0.84	..	47.08	0.54	39.92	84.02	1.13
80 ft.	20.70	1.82	..	41.76	0.94	34.34	74.54	1.97
90 ft.	20.84	2.18	..	41.16	0.88	38.86	73.51	1.85
100 ft.	24.38	1.64	..	38.92	6.96	32.68	69.52	2.2

BORE HOLE NO. 2.

Bhoikhera.

1 ft.	..	..	..	43.74	..	..	78.11	..
2 ft.	..	..	..	40.66	..	..	72.61	..
22 ft.	..	..	..	47.30	..	..	84.62	..
23 ft.	..	..	..	52.43	..	..	93.62	..
24 ft.	..	..	..	51.87	..	..	92.62	..
25 ft.	..	..	..	45.42	..	..	81.11	..
30 ft.	6.84	1.16	..	51.17	0.42	40.41	91.38	0.88
40 ft.	19.58	4.48	..	41.64	0.72	33.51	74.36	1.51
50 ft.	11.05	1.78	..	48.79	0.30	38.16	87.13	0.63
60 ft.	7.77	1.48	..	50.47	0.82	40.46	90.13	1.72
70 ft.	14.16	2.42	..	44.58	1.28	36.44	79.61	2.69
80 ft.	9.24	0.96	..	48.23	1.66	39.07	86.16	2.23
90 ft.	..	..	..	47.01	..	..	..	..
100 ft.	13.10	5.40	..	45.71	0.09	35.54	81.62	0.18

BORE HOLE NO. 3.

Kirkheda.

3 ft.	8.56	5.04	..	47.50	0.60	38.14	85.03	1.30
6 ft.	14.92	1.38	..	46.20	0.90	36.46	82.50	1.89
7 ft.	..	..	..	41.16	..	..	73.50	..
8 ft.	14.32	1.32	..	45.04	1.18	37.68	80.43	2.48
10 ft.	19.38	2.08	..	43.12	1.39	34.03	77.00	1.05
11 ft.	..	..	..	49.00	..	..	87.50	..

Depth.	SiO ₂	Al ₂ O ₃ Fe ₂ O ₃ TiO ₂	CaO	MgO	L.I.	CaCO ₃	MgCO ₃
12 ft.	12.70	6.76	44.76	0.33	35.47	79.93	0.69
13 ft.	17.46	4.53	42.44	1.12	33.56	75.80	2.35
17 ft.	11.49	1.76	47.08	0.90	37.82	84.07	1.93
18 ft.	19.50	2.74	41.43	1.00	34.48	73.94	1.91
21 ft.	16.48	1.80	43.12	1.18	36.60	77.00	1.92
22 ft.	11.86	0.66	48.16	0.24	38.42	86.00	0.50
24 ft.	16.98	1.38	44.24	1.06	34.48	79.00	1.91
25 ft.	21.80	1.30	41.56	0.62	33.80	74.26	1.16
28 ft.	14.16	10.14	40.88	0.88	33.08	73.00	1.85
32 ft.	17.96	4.86	41.32	0.84	34.17	73.75	1.76
33 ft.	19.72	6.04	40.71	0.43	32.51	72.70	0.90
36 ft.	..	..	48.16	..	..	86.00	..
37 ft.	..	..	47.60	..	..	85.00	..
39 ft.	..	..	53.76	..	..	95.98	..
40 ft.	..	..	47.04	..	..	83.93	..
42 ft.	..	..	45.78	..	..	81.75	..
44 ft.	..	..	46.48	..	..	83.00	..
50 ft.	8.92	5.53	46.84	0.36	36.93	83.64	0.64
51 ft.	..	..	42.84	..	..	76.50	..
52 ft.	..	..	41.02	..	..	73.25	..
58 ft.	..	..	41.44	..	..	71.14	..
60 ft.	..	..	45.36	..	..	81.00	..
67 ft.	..	..	42.70	..	..	75.53	..
73 ft.	..	..	44.52	..	..	79.50	..
74 ft.	..	..	40.88	..	..	73.00	..
75 ft.	..	..	42.84	..	..	76.50	..
80 ft.	..	..	42.84	..	..	76.50	..
82 ft.	..	..	46.76	..	..	83.50	..
83 ft.	..	..	45.64	..	..	81.50	..
84 ft.	..	..	42.84	..	..	76.50	..
86 ft.	..	..	40.60	..	..	72.50	..
88 ft.	..	..	43.68	..	..	78.00	..
90 ft.	..	..	44.56	..	..	79.56	..
98 ft.	..	..	41.44	..	..	74.00	..
100 ft.	..	..	40.32	..	..	72.00	..
101 ft.	..	..	44.17	..	..	78.95	..
110 ft.	12.95	1.86	45.63	0.18	36.04	82.19	0.34
111 ft.	..	..	41.72	..	..	74.50	..
113 ft.	..	..	40.60	..	..	72.50	..
122 ft.	20.95	1.92	40.04	2.87	34.20	71.90	5.45
131 ft.	19.86	1.97	42.46	1.46	33.75	75.82	3.06

BORE HOLE No. 4.

Near Chittorgarh Fort

1 ft.	12.96	5.36	44.86	1.00	36.00	80.05	2.1
10 ft.	10.22	1.76	46.27	0.49	39.96	..	..
30 ft.	15.60	3.90	45.99	0.55	33.85	..	..
40 ft.	14.34	1.92	47.01	0.37	36.36	82.99	0.67
50 ft.	10.90	2.00	48.02	0.79	37.79	85.47	1.65
60 ft.	12.98	2.92	45.90	1.20	36.92	81.70	2.52
90 ft.	13.70	2.96	46.26	0.65	36.40	82.23	1.36
100 ft.	8.06	2.06	49.30	1.08	39.22	87.75	2.26

BORE HOLE No. 5.

Bhilon-ka-Kheda

3 ft.	..	..	42.07	..	..	75.31	..
12 ft.	..	..	45.98	..	..	82.10	..
20 ft.	..	..	43.18	..	..	..	..
31 ft.	..	..	46.82	..	..	..	..
32 ft.	..	..	44.31	..	..	..	..
34 ft.	..	..	43.44	..	..	77.60	..
40 ft.	..	..	45.36	..	..	..	..
70 ft.	34.10	1.20	35.30	0.90	27.76	63.10	1.89
100 ft.	22.20	1.20	42.07	0.80	33.05	75.12	1.68

BORE HOLE NO. 6.

Champsi-ka-Kheda No. 1

Depth.	SiO ₂	Al ₂ O ₃ Fe ₂ O ₃ TiO ₂	CaO	MgO	L.I.	Ca CO ₃	Mg CO ₃
1 ft.	43.68	..	..	..	..
2 ft.	40.88	..	..	..	..
4 ft.	45.08	..	..	..	..
5 ft.	4.48	..	..	..	..
6 ft.	44.52	..	..	..	..
7 ft.	48.44	..	..	..	..
8 ft.	44.24	..	..	..	..
9 ft.	48.72	..	..	..	..
10 ft.	11.35	0.81	48.78	0.32	38.68	87.11	0.67
11 ft.	47.32	..	..	..	..
13 ft.	44.80	..	..	..	..
14 ft.	41.72	..	..	..	..
15 ft.	43.78	..	..	..	..
20 ft.	9.50	1.48	49.11	0.71	39.36	87.69	1.49
21 ft.	46.48	..	..	..	..
22 ft.	41.72	..	..	..	..
23 ft.	41.44	..	..	..	..
25 ft.	45.36	..	..	..	..
26 ft.	45.92	..	..	..	..
27 ft.	45.92	..	..	..	..
28 ft.	45.64	..	..	..	..
29 ft.	42.00	..	..	..	..
30 ft.	45.36	..	..	..	..
31 ft.	46.20	..	..	..	..
34 ft.	46.27	..	..	..	..
35 ft.	42.84	..	..	..	..
36 ft.	44.52	..	..	..	..
38 ft.	44.20	..	..	..	..
40 ft.	49.08	..	..	..	..
49 ft.	48.79	..	..	80.50	..
52 ft.	54.60	..	..	87.12	..
53 ft.	46.76	..	..	..	..
54 ft.	46.20	..	..	..	..
56 ft.	51.24	..	..	..	..
57 ft.	48.16	..	..	..	..
59 ft.	47.32	..	..	..	..
60 ft.	9.40	1.16	49.32	1.09	39.95	88.07	2.29
61 ft.	43.40	..	..	..	..
62 ft.	40.32	..	..	..	..
63 ft.	40.32	..	..	..	..
64 ft.	42.84	..	..	..	..
65 ft.	47.60	..	..	..	..
67 ft.	42.56	..	..	..	..
69 ft.	48.39	..	..	..	..
70 ft.	43.40	..	..	..	..
71 ft.	44.24	..	..	77.50	..
72 ft.	44.52	..	..	..	..
73 ft.	43.12	..	..	..	..
74 ft.	43.12	..	..	..	..
76 ft.	43.40	..	..	..	..
77 ft.	43.40	..	..	..	..
79 ft.	42.00	..	..	..	..
80 ft.	10.77	1.62	48.40	1.03	39.15	86.42	2.66
89 ft.	49.00	..	..	..	..
90 ft.	40.32	..	..	..	..
93 ft.	43.40	..	..	..	..
100 ft.	44.24	..	..	79.00	..

Champsi-ka-Kheda No. 2

BORE HOLE No. 7

2 ft. 6"	..	..	40.88	..	..	72.98	..
3 ft. 6"	..	..	44.52	..	..	..	..
4 ft. 6"	..	..	45.64	..	..	..	..
5 ft. 6"	..	..	46.76	..	..	..	..
6 ft. 6"	..	..	43.68	..	..	..	..

Depth.	SiO ₂	Al ₂ O ₃ Fe ₂ O ₃ TiO ₂	CaO	MgO	L.I.	Ca CO ₃	Mg CO ₃
9 ft. 6"	..	..	45.92	..	..	..	..
10 ft.	20.46	1.17	43.16	0.16	34.09	77.07	0.34
11 ft.	..	..	42.00	..	..	..	..
15 ft.	..	..	41.72	..	..	..	..
20 ft.	13.01	1.30	47.60	0.46	38.15	85.04	0.97
21 ft.	..	..	45.36	..	..	..	..
29 ft.	..	..	40.88	..	..	..	..
30 ft.	16.44	2.53	44.84	0.77	36.08	80.07	1.62
39 ft.	..	..	45.08	..	..	..	..
40 ft.	14.95	1.01	46.65	0.13	36.80	83.30	0.28
43 ft.	..	..	45.92	..	..	..	..
50 ft.	..	..	45.61	..	..	..	..
51 ft.	..	..	44.60	..	..	..	..
52 ft.	..	..	45.92	..	..	..	..
60 ft.	14.13	0.67	42.24	0.45	40.27	82.01	0.95
62 ft.	..	..	45.92	..	..	..	..
68 ft.	..	..	46.76	..	..	..	..
71 ft.	..	..	42.28	..	..	..	..
74 ft.	..	..	45.08	..	..	..	..
77 ft.	..	..	41.16	..	..	..	..
79 ft.	..	..	40.60	..	..	..	..
80 ft.	25.04	2.72	39.82	1.08	32.41	71.11	2.20
82 ft.	..	..	43.41	..	..	..	..
90 ft.	19.12	1.99	43.37	1.00	35.18	77.45	2.10
91 ft.	..	..	43.12	..	..	..	..
97 ft.	..	..	40.18	..	..	..	..
100 ft.	23.40	1.97	41.02	1.34	33.80	73.26	2.81

BORE HOLE No. 8

Seeva No. 1

1 ft.	14.66	2.32	45.42	0.56	33.31	81.10	1.77
4 ft.	..	..	42.01	..	..	75.02	..
5 ft.	..	..	43.07	..	..	76.94	..
6 ft.	..	..	40.38	..	..	72.11	..
8 ft.	..	..	43.09	..	..	76.95	..
11 ft.	..	..	41.46	..	..	74.03	..
12 ft.	..	..	44.72	..	..	79.14	..
13 ft.	..	..	41.19	..	..	73.55	..
16 ft.	..	..	44.17	..	..	78.87	..
21 ft.	..	..	41.16	..	..	74.04	..
42 ft.	..	..	42.84	..	..	76.50	..
44 ft.	..	..	45.08	..	..	88.00	..
46 ft.	..	..	40.04	..	..	71.50	..
50 ft.	16.60	6.75	42.10	1.10	33.45	75.18	2.31
54 ft.	..	..	43.40	..	..	77.50	..
56 ft.	..	..	40.88	..	..	73.00	..
61 ft.	..	..	46.48	..	..	83.00	..
68 ft.	..	..	43.96	..	..	78.50	..
70 ft.	..	..	46.03	..	..	82.19	..
72 ft.	..	..	45.78	..	..	81.75	..
73 ft.	..	..	43.68	..	..	78.00	..
74 ft.	..	..	45.46	..	..	81.50	..
75 ft.	..	..	43.40	..	..	77.50	..
76 ft.	..	..	45.64	..	..	81.0	..
76 ft.	..	..	41.98	..	..	74.96	..
77 ft.	..	..	45.43	..	..	81.12	..
78 ft.	..	..	49.90	..	..	87.50	..
79 ft.	..	..	42.10	1.26	34.37	75.18	2.65
80 ft.	19.62	2.65	46.84	..	..	83.64	..
82 ft.	..	..	43.65	..	..	77.94	..
86 ft.	..	..	45.09	..	..	84.43	..
88 ft.	..	..	50.32	..	..	89.86	..
89 ft.	..	..	41.10	1.10	32.89	73.5	2.31
90 ft.	22.75	2.10	45.31	..	..	80.91	..
91 ft.	..	..	41.4	..	..	73.96	..
92 ft.	..	..	46.48	..	..	83.07	..
96 ft.	..	..	45.08	..	..	80.50	..
98 ft.	..	..	42.84	..	..	76.36	..
99 ft.	..	..	41.44	..	..	74.00	..
100 ft.	..	..	..	..	..	..	..

Segwa No. 2

BORE HOLE No. 9

Depth.	SiO ₂	Al ₂ O ₃ Fe ₂ O ₃ TiO ₂	CaO	MgO	L.I.	CaCO ₃	MgCO ₃
6 ft.	41.50	..	..	..	..
13 ft.	47.15	..	..	..	..
20 ft.	46.27	..	..	..	..
25 ft.	43.18	..	..	..	..
26 ft.	41.78	..	..	..	..
27 ft.	45.14	..	..	..	..
30 ft.	45.98	..	..	..	..
31 ft.	44.86	..	..	..	..
35 ft.	45.98	..	..	..	..
37 ft.	44.50	..	..	..	..
38 ft.	46.27	..	..	..	..
39 ft.	45.42	..	..	..	..
40 ft.	45.96	..	..	..	..
41 ft.	45.71	..	..	..	..
43 ft.	43.18	..	..	..	..
46 ft.	42.06	..	..	..	..
47 ft.	47.78	..	..	..	..
48 ft.	43.34	..	..	..	..
50 ft.	44.30	..	..	..	..
55 ft.	41.78	..	..	..	..
56 ft.	42.62	..	..	..	..
60 ft.	39.26	..	..	..	..

BORE HOLE No. 10.

Santhi

1 ft.	20.72	3.40	41.72	0.89	33.21	74.50	1.80
10 ft.	22.62	1.38	41.50	0.22	32.84	74.10	0.46
20 ft.	22.62	1.32	41.72	0.43	34.13	74.50	0.90
33 ft.	..	..	41.44	..	..	..	..
41 ft.	..	..	43.40	..	..	..	..
50 ft.	19.54	2.04	43.40	0.32	34.45	77.50	0.67
60 ft.	17.16	2.40	44.12	0.48	35.19	78.78	1.00
69 ft.	..	..	40.88	..	..	..	..
83 ft.	..	..	42.28	..	..	..	..
90 ft.	18.93	2.06	44.30	0.20	34.42	79.10	0.42
100 ft.	16.08	8.14	41.22	0.47	32.91	73.60	0.98

Analysis of Shale Samples of Chittorgarh area.

	Lower Nimbahera shale	Upper Suket Shale	Sawa clay
1. Loss on ignition	5.44	6.34	5.66
2. Si O ₂	64.24	65.12	66.78
3. Al ₂ O ₃	20.31	16.72	23.59
4. Fe ₂ O ₃	7.19	8.98	1.31
5. Ti O ₂	0.30	0.50	0.96
6. Ca O	Trace	Trace	0.37
7. Mg O	1.77	1.56	Nil
8. SO ₃	Trace	Trace	Nil