6.0 Mining and Production

6.1 BACKGROUND OF IRON ORE MINING IN INDIA

India is well-endowed with both haematite and magnetite iron ores since the total in situ reserves of the mineral are about 17 billion tonnes and recoverable reserves 12.75 billion tonnes[1]. Further, abundant availability within shallow depths is a great boon as it helps less expensive exploration and mining by opencast method. There were some 270 working mines in 1995-96 producing about 67 Mt, but bulk production (about 60%) came from only 14 large mechanised mines producing more than 1 Mt each per year and most of them were from public sector undertakings. Since last two decades, emphasis has been laid on mechanisation of iron ore mines in India and about 90 % iron ore production comes from mechanised mining sector and only 10 percent from labour-intensive manual mines. In 1993-94 and in 1994-95, India produced about 60 and 65 Mt[2] of iron ores, respectively.

In pre-Independence period, iron ore mining activities were limited in the country and the mining operations were not based on sound and scientific methods. However, in late 50s, mechanisation of iron ore mines was gradually introduced in India. But still many mines were being worked manually and 230 such mines were under operation in the year 1995-96[2]. Since 70s, opencast mining around the globe including India has undergone seachange due to advent of gigantic mining equipment for opencast mining. In true sense, all the iron ore mines being operated by mechanised method are presently being mined scientifically in India. Manually operated mines are gradually following the systematic method of mining.

6.2 TYPES OF MINEABLE ORES[3]

The iron ore mining is being carried out in 5 sectors in India. The major ore being mined in various districts till date is hematite which occurs in 4 sectors whereas magnetite ore is being mined in the 5th sector as described below:-

Sector 1 (Eastern Sector) Bihar-Orissa	Around Barajamda covering districts of Singhbhum in Bihar, and Keonjhar, Sundergarh and Mayurbhanj districts in Orissa.
Sector 2 (Central Sector) Madhya Pradesh & Eastern Maharashtra	This covers Rajhara-Dalli deposits of Durg district and Rawghat-Bailadila deposit of Bastar district in Madhya Pradesh besides the nearby Surjagarh deposit in Maharashtra.
Sector 3 (Southern Sector)	Bellary-Hospet Sector covering iron ore deposit in Sandur range in Bellary district, Karnataka.
Sector 4 (Goa & Western Maharashtra)	Goa-Redi covering iron deposits in Goa and Redi in Sindhudurg district of Maharashtra.
Sector 5 (Kudremukh)	Magnetite deposits in Chickmagalur district of Karnataka

6.3 CLASSIFICATION OF IRON ORE

Based on the beneficiation characteristics and utility, iron ore in India can be classified into the following categories[4] :

Category I :	Directly marketable ore
Category II :	Washed ores
Category III :	Magnetite-quartzite or haematite-quartzite rock
Category IV :	Intermediate rocks
Category V :	Blue dust

The Category I includes the lumps from manual mines and semi-mechanised mines having only crushing and screening plants. The Category II includes lumps and fines generated from mechanised mines involving close-circuit operation. All these large capacity mines producing over 1 Mt of iron ore (lump -40 mm +10 mm ; fines -10 mm +60 mesh) could be included in this category. As regards the Category III, it involves fine grinding followed by magmatic concentration to produce magnetite concentrates. Concentration increases the Fe percentage of fines from as low as 30% to as high as 65%. Presently, at Kudremukh iron ore mine, this technique is adopted for the preparation of concentrates for exporting and for feeding the pellet plant at Mangalore. In Category IV, the complicated methods of crushing, screening, concentration and flotation are done to upgrade the ore from deposits which require sizeable investment for such chain of operations. However, in India this type of deposit is not considered for mining at present. The Category V includes blue dust which is found in almost all the deposits of iron ore covered under Category I & II. It is actively associated with the final product either as fines or as washed ore.

Indian iron ore mining covers generally Category I and II deposits for mining haematite ore and category III for mining magnetite-quartzite.

6.4 MINING

Normally, iron ore mining is done by opencast method all over the world. Indian iron ore mines may be broadly divided into two categories, viz. manual and mechanised. Majority of the large mechanised mines is in the public sector whereas manual mines are mainly in the private sector. Some mechanised mines in Goa, Bihar and Orissa are also being mined by the private sector. To cater to the increasing domestic and export demands, some existing manual mines are being mechanised. The present production capacity of iron ore in India is around 84 Mt per year.

6.4.1 Manual Mines

This method of mining is generally confined mainly to float ores. Mining of reef ore is also being done manually on a small scale. The float ore area is dug-up manually with picks, crowbars and spades, and the material is manually screened to separate plus 10 mm float ore which is then stacked up. The waste is thrown back into the pits. Generally, the recovery of float ore ranges from 30 to 50 percent or at times even more. As regards reef ore workings, holes are 0.6 m deep and 35-40 mm diameter which are drilled with hand-held Jackhammers with a spacing of about 0.6 m and each hole is charged with 150-200 g gunpowder or special gelatine cartridges. Usually Jackhammer drills are operated with the help of portable air-compressors. The tonnage broken per kg of gunpowder is around 2.5-3 tonnes. The blasted ore is manually loaded into trucks for transport either to the railway station or to the buyer's destination directly. Cost of mining and OMS varies from mine to mine. Presenlty, OMS in manual iron ore mines for producing 10-50 mm lump is about 1.5-2.0 tonnes. A typical example of such a manual mine in Bellary sector where no machinery is deployed is cited here. The labour in this mine is paid around Rs. 45/- per day for skilled category and Rs. 33 per day unskilled category including women. Presently a typical manual mine in India produces around 20,000 t of 64-67% Fe lump and 3,500 tonnes of 65-66% Fe fines. The total mandays utilised were in the region of 10,000 per year. The fines were sold to Goan companies while the lümpy ores were procured by MMTC.

6.4.2 Mechanised Mines

The history of mechanised mining operation starts with the establishment of iron ore mines in Gua in Singhbhum district, Bihar follwed by TISCO's Gorumohisani mine in Mayurbhanj district, Orissa and Noamundi iron ore mine in Singhbhum district, Bihar. Mechanisation in Goan iron ore mines came into effect from the late 50s. With the establishments of integrated steel plants in India, setting up of captive mechanised iron ore mines was developed at Kiriburu, Rajhara, Bailadila, Barsua, Joda, Bolani, Daitari, Donimalai, Kudremukh, Meghatuburu and Goa.[4]

Apart from a few mines developed for iron ore export, most of the fully mechanised mines are captive to various steel plants and have been developed up to their requirements. In these mines, mining is invariably done by systematic formation of benches by proper drilling and blasting. The loading operations are also fully mechanised and transportation is facilitated by maintaining good mine roads having dust suppression arrangements. Further, ore handling, washing, and screening operations are mechanised. The degree of mechanisation and the size of the machinery varies with the material required to be handled by the mines. Three typical mines ranging from 1 Mt output to the largest with 22 Mt material handling are discussed separately as case studies in this Chapter.

Generally, benching is started from the top of the hill and carried downwards as the ore at the top gets exhausted. Except in uniform deposits, if the direction of the bench is along the strike of the beds, it encounters different beds of ores as the working face advances, resulting in considerable fluctuations of the grade of ore produced, unless many benches are worked simultaneously at different depths. This, in turn, requires a large number of smaller machines which create their own problems of supervision, maintenance, etc. It is, therfore, commonly preferred to open-up benches as far as possible across the strike of the beds, so that more uniform grade of the ore is produced.

The height of the benches is dependent on several factors, such as output requirement, shape, size and depth of occurrence of orebody, geological disturbances suffered by the orebody, hardness and compactness of orebody, type and size of the machinery proposed to be deployed, availability of finances, etc. - all are interdependent factors. The bench height generally adopted in fully mechanised mines varies between 8 and 12 m. However, in Goa region, where the ore is softer, hydraulic excavators (backhoe) and wheel loaders are the principle loading equipment used; height of benches is restricted between 4 and 7 m. The length of the face is also dependent on various factors, such as contours of deposit, output required, variation in grade and blending requirements, capacity of loading machinery, etc and varies between wide limits from as small as 60 m to as large as 400 m. The width of the bench is governed to a large extent by the size of the largest machinery deployed and varies from 30 to 50 m.

6.4.3 Drilling and Blasting

As an universal practice, iron ore is dislodged by drilling blastholes according to a particular pattern which depends on the bench height, the hole diameter, the drilling machinery deployed and the types of explosives used. These blastholes are vertical but can be inclined also for obtaining better blasting results.

The 310-mm-dia rotary drill is the largest so far being deployed in India. Rotary drill is used normally in the size from 150 to 250 mm. However, in some foreign countries, rotary drills up to a size of 500 mm dia are also used. Thus, the depth and diameter of blastholes, spacing and burden are interrelated. The largest diameter holes allow expanded drilling patterns in general and help in reducing generation of fines in softer ores. On the other hand, in hard ores or in strata where the hard bands are present, they can give poor fragmentation and toe formation. The poor fragmentation leads to lower rate of loading and increased wear and tear on the loading machinery. Investigations carried out by the Swedish State Power Board, by comparing the performance with 100 mm and 50 mm diameter blastholes, have shown that the digging rate of the shovels was 50 percent higher with small diameter blastholes. Drilling with 150 mm diameter blastholes has been the common practice in Indian iron ore mines. Probably, this is due to ready availability of indigenous drill machines of the size. But higher rate of production makes the incumbent to adopt greater bench heights and larger diameter holes. The greater bench heights permit the use of large shovels which in turn can handle larger boulders and permit larger spacing and burdens.

The quantity of explosive charged mainly depends upon the hardness of the ore as ore blasted ranges from 5 to 8 tonnes per kg of explosive for hard ores, 8 to 10 tonnes for medium hard ores and 10 to 12 tonnes for soft ores. The stemming column should ideally be equal to the burden but normally varies between 0.7 and 1.0 time the burden.

Secondary drilling and blasting in mines is usually done by jackhammer drills powered by compressed air and with slurry/gelatine cartridges.

In hard ores, even "drill masters" give as low a drilling speed as 2.0 to 2.2 m per hour or 15.0 m per shift, but in medium hard ores, a drilling rate of 4.5 to 4.8 m per hour or 30.0 m per shift is quite common. Wagon drills under different strata conditions give drilled meterage varying from 40 to 66 per shift but it is in the range of 48 to 53 per shift in the soft ores.

The accessories used with todays blast have kept pace with other technological developments in mining industry. The development of non-electric blasting systems has eliminated the risks associated with electric blasting systems which are sensitive to the weather conditions and susceptible to stray current or even hand-held wireless equipment. Due to availability of high capacity dozers (700 hp), in some cases, drilling/blasting especially in case of overburden removal, is eliminated. High capacity dozer can rip and doze more effectively where contact plane of overburden/ore and that of different grade ores is uneven. This ripping/dozing operation is eco-friendly; noise/vibration is practically nil and generation of dust is very less.

6.4.4 Specific Problems in Deep Mines

With the advent of high capacity equipment in mining industry, opencast mines in India are being worked at deeper horizons and some iron ore mines have gone beyond 100 m depth. This, in some cases, has resulted in failure of slopes. The incidence of such failure, which is more prevalent in Goa region, necessitated modified pit configurations like flatening the ultimate slope angles, removal of more overburden which is soft and can absorb more storm water. In Goa region, footwall slope failure is a common feature. In many cases, height of benches are reduced and bench widths are increased to protect the slope. Thus, slope stability plays an important role in mining iron ore in Goa region, specially in those areas where orebodies are soft and rainfall is high. On the other hand, due to high incidence of rainfall and seepage of groundwater, huge quantity of water gets accumulated in deep pits and it needs regular dewatering to keep the pit bottom dry for continuation of mining operation.

6.5 PRODUCTION OF IRON ORE

6.5.1 Leases

In India, total number of iron mines as on 1.1.1994 was in 689 leases, covering an area of 111,160 hectares. Of this, 220 leases in Goa (North/South) have an aggregate area of 17,051.96 hectares. Statewise and districtwise distribution of leasehold areas as on 1.1.1994 are given in Table 6.1.

TABLE : 6.1 DISTRIBUTION OF IRON ORE LEASES AND LEASE AREA AS ON 1.1.1994

State/District	No. of Leases	Lease Area in Hectares
Andhra Pradesh		
Anantpur	4	333.15
Khammam	7	658.41
Krishna	6	52.09
Kurnool	6	18.89
Nellore	2	274.00
Ongole(Prakasam)	3	9.03
Total	28	1345.57
Bihar		
Palamau	10	241.21
Singhbhum	37	11263.60
Total	47	11504.81
Goa		
North Goa	94	7203.10
South Goa	126	9848.86
Total	220	17051.96
Haryana		
Mahendragarh	1	86.20
Total	1	86.20
Karnataka		
Belgaum	2	24.68
Bellary	120	15878.71
Bijapur	2	82.96
Chickmagalur	7	5554.97
Chitradurga	13	1618.78
Dharwar	4	190.21
Gulbarga	1	123.84
Shimoga	2	209.63
Tumkur	8	761.29
Uttar Kannad	28	2279.02
Total	187	26857.98

Table 6.1 (Concld.)

Kerala		
Kozhikode		86.54
Total	1	86.54
Madhya Pradesh		
Bastar	11	11362.77
Durg	4	2822.56
Gwalior	3	60.69
Jabalpur	8	158.70
Total	26	14370.57
Maharashtra		
Bhandara	1	43.82
Gadchiroli	1	25.90
Chandrapur	3	268.32
Kolhapur	1	143.95
Ratnagiri	1	12.01
Sindhudurg	24	1269.41
Total	30	1483.16
Orissa		
Cuttack	2	3038.01
Keonjhar	76	22223.18
Mayurbhanj	13	3885.60
Sundargarh	38	7110.73
Total	129	36291.88
Rajasthan		
Jaipur	12	1668.91
Jhunjhunu	3	144.63
Sikar	4	273.02
Total	19	2086.56
Grand Total	689	1,11,164.66

Source : Indian Bureau of Mines, Nagpur.

6.5.2 Mines

In India, number of working mines of iron ore in 1993-94 was 255, out of which 32 mines were in public sector and 223 in private sector. In the same year, Category A and Category B mines were 78 and 177, respectively. All of these iron ore mines are worked by opencast methods. Karnataka State has a maximum number of working mines (78). In Orissa and Goa, 73 and 43 working mines were in operation in the 1993-94 (Table 6.2).

Further, from Table 6.2, it can be seen that total number of working iron ore mines in India fluctuated between 255 and 276 since 1992-93. But the number in public sector undertakings was almost constant, varying between 32 and 37. It is interesting to mention that though the number of mines has not practically increased, production has gone up from 57 to 67 Mt. (Please refer Table 6.4 on page 106) which indicates more mechanisation in this sector.

TABLE 6.2 : STATEWISE NUMBER OF MINES IN INDIA

State/District	1992-93	1993-94	1994-95	1995-96
INDIA	275	255	276	267
Public Sector	32	32	36	37
Private Sector	243	223	240	230
Andhra Pradesh	15	10	7	3
Bihar	30	27	22	22
Goa	49	43	43	46
Haryana	1	1	1	1
Karnataka	80	78	82	81
Madhya Pradesh	12	11	12	13
Maharashtra	3	4	11	9
Orissa	74	73	82	82
Rajasthan	11	8	10	10

Source : Indian Bureau of Mines, Nagpur.

6.5.3 Principal Producers in India

The important Central Public Enterprises of the Government of India producing iron ore are Steel Authority of India Limited (SAIL), Kudremukh Iron Ore Company Ltd (KIOCL), National Mineral Development Corporation Ltd. (NMDC) and Indian Iron & Steel Company (IISCO). The State Government undertakings engaged in this field are OMC Ltd., Haryana Minerals Ltd. and Mysore Minerals Ltd., and major private owners/producers are TISCO, Sesa Goa Ltd, V.M.Salgaoncar and Chowgule & Co. The list of the principal producers of iron ore in India is given in Table 6.3

6.5.4 Production Analysis

The production of iron ore in India from the year 1989-90 to 1995-96 is given in Table 6.4. It shows that the minimum production is 55,437,000 tonnes in 1989-90 valued 5,118 million rupees and maximum in the year 1995-96 i.e. 66,578,000 tonnes valued 12,867 million rupees. It shows the quantum jump in production and value.

It is interesting to note from the Table 6.5 (see p. 106) that 50 percent of the country's total production comes from 9 large mines, each producing more than 2 Mt per year whereas

TABLE 6.3 : PRINCIPAL PRODUCERS OF IRON ORE IN INDIA

Sl.No.	Name & address of producer	Location of Mine	
		State	District
1.	The Steel Authority of India Ltd., Ispat Bhavan, Lodhi Road, New Delhi - 110003.	Bihar M.P. Orissa	Singhbhum Durg Keonjhar Sundergarh
2.	National Mineral Development Corpn. Ltd., 19-3-311/A, Khanij Bhawan, Masab Tank, Hyderabad - 28.	Karnataka M.P.	Bellary Bastar
3.	Kudremukh Iron Ore Co. Ltd, 11 Block, Koramangala, Bangalore - 34.	Karnataka	Chikmagalur
4.	The Tata Iron & Steel Co. Ltd., 24,Homi Mody Street, Fort, Bombay - 23.	Bihar Orissa	Singhbhum Keonjhar
5.	The Indian Iron & Steel Co.Ltd., 30, Chowringhee Road, Calcutta - 700071.	Bihar	Singhbhum
6.	M/s Sessa Goa Ltd., Altinho, Panjim, Goa - 403001.	Goa	Goa
7.	M/s V.M. Salgaoncar & Bros.(P) Ltd., Salgaoncar House, P.L. Gomes Road, P.B.No.14, Vasco-da-Gama, Goa - 403803.	Goa	Goa
8.	Chowgule & Co. (P) Ltd., Chowgule House, Marmugoa Harbour, Goa-403 803.	Goa	Goa
9.	Dempo Mining Corpn. Ltd., Dempo House, Campal, P.B.No.116 Panjim, Goa - 403001.	Goa	Goa
10.	M/s Casme Coasta & Sons Altinho, Mapuse, Goa.	Goa	Goa
11.	The Orissa Mining Corpn. Ltd., P.B.No.34, Bhubaneshwar - 751 001.	Orissa	Keonjhar Sundergarh
12.	Sociedade Timblo Irmaos Limitadu (Represented by Timblo(P) Ltd.)	Goa	Goa
13.	M/s R.S. Shatye & Bros. Trionars Apartments, 14, Ist Floor, Opp. Dorando Cinema, Panjim, Goa	Goa	Goa
14.	M/s R.S. Ghouse, P.B.No.204, Margao, Goa.	Goa	Goa
15.	Essel Mining & Industries Ltd., 10, Camac Street, Calcutta - 17	Orissa	Keonjhar Sundergarh
16.	Bharat Process & Mechanical Engineers Ltd., Chartered Bank Building, Calcutta - 1.	Orissa	Keonjhar
17.	M/s D.B.Bandodkar & Sons(P) Ltd., Post Velguem, Via Pale, Goa 403 105	Goa	Goa
18.	M/s Mineira Nacional Limitada, Angela Dias Building, P.B.No.171 Swatantrya Path, Vasco-da-Gama Goa - 403 802.	Goa	Goa
19.	Smt. Geetabala Manohar Parulekar Mapusa Bardez, Goa.	Goa	Goa
20.	Rungta Mines(P) Ltd., Chaibasa, Singhbhum, Bihar and P/16, Kalekar Street, Calcutta - 70.	Bihar Orissa	Singhbhum Keonjhar, Sundergarh
21.	M/s N.S. Narvekar Minerals Ltd., P.O.Kalay, Goa - 403 704.	Goa	Goa
22.	Sandur Manganese and Iron Ore Ltd., Yeshwant Nagar, Sandur - 583 119	Karnataka	Bellary
23.	M/s Mineral Sales(P) Ltd., Baldev Bhavan, 117, Maharshi Karve Road, Bombay - 400 020	Goa Karnataka	Goa Bellary
24.	S.B.Minerals, P.B.No.58, Krishna Rajendra Road, Hospet - 583 201 Dist.Bellary (Karnataka).	Karnataka	Bellary

TABLE 6.4: PRODUCTION OF IRON ORE IN INDIA (FROM 1989-90 TO 1995-96)

(Quantity in '000 tonnes)
(Value in Rs '000)

Year	Production	
	Quantity	Value
1989-90	55,437	5,118,816
1990-91	55,591	5,873,167
1991-92	58,534	7,499,513
1992-93	57,147	9,066,690
1993-94	59,645	10,393,914
1994-95	64,507	11,862,407
1995-96(p)	66,578	12,867,310

(P) Provisional

production from 107 mines, each producing less than 10,000 t per year, has the share of less than 1 percent of the country's production. So productionwise, small-scale iron ore mines in India are insignificant.

TABLE 6.5: PRODUCTION OF IRON ORE 1994-95

(By Frequency Groups)

Production Group(t)	No. of Mines	Production for the Group ('000 t)	Percentage of Total Production
Up to 10,000	107	365	0.56
10,001 - 25,000	44	697	1.08
25,001 - 50,000	27	972	1.51
50,001 - 1,00,000	27	1,926	2.99
1,00,001 - 5,00,000	47	11,852	18.37
5,00,001 - 10,00,000	9	6,704	10.39
10,00,001 - 20,00,000	6	9,499	14.73
Above 20,00,000	9	32,492	50.37
Total : All Groups	276	64,507	100.00

Source : Indian Bureau of Mines, Nagpur

Presently, India is producing more fines than lumps at the ratio of 60:40 which may go up further as most of the deposits in hinderland areas contain more fines of iron ores which are now in high demand in export market and in domestic market, and technology is now available for making sinters and pellets from fines. Table 6.6 shows lumps and fines production pattern for last four years and reveals the trend of more production of fines as compared to lumps specially in Goa and Bihar.

Due to economic reforms, iron ore production will experience further boom and may touch 80 Mt by the turn of this century. And with the availability of better infrastructure for transportation and shipments coupled with upswing of world steel market, production may reach the height beyond 100 Mt by A.D. 2005.

6.5.4.1 Statewise Production During 1992-93 to 1995-96

Statewise and gradewise production details of iron ore are given in the Table 6.6 for the last four years. From the Table, it can be seen that during this period, lumpy ore was produced mainly in Madhya Pradesh, Orissa and Bihar. Average production per year from these States was 8.5 Mt, 5.7 Mt, and 4.7 Mt, respectively. Production of fines came mainly from Goa, Madhya Pradesh and Bihar where yearly average production was 11.9 Mt, 7.1 Mt, and 6.9 Mt, respectively, during the same period. But concentrate was produced only in Karnataka with average production of 5.8 Mt per year though a small quantity of concentrates was also produced in Goa - less than 0.5 Mt per year, during this period.

6.6 CONSERVATION OF IRON ORES IN INDIA

6.6.1 General Information

It is true that the iron ore reserve base for industrial economy is not in immediate danger of exhaustion but its judicious use is the need of the day. By means of improved exploration techniques, modern mining methods, sophisticated ore processing and metallurgical treatment, higher recovery of iron metal is being achieved. Present day practice is to achieve orderly development with minimum waste in the case of non-renewable ones, like iron ores and to preserve the social and aesthetic value of natural environment for succeeding generations. In fact, the meaning of conservation has changed over the years from the negative objective of restriction of use to the positive one of better utilisation of our resources and our environment

TABLE 6.6 : STATEWISE, GRADEWISE PRODUCTION OF IRON ORE (FROM 1992-93 TO 1995-96)

(Qty in '000 tonnes , Value in Rs. '000)

State	Year	Total		Lumps									Fines				Concentrates	
		Qty	Value	above 67% Fe	65-67% Fe	62-65% Fe	60-62% Fe	58-60% Fe	55-58% Fe	below 55% Fe	Total lumps	Value	above 62% Fe	62% Fe & below	Total fines	Value	Qty.	Value
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
INDIA	1992-93	57495	9088162	3298	8558	8532	2186	628	271	87	23560	3362164	21156	7367	28523	3869256	5412	1856752
	1993-94	59645	10393914	3119	9242	8645	2133	755	34	114	24042	3849186	20921	8117	29038	4390848	6565	2153880
	1994-95	64507	11862407	3479	9155	9595	3280	852	174	131	26666	4595260	24088	7595	31683	4957239	6158	2309908
	1995-96(P)	66578	12867310	3932	10007	10415	3423	857	175	147	28956	5092051	23907	7389	31296	4932156	6326	2843103
ANDHRA PRADESH	1992-93	161	7762	2	45	60	10	--	--	--	117	6396	39	5	44	1366	--	--
	1993-94	191	8675	2	69	40	2	--	--	--	113	6266	70	8	78	2409	--	--
	1994-95	186	7459	5	74	20	1	1	--	--	101	5149	75	10	85	2310	--	--
	1995-96(P)	187	8177	6	89	24	1	1	--	--	121	6256	57	9	66	1924	--	--
BIHAR	1992-93	10042	1205521	--	1137	1770	1084	34	5	5	4035	503403	5198	809	6007	702118	--	--
	1993-94	10682	1463292	--	1333	1868	1143	16	--	0	4360	637300	5552	770	6322	825992	--	--
	1994-95	12053	1685599	--	1661	2280	1156	14	--	--	5111	758594	6089	853	6942	927005	--	--
	1995-96(P)	12613	1907282	--	1702	2336	1185	14	--	--	5237	802818	6470	906	7376	1104464	--	--
GOA	1992-93	13777	1876492	--	--	313	968	567	212	53	2113	323068	5408	5854	11262	1534691	402	18733
	1993-94	14185	2300914	--	--	666	843	689	30	77	2305	415887	4453	7062	11515	1833271	365	51656
	1994-95	15489	2564868	--	--	475	1312	810	169	78	2844	476378	5990	6182	12172	2021542	473	66948
	1995-96(P)	14836	2168967	--	--	474	1309	808	169	77	2837	422624	5774	5959	11733	1708545	266	37798
HAR-YANA	1992-93	15	1383	--	--	--	15	--	--	--	15	1383	--	--	--	--	--	--
	1993-94	16	2737	--	--	--	16	--	--	--	16	2731	--	--	--	--	--	--
	1994-95	8	1413	--	--	--	8	--	--	--	8	1413	--	--	--	--	--	--
	1995-96(P)	5	815	--	--	--	5	--	--	--	5	815	--	--	--	--	--	--

(Contd.)

Table 6.6 (contd.)

KARNATAKA	1992-93	11167	2610875	394	1894	1438	--	--	--	--	3726	441895	2270	161	2431	330961	5010	1838019
	1993-94	12042	2826329	354	2096	1140	100	--	--	--	3690	469918	1950	99	2152	254187	6200	2102224
	1994-95	12431	3120387	512	2094	1609	13	+	2	--	4230	564548	2389	127	2516	312879	5685	2242960
	1995-96(P)	12484	3591593	555	2268	1743	14	+	2	--	4582	603454	1749	93	1842	182834	6060	2805305
MADHYA PRA-DESH	1992-93	14112	2376681	2902	3199	1811	17	--	--	--	7929	1405266	6135	48	6183	971415	--	--
	1993-94	15014	2564590	2763	3263	2204	2	--	--	--	8232	1501670	6764	18	6782	1062920	--	--
	1994-95	16083	2998559	2962	2190	2645	724	--	--	--	8521	1778958	7535	27	7562	1219601	--	--
	1995-96(P)	17426	3456390	3371	2493	3011	824	--	--	--	9699	2111300	7699	28	7727	1345090	--	--
MAHA-RASH-TRA	1992-93	70	6472	--	--	--	--	--	54	16	70	6472	--	--	--	--	--	--
	1993-94	61	5944	--	--	--	--	37	--	24	61	5944	--	--	--	--	--	--
	1994-95	164	9267	--	--	--	48	16	--	37	101	6485	--	63	63	2782	--	--
	1995-96(P)	172	10113	--	--	--	65	21	--	50	136	8495	--	36	36	1618	--	--

(Concld.)

ORISSA	1992-93	8113	999668	--	2283	3140	92	2	--	--	5517	670963	2106	490	2596	328705	--	--
	1993-94	7425	1218804	--	2481	2727	27	1	--	--	5236	806735	2029	160	2189	412069	--	--
	1994-95	8065	1472319	--	3136	2566	18	2	--	--	5722	1001199	2010	333	2343	471120	--	--
	1995-96(P)	8820	1721126	--	3453	2827	20	2	--	--	6304	1133440	2158	358	2516	587684	--	--
RAJAS-THAN	1992-93	38	3308	--	--	--	--	25	--	13	38	3308	--	--	--	--	--	--
	1993-94	29	2635	--	--	--	--	12	4	13	29	2635	--	--	--	--	--	--
	1994-95	28	2536	--	--	--	--	9	3	16	28	2536	--	--	--	--	--	--
	1995-96(P)	35	2847	--	--	--	--	11	4	20	35	2847	--	--	--	--	--	--

(P) = Provision

++ = Negligible

Source : Indian Bureau of Mines, Nagpur.

in order to make possible better and fuller lives for all people.

In past, the concern for judicious development of iron ores was rather negligible as is reflected in the limited production. Generally speaking, rat-hole mining was prevalent and only eyes of the deposits were taken out without any proper planning. Earnest efforts for orderly development and conservation of iron ores were made only after Independence by formulating various rules, acts and by offering suggestions for betterment.

At present, production of iron ores in the country is designed to meet the indigenous requirements of the steel plants, other ancillary industries and exports to other countries. The reserves of iron ores are very large and internal production will fully meet the demand in future years also. The reserves of high grade ores are, however, limited and the demand, by and large, is for high grade calibrated ores. As a result, selective mining is practiced and the fines, which vary from 20 to 60% of the r.o.m. depending upon the types of deposits, are dumped along with waste rock[5]. Greater use of sinters, however, has enabled the setting-up of washing plants and the washed fines are being utilised in the country. Most steel plants except IISCO's Burnpur have their own sinter plants through which the washed iron ore fines from their captive mines are used regularly. There is export demand also for iron ore fines from Goa region. Washing plants have been setup at export-oriented mines, like Bailadila, Donimalai and Daitari. Export of iron ore concentrate and pellets from Kudremukh quartz-magnetite mine is a landmark in the utilisation of quartz-magnetite rock of which India has large resource.

Iron ore deposits of different sectors in India have different conservation problems due to their location, basic physical and chemical specifications, properties and characters. Enough exercises have been carried out concertedly by the IBM, mining industry and educational and research institutes for coming to a conclusion regarding threshold values of iron ores in India. Fortunately, the same has been reached in respect of haematite iron ores of Goa and Bellary-Hospet sectors which have 55 percent and 58 percent Fe content, respectively[6]. As the GSI and the State Directorates of Mines & Geology assessed the iron ore reserves based on a cutoff at 55 percent Fe content, the same may be considered as the threshold value for other sectors till something concrete is settled. Based on the above, some important conservation problems being encountered in different iron ore sectors of India are discussed hereafter:

6.6.2 Conservation Problems in Bihar-Orissa Iron Ores

Indian haematite iron ores, particularly in Bihar-Orissa are aluminous in nature but rich in iron, i.e. Fe content. Alumina is believed to exist in iron ores especially as lateritic clay, formed by decomposition of basic rocks under tropical condition and is found to exist more in fine ores than in lumpy ores. The iron ores of this area contains 1 to 11 % alumina which increases viscosity of slag in the blast furnace. This, in turn, results in increase in coke consumption rate and otherwise lowers the blast furnace productivity. It is estimated that for every 1 percent reduction in the alumina content of ores, coke and flux rates decrease by 40 kg and 60 kg, respectively, and the consequent increases in production of pig iron would be about 2 to 2.5 percent.[7]

In view of the high alumina, the ratio of alumina : silica which should be 1:1 to 1:1.5 with silica predominating is disturbed. In fact, alumina and silica together should preferably be less than 5 to 6 percent and alumina should not exceed 3 percent to provide an ideal blast furnace feed. Alumina percolates and segregates more into fines when aluminous ore is crushed and washed. Thus, the inherent aluminosity of the fines gets enhanced instead of satisfying the siliciousness needed in the fines usuable for pellet and sinter feed.

Due to alumina problem and nonavailability of any immediate possible economic remedy through the R & D efforts so far undertaken by various laboratories and institutes, the steel plants in eastern India are utilising higher grade of iron ores to minimise the consumption of coke which is very scarce and costly to import. Further, the overall grade of iron ores in the captive mines of the steel plants of this area is not good, which has led the steel plants, particularly of M/s SAIL to purchase high grade iron ores from noncaptive mines of Bihar-Orissa area to blend with their ores and to make a suitable blast feed.

Over and above, a number of sponge iron plants are taking/purchasing hard-lumpy-sized high grade iron ores with stringent physical and chemical specifications from Barajamda-Banspani area of Bihar-Orissa sector. This results in generation of high grade curshed fines for which there is no market now. Even for export, sized iron ore of 64 pecent Fe-content only is accepted from this sector.

Thus, it becomes quite clear that the lower grade iron ores as well as high grade iron ore fines of noncaptive mines of Bihar-Orissa sector have no market eventhough these are produced while carrying out mining. Considering the reserves assessed on the basis of 55 percent Fe content cutoff, the entire quantity of ores from 55 to 60 percent Fe-content has become rejects in all sense. Continuous stacking of it separately in a scientific manner not only requires sufficient land but it also blocks the capital of the noncaptive mines. This is a great conservation problem. The various R&D organisations are constantly putting their efforts to find out some economically viable solution. The Research & Development Centre for Iron & Steel (RDCIS), Ranchi of M/s. SAIL has found out use of polymer for differential removal of alumina and upgrading iron ores but this is highly cost-bearing and uneconomic[7]. It is still carrying out further study to find out some cheaper method. Depending on the quantum of high grade fines, some steel plants like Bokaro and Rourkela have started offtaking the same for their sinter plants. Another possible important market for this high quality fines may be found in oil-producing countries where haematite fines may be used for pipeline coating. This is called High Density Aggregates (HDA) which could only be produced by crushing high grade lumpy ore.

6.6.3 Conservation Problems in Madhya Pradesh Iron Ores

The subgrade iron ores of Bailadila area of this sector are stacked and stockpiled separately for its nonavailability of any market demand now. Based on the geological findings, it is expected that better grade ores are likely to be available while carrying out mining at depth. The mineowners are continuously stacking the subgrade ores with that hope. They feel that there will be an opportunity for them to blend the aforesaid subgrade ores with better grade ores likely to be obtained from the year 1998-99[8]. This approach of the mineowners of this area is definitely good from view point of conservation of minerals.

6.6.4 Conservation Problems in Karnataka Iron Ores

Magnetite iron ore deposits in Kudremukh range in Karnataka were known since 1913[9]. The deposit consists of 610 Mt of weathered magnetite and haematite ores apart from primary ore of about 400 Mt.[10] Average grade of the ore being 38.6 percent Fe-content, no attempt was initially made for its exploitation.[10] M/s National Mineral Development Corporation (NMDC) initiated plans to develop the low grade magnetite deposits of this range during 1966.[9] They carried out feasibility and pilot plant studies during 1968. It was a great achievement from the view point of conservation of minerals when the development of Kudremukh deposit became an international venture on 4th November, 1975[9]. Kudremukh Iron Ore Company Limited (KIOCL) incorporated during April, 1976 appointed M/s Metchem Consultants Ltd., Canada, in August, 1976 for carrying out research, engineering, construction management and supervision of production of the iron ore concentrate during the first three years of production. The plant was commissioned ahead of schedule during 1980 with a design to produce 7.5 Mt of concentrate per annum. The mine was designed/planned to produce 19.75 Mt of r.o.m. ores with an average grade of 38.6

percent Fe and overall quantity to be handled including waste to the tune of 22.60 Mt per year[10]. At present, it has been planned to mine only the weathered ore which is classified as soft weathered ore (422 Mt) and magnetite schist (36 Mt). Kudremukh is using latest technology in beneficiation of iron ore, enriching it from about 39 percent to over 66 percent Fe-content concentrate[10]. A wet concentration process involving magnetic separation and gravity separation by spirals has been adoped for beneficiating this low grade magnetite iron ores with an aim to obtain the product in the form of finely ground slurry to make it easy for transportation through pipeline up to Mangalore over a distance of about 67 km[9]. About 3 Mt iron ore concentrates are being used to make pellets in KIOCL's own pelletisation plant at Mangalore. The rest of the concentrates as well as the pellets are exported to different countries like Hungary, Australia, Romania, Yugoslavia, China, Japan and North Korea and thereby earning a lot of foreign exchange. This conversion of yesterdays waste or unwanted/nonmarketable ores to todays wealth, earning foreign exchange, is an excellent example of the conservation and development of minerals by adopting modern technology.

In Bellary-Hospet area, as the off-take of iron ores is of above 63 percent Fe grade, both for internal consumption and export, the major conservation problems being faced by the mineowners were the stacking of subgrade ores up to 58 percent Fe-content and generation of nonmarketable iron ore fines to the tune of about 60 percent of the total r.o.m. ore production. Eventhough both grades are being stacked separately, nonavailability of space as well as blocking of capital poses a great problem: The decanalisation for the iron ore fines (-10 mm size) in this area which has come in force recently is expected to help the entire ore fines to be utilised in the domestic and export markets. Planning for more sinter-making capacity to utilise the ore fines is also under consideration. All these attempts are likely to solve the conservation problem of iron ore fines in this area.

So far as subgrade ores are concerned, about 50 Mt of such ores has already been stacked separately by most of the B-Category working mines in this area. The possibility of utilising this subgrade ore by upgrading the same through modern oredressing technology is being tried. This is particularly important from the view point of a private steel plant of M/s. JINDAL coming up in the area over and above the existing one of M/s. Visvesvarya Iron & Steel Ltd. (a subsidiary of M/s. SAIL).

IBM is also regularly monitoring and conducting studies for possible utilisation of the aforementioned nonmarketable ores.

6.6.5 Conservation Problems in Goan Iron Ores

In Goa, the marketable iron ore is generally above 58 percent. The ores of this area are more friable and fine in nature and are 100 percent export-oriented right from the beginning. Threshold value of the ore being 55 percent Fe-content, the ore between 55 and 58 percent Fe-content[11] and some quantity of the lumpy ores intermixed with gangue minerals generated or produced (incidental to mining) are the main conservation problems. The lumpy ores, depending on its quality, are at times crushed and blended with the fine ores and exported. However, for subgrade ores of 55 to 58 percent Fe-content[11], there is practically no market now.

IBM is regularly monitoring the generation of subgrade fine ores as well as nonmarketable lumpy ores to see that those are stacked separately for possible future use. Side by side, a number of ore beneficiation plants have also started coming up to upgrade the nonmarketable ores to a marketable one, particularly from the export point of view.

Further, in a recent development for the utilization of silicious magnetitic ores with low iron content of Goa region, a beneficiation plant has been set up at Todou in South Goa where magnetite ores of below 6 mm size with 35 to 40 percent Fe content, 35 to 45 percent silica content and above 5 percent FeO content, is beneficiated to have a concentrate of around 64 percent Fe content with weight recovery of about 40 percent and metal recovery 60 to 70 percent.[11] Another beneficiation plant of similar nature is under trial run for future commercial use.

6.7 TECHNOLOGICAL ADVANCEMENT IN IRON ORE MINING

6.7.1 Development in the Field of Machinery, Geostatistics and Geophysics

Technology available elsewhere in the world for mining minerals by opencast method is now slowly and steadily being introduced in India on enduring basis. The modern concept "optimization is being visualized through existing syndrome of maximization" is the prevailing philosophy of mining in India. And it is the 'optimization' which has brought in the following techniques and their application :

(i) Application of geostatistics for mining deposits in widely variable grades of ores.
(ii) Deployment of efficient exploratory drilling rigs for faster assessment of grades, shape and size of deposits.
(iii) Application of seismological studies for ripping overburden/ores, replacing conventional drilling/blasing systems.
(iv) Use of large capacity front-end-loaders and wheel loaders.
(v) Deployment of articulated dumpers for negotiating uneven topography and sharp bends.
(vi) Use of wire nets for tyre-mounted mobile and semi-mobile units for longer tyre life.
(vii) Use of site-mixed explosives of variable strength
(viii) Introduction of the delay detonators and other modern accessories like NONEL in sequential blasting machines.
(ix) Use of seismograph for monitoring and control of ground vibration induced by blasting.

6.7.2 Rock Mechanics

For last twenty years, considerable progress has been made in the field of geotechnical studies. Now optimum slope angle of opencast mines specially of soft formation like iron ore deposits in Goa can be determined for economic and safe mining. Further, advanced rippability tests in practice in India are also advantageous for cost reduction on overburden removal. Such tests facilitate to avoid drilling, blasting, and ensure environment-friendly mining activity.

6.7.3 Computerisation

Electronic and computers are also finding easy access to the field of mining specially in area of reserve evaluation, control of ore grade and optimum utilization of mining equipment in large opencast mines producing variable ore grades.

Computer applications in the "Indian Iron Ore Mining and Mineral Industry" started during the seventies though initially applications were confined to analysis of drill-hole data for geostatistical and ore reserve estimation. Now, considerable progress in application of computers has been made in the field of exploration and exploitation of various minerals. Larger mining companies developed the computer applications with in-house facilities in the area of geostatistics, orebody modelling, deposit evaluation, and mine planning and scheduling. Some software programmes widely used in mining industry including iron ore mines are as stated below :

1) Metal Mines	a) DATAMINE, UK.
	b) SURPAC, AUSTRALIA
	c) TECHBASE, USA
	d) CRYSTAL, INDIA
2) Rock Mechanics	a) BESOL, USA
	b) FLAC, USA
	c) BEM & FEM, BEFO, SWEDEN
3) Mineral Processing	JKSMET, AUSTRALIA

A software package called "PRISM" which is capable of detailed analysis in relation to project planning and monitoring for new and on-going projects is being used extensively[12].

6.7.4 Slurry Transport

Further hydro-transportation of iron ore has added new dimension. In KIOCL, such transport system is functioning smoothly for a stretch of 67 km.

6.8 CASE STUDY

6.8.1 Case Study I

Mine Producing 1 Mt per Annum

In the private sector, this iron ore mine is situated 17 km from Bicholim town in North Goa. The mine is worked by mechanized opencast method using heavy earth-moving machines like hydraulic excavators, dumpers, ripper dozers, etc. (See Table 6.7). The mine produces more than one million tonnes iron ore on an average and further handles 2 Mt of waste rock per annum. There is only one working pit which extends over a strike length of 1.7 km. The workings are above the general groundwater level. The lowest floor level is at 32 m above MSL. The groundwater is met below 15 m MSL.

The lithological sequence of the rock types encountered in the area is as follows:

Laterite	6 - 30 m
Phyllitic and limonitic clays	15 - 40 m
Iron ore (Lumpy, powdery & friable)	20 - 60 m
Hard banded ferruginous - quarzite (inconsistent horizon)	Not established

The overburden consists of laterite and clays. The laterite is hard and requires drilling and blasting while the clay is soft and is removed directly by excavators. This activity of removing overburden is mainly done in the monsoon between June and September. The primary drilling is done with Ingarsoll-Rand drill master, drilling 150-mm dia. holes using button bits and blasting is done with slurry explosives. Equipment deployed in this iron ore mine are detailed in Table 6.7.

Iron ore production from the mine is obtained between October and June which are

TABLE 6.7 : EQUIPMENT DEPLOYED IN THE MINE

S.No.	Machinery	Identification No.(Sr.No.)	Code No.	Capacity	H.P.	Total hours worked	Date of Commi-ssion
1.	L & T Poclain 300 CK loader	B0079	010592	3.2 cu m	330	5669	28.9.1985
2.	L & T Poclain 300 CK Loader	B-0086	020531	3.2 cu m	330	5407	17.4.1986
3.	L & T Poclain LC 80 Backachor	51	030591	0.7 cu m	86	--	1.10.1977
4.	Michigan 125 B Swati Wheel Loader	439446	010544	4.0 cu yd	185	21626	1977
5.	Komatsu D155-S1 Traxcavator (U/B)	1125	010577	4.5 cu m	265	17364	28.7.1981
6.	Komatsu D95-S2 Traxcavater (working)	2084	010573	3.2 cu m	265	17364	28.7.1981
7.	Komatsu D355-A1 Vikrant Dozer Ripper	1467	010431	90,000 kg.	400	27250	5.12.1975
8.	Komatsu D375-A1 Vishwashakti Ripper Dozer	11255	010436	--	510	1412	13.1.1988
9.	BEML D-155-A1 Dozer	2166	030412	--	365	--	Sept.1982
10.	Huber Motor Grader 9D	902810826	011702	--	135	7542	11.9.1975
11.	Terex Highway Rear Dumper R25	H1268	010659	22 tonnes	320	10822	19.10.1976
12.	Terex Highway Rear Dumper R25	H1344	010662	22 tonnes	320	10576	5.10.1977
13.	Terex Highway Rear Dumper R25	H1347	010665	22 tonnes	320	10591	5.10.1977
14.	Halco Track Drill No.2 CM/130/475 CL	2707	010312	4"X10 m	--	11001	1.3.1977
15.	Drill Master No.2 DM 20	77DMO71	030322	6"X17 m	167	13733	1977
16.	Drill Master IDM-20	8206215	020302	6"X17 m	185	2575	1982

dry months. The iron ore is friable and powdery and it does not require any blasting. However, due to its compact nature, the productivity of the loading equipment is enhanced if the ore is ripped and dozed for feeding them. This is the general trend in Goan mines where the laterite capping requires drilling-blasting. The ore and other waste are generally soft. Hence, there is the overwhelming trend of using wheel loaders, traxcavators and now hydraulic excavators as the primary loading equipment. Deployment of hydraulic excavators as backhoe is the common practice when mining operations are carried out below the groundwater level which is invariably lowered by pumping before extracting iron ore from the pit concerned.

Iron ore is loaded by the excavators and transported by "Tata tippers" to the screening/working plants. Overburden and waste rocks are also transported mainly by Tata tippers. The Terex dumpers are used only for the transportation of big boulders. Six benches, each of 8-metre height, are operated in ore and waste. The average lead distance for ore and waste is 2.5 km. The mineral treatment plant consists of a simple dry sintering plant having vibrating screen which separates r.o.m. into -10 mm fines, +10 mm to -25 mm lumps and +25 mm lumps.

6.8.2 Case Study II
Mine Producing 5 Mt per Annum

This is a public sector mine and is highly mechanized one, operated by opencast method with shovel-dumper combination. The mine works by a system of deep-hole drilling and blasting. The crushing plant is located at 1104 mRL on the eastern flank of the orebody. The mine handles a total excavation of nearly 6 Mt including waste. It produces annually around 5 Mt iron ore.

The mine is divided into two working blocks, namely (1) South (2) Central and North-West blocks extending over a total strike length of 3.75 km. The working benches are above 1128m MSL and these are at 1128 m, 1140 m, 1152 m and 1164 m in the South Block, and 1176 m, 1152 m and 1164 m in the Central and NW Blocks.

It is a hill slope working by opencast method and therfore no overburden removal is involved. The waste material occurring with the iron ore is shale and banded haematite quartzite (BHQ). The waste is disposed off in a shallow valley outside the economic limits of the mine. The r.o.m. ore with a proper blend from different benches is fed to the crushing plant near the mine at 1102 mRL. The blasted material is carried by 50-t dumpers from the mine faces and fed to the crushing plant. The mine plans to win 6 Mt of ore from its present production of around 5.1 Mt. The present average grades being mined are lump ore grading Fe 67.8%, SiO_2 0.7 %, Al_2O_3 1.2 % and fines grading Fe 65%, SiO_2 2.7 % and Al_2O_3 2.3 %. As deeper levels are mined in late stages, the grade is expected to improve to Fe 68.2%, SiO_2 0.6%, Al_2O_3 1.0% for lumps and Fe 66.3%, SiO_2 2.7% and Al_2O_3 1.6% for fines.

The design of the bench is as under :

Bench height : 12 m (maximum digging height of the shovel + 3 m)

Bench slope : 80 - 85°

Bench width : 60 m (minimum)

In order to obtain desired output as per plan, 6 to 7 benches are worked simultaneously. Mine benches are advanced to secure uniform depletion in the different knocks. For blending and grade control, the faces are aligned to the extent possible, across the strike of the deposit. The effective face length of the mine is 600-700 m.

Primary drilling is done by 250-mm electric rotary drills and secondary drilling by 105-mm rotary percussive diesel drills and loaded into 50-t dumpers. There are 8 to 10 active faces at a time and 6 numbers of 250-mm-dia drills are used for primary drilling. One number of 150-mm-dia drill has been procured for developmental drilling. For secondary drilling in toes, boulders, etc., 105/112-mm rotary and diesel driven drills are utilised and 4 drills are in operation (Table 6.8).

The strata have been classified as very hard, hard and soft. For a 12-m bench, 15 -m holes are

TABLE 6.8 : MACHINERY DEPLOYED IN THE MINE

	Machine	Number
A)	**DRILLS**	
	Primary Drilling	
	Drill Master Hydraulic (250 mm dia.) IR Make	2
	IDM - 70 (250 mm dia) IR Make	1
	SBSH - 250 MM (250 mm dia.) Russian Make	3
	Developmental Drilling	
	C650 D-(150 mm RECP Make)	1
	Secondary Drilling	
	ICM-260 (105/112 mm dia. IR Make)	3
	Crawler Master (105/112 mm) IR Make	1
B)	**EXCAVATION**	
	Electric Shovels (4.6 cu m bucket capacity)	7
	PC -650 (Diesel operated 3.1 cu m bucket capacity) Hydraulic Shovel for developmental works.	1
	Front-end loader (3.8 cu.m. bucket capacity for fine ore reclamation at screening plant)	2
C)	**HAULING/TRANSPORT**	
	Haulpack (50 t, BEML Make)	18
	Caterpillar (50 t, HM Make)	5
D)	**MISCELLANEOUS EQUIPMENTS**	
	Dozers & Graders	4
	D-355A Komatsu Dozer	8
	Wheel Dozer	1
	Motor Graders	3
	Water Sprinklers	not known
	Tanker of 30 cu m capacity each	4

normally drilled so that 2-m subdrill is available and 1-m variation can be achieved for the purpose of flexibility of floor level.

The drilling parameters followed are as below :

	Type of ore	Spacing	Burden	Incli-nation
1.	Very Hard Ore (Steel Grey/Blue Haematite/BHQ)	6.5 m	5.5 m	Vertical
2.	Hard Ore (Laterite and Laminated Ore)	7 m	6 m	Vertical (15% incline in many cases)
3.	Soft Ore (Flashy Ore/Blue Dust/Shale)	8 m	7 m	Vertical

Holes are drilled in 2 to 3 rows in staggered pattern but in softer formation, 4 to 5 rows are drilled.

Cartridged slurry and emulsion explosives supplied by M/s. IBP, M/s. ICI/ M/s. IDL, M/s. MEL and M/s NFCL are used. Safety fuse is practiced for firing. The powder factor achieved is around 6 t/kg of explosives used.

Loading and hauling : The mine works on three-shift basis, two operating shifts and one for maintenance. The average haul distance to crusher is about 1.5 km. Twenty-three rear discharge 50-t dumpers are deployed. Loading is done by seven 4.6-m^3 shovels. One hydraulic shovel of 3.1-m^3 capacity is provided for developmental works. In each production shift, 12-15 dumpers are made available to fulfill targeted production. Support is provided by D355A Komatsu dozers, front-end loaders, motor grades for loading point cleaning.

The area is receiving 3,000 mm average rainfall in a year and the haulage roads are given a cross-slope towards the high-wall to prevent road erosion. The culverts and valleys provide natural outlets for water from the mine area.

Since the ore is of very high grade, no beneficiation is required to meet the quality requirements. Only ore processing is required to get the product sizes. For this purpose, crushing and cleaning plants, and conveying systems for various products have been created. The products are lumpy ore (-150+10 mm) and -10 mm fines. The fine ore handling system conveys fines produced in the screening plants to stacks and is loaded into robes. A third product, i.e. calibrated ore (-40 mm+10 mm) is also produced. The fraction which occurs in the lump ore is screened and separated for despatch. In future, the entire lump ore may be connected to calibrated ore and fine ore with due modifications in view of increasing demand for it.

Power supply to the mine and other facilities is through a 132 KV MPEB substation. It is stepped down to 32 KV at main substation and further in stages, up to 3.3 KV for final use in the mine.

The mine has a fleet of earth-moving machinery and drilling rigs. Excavators including front-end loaders have the capacity range of 3.1 to 4.6 m^3 ; drilling rigs are of dia 105 mm, 150 mm and 250 mm, but all the hauling equipments are of 50-t capacity. Apart from these, the fleet of equipments includes dozers, graders, water sprinklers and tankers. Details of these equipment are given in the Table 6.8.

6.8.3 Case Study III
Mine Producing Over 18 Mt r.o.m. (6 Mt Concentrate) per Annum

6.8.3.1 Deposit

The cluster deposits occur as banded magnetite quartzite with an average thickness of iron formation extending up to 100 m. The top layer of iron formation is weathered where magnetite is partially oxidised to haematite. The underlying primary BMQ is similar to taconite ore. The present scope of mining includes only the weathered ore which has an average iron content of 38 percent. This is beneficiated to procure concentrate of +67 percent iron.

Extensive and detailed exploration by way of drilling, aditing, trenching and pitting has been carried out at the deposit. These deposits are known to be among the largest deposits in the world. In one of the deposits, where the mining is currently carried out, reserves of 700 Mt of weathered ore and 450 Mt of primary BMQ have been proved. Besides, there are other deposits in the vicinity with probable reserve of 4,000 Mt.

The mine is one of the largest iron ore mines in the world with low grade iron ore but 100 percent export-oriented unit producing 6 Mt of concentrates and 15 Mt r.o.m. It is located in the State of Karnataka : in the Aroli Ranges of the Western Ghats. The nearest railhead is Mangalore which is 110 km away by road from the mine. Mangalore is also the port where the company's export terminal facilities are located. These deposits are located 100 km east of Karnataka on the West Coast of India. The project site is well connected by highways with adjoining towns.

6.8.3.2 Orebody

(i) The orebody is initially divided into two working pits, namely East and West Pits; further an extension called K_1 was added to the East Pit, which provides 20 Mt of ore. During the prospecting stage, in addition to trenches, pits and adits, boreholes were drilled in 200 m x 100 m grids. The borehole data formed the basis of cross-sections from which detailed slice plans were prepared. The ores were classified into 17 different types based on their physical properties assessed through beneficiation.

(ii) The orebody consists of a main ridge about 6 km long and has four secondary ridges in the shape of a head. The width of the deposit is 800 m. The deposit is of sedimentary pre-Cambrian ore formation, consisting of laminated magnetite and quartzite. The exposed ore is weathered and friable ore contains significant amounts of hematite, goethite and limonite. There is no overburden of any significant thickness anywhere. The orebody consists of large patches of phyllite clay and magnetite schist which constitute about 10% of the estimated waste for removal. The total reserve of weathered ore and transitional hard weathered ore is about 610 Mt. The mine was required to handle 22.5 Mt r.o.m. and waste to produce around 7.5 Mt of concentrate with 4% silica. However, market conditions dictated that the mine should produce concentrates at around 3% silica and with this higher quality, the mine has been able to achieve 6.05 Mt of concentrate per annum so far.

(iii) The slice plans and cross-sections were processed with the help of computers by Metchem, Canada. The detailed mine plan has been prepared showing road alignments, and working plans for the first 10 years of operations. The orebody was divided into 32 benches, each 14 m high, starting from the first bench at a level of 1281 mRL. The two crushers were located, one each in East and West Pits at 1015 mRL and 1025 mRL, respectively.

Winning the ore is by conventional shovel-dumper operation wherein the r.o.m. is dumped into the two 150 cm x 225 cm gyratory crushers located in each pit, reducing size of the ore to -17.5 cm in a single stage. The 160-cm steel cord belt conveyors carry the ore down to a transfer tower from where the two streams of ore mix and are further transported to the surge pile (capacity 0.35 Mt) by 180-cm steel cord conveyor belt. The ore is recovered by feeders below the surge pile, to eight numbers of silos through a system of belt conveyors. The ore is now taken into the autogeneous mills (4 No.) ground to -20 mesh and subjected to the first stage of magnetic separation. The concentrate is produced by passing through stages of magnetic separation after ball milling and treating the nonmagnetic portion by spiralling and flotation techniques. The concentrate is stored in agitated tanks prior to pumping to loading point in stages.

A number of new concepts and technology have been brought in by the project and implemented.

(a) The project utilises low grade ore made viable by very large scale of exploitation and cheap transportation to the port through slurry pipeline.

(b) The gyratory crushers of 4000-tph capacity each, do away with further stages of crushing.

6.8.3.3 *Drilling*

Drilling and blasting of the ore required large inventories. Large diameter blasthole rotary drills, capable of drilling holes up to 17.8 m in one pass (without the need to add or remove drill steel for each hole) were purchased from Buyers Exie of the USA. Subsequently, two more drills of similar specification, but all hydraulic, have been added. There are four Ingersoll Rand rigs of the USA.

6.8.3.4 *Blasting*

The drilling and blasting activity is closely coordinated by the Mine Engineering Department. They prepare the site plan, the drilling plan, stake out the drill site, prepare the 'as drilled' blasthole plan, the explosive loading charts, the hookup plan and the post-blast plan for use by the operators.

To facilitate continuous availability of ore, for quantity as well as blending requirements, three-month inventory is maintained at the mine. In addition, the mine works all through the heavy monsoon, when the water-charged strata do not permit drilling. The pre-monsoon months therfore require additional drilling/blasting to take care of the monsoon and post-monsoon months.

The 14-m benches are drilled to a full depth of 17.8 m at the time of drilling and backfilled to the planned depth. This takes care to add 10% subdrill and 1.4 m of the hole will be backfilled, keeping 15.4 m depth. The additional depth drilled takes care of the spalling from the blasthole sides which is substantial due to the friability of ore. Burden spacing varies between 10 m x 10 m , and 11.5 m x 11.5 m in most cases. Specific care is taken to see that blastholes passing through the hard bands in particular are charged with higher aluminised charges. The stemming column is kept at around 7 m in case of soft holes. Charge varies from 72 kg/m to 98 kg/m of blasthole depending on formation. If any blastholes are changed during monsoon, the explosive density is kept at around 1.05 to displace water while charging. The explosive, as it is pumped into the blasthole, has a density of 1.2 which stabilises at 1.05. The blastholes are stemmed after the gassing process is completed taking precaution to see that the detonating cord at the collar is not left exposed.

The specific gravity of the low grade ore is around 2.3 to 2.5 only. Explosive loading sheets showing charge densities appropriate to the hardness of the strata around holes are supplied to the blasting crew and the holes are loaded. One kg of boosters per hole is used. The pumpable slurry system is able to supply emulsion or slurry explosives. In both cases, the percentage of aluminium and the specific gravity can be varied from hole to hole. The holes can be loaded up to 15 days before the day of the blast although in case of slurry explosives in wet strata, sleeping more than 5 days in the hole has not given good results.

Conventional detonating cord connections are made and entire blasting is done. Non-electric blasting has been tried with indigenously available systems. Explosive consumption of around 200 g per tonne of ore is typically achieved. The soft ore with hard bands in between does not allow burden spacings to be enlarged any further.

The mine consumes about 3,500 t of pumpable slurry and emulsion explosives per annum. Ease of excavation by shovels and the grinding factor are kept in mind while evaluating blast fragmentation.

6.8.3.5 *Loading*

The P & H 2100 BL Rope shovels are deployed in faces located in the East and West Pits depending on the blending requirements. The control room monitors the loads to be brought to the crusher from each shovel on an hourly basis. All the shovels and dumpers are in communication with the control room through FM radio sets. In case of a shovel breakdown, the control room will switch to another shovel and divert dumpers to the new shovel. In general, six shovels are named in each shift for production purposes, but any shovel for development activity is normally operated in general shift. One shovel is normally under major maintenance and another is either at the stockpile or in developmental work. Thus, there are eight shovels available and availability is around seventy-five percent and utilisation thereof around seventy-two percent.

6.8.3.6 *Haulage*

After studying different aspects of haulage which would be suitable to the mine, the 120st electric transmission WABCO 120 C truck was purchased. The truck has been performing very well and the company received, in October, 1994, another batch of three trucks of the same make with improved wheel motors and electronics. The Coal India has been benefited much from this experience of electric transmission. The truck availability has been found more than 65 percent.

A fleet of thirty WABCO 120 C electric dumpers is available at the project; twenty-one trucks are on the orebody and the rest in the Central Shops for major maintenance and repairs. Out of the twenty-one trucks at the mine, depending on the running breakdown attended at the mine service station, around 17 trucks are available for hauling from the shovels. Truck availability of around 55-56% is now being achieved. The trucks have completed more than 2,500 operating hours in general and the availability has slipped from 65% to the present 55%. The typical average lead distance from the mine is 2.2 km per trip.

At this mine, road design and maintenance deserve attention and hence have always been given the importance. The mine is located in a high rainfall area and special care in designing the roads was taken to prevent road erosion by water. The roads have been designed entirely on cut at 6.25% gradient with properly laid out curves. These have been designed to avoid blind corners and further have been bermed with 2.5 m embankments on edges. The berms have prevented many serious accidents to 120-t dumpers. The drain water is carried down to 4 m x 4 m size concrete culverts suitably placed at intervals across the road. The outlets of the culverts have been placed on ridges so as to avoid erosion. The roads have a cross-slope 2-4% towards the highwall drain to prevent water running along the road surface. Since the ore is generally soft, the roads have to be solid to increase its load-bearing capacity. The roads are packed with 20 cm size rock aggregates and topped with 1.2 cm gravel and finally topped with high grade fine ore or washed silt.

6.8.3.7 *Equipment Deployed*

The details of mining mchinery being used in the project are enumerated in Table 6.9.

6.8.3.8 *Quality Control*

The bench slice plans are used to prepare a tentative excavation plan for a particular year. These are again used for updating actual excavation and the quarterly excavation plan. Areas are delineated every month with due consideration to the shipping schedules. The drilling areas are determined to maintain an adequate stock of low and high grade ores.

TABLE 6.9 : DETAILS OF HEAVY EARTH MOVING MACHINERIES

Sl. No.	Model/HP	Capacity	Number on Property
1.	Shovel P & H 2100BL	14 cu.yd	8
2.	Production drill BE 60R Series III Rotary Electric	$12\frac{1}{4}$ inches	3
3.	Production drill IR DMH Rotary Hydraulic	$12\frac{1}{4}$ inches	2
4.	Dumpers WABCO	120 st.	30
5.	Dozer D355A KUMATSU	410 hp	8
6.	Dozer D80A BEML	120 hp	1
7.	Dozer D265 KOMATSU	--	1
8.	W.Loader Cat 988 B	6 cu yd/375 hp	3
9.	W.Loader Dresser WA-600	7.5 cu yd	2
10.	R.T.Dozer Clasik	280 hp	6
11.	16G Cat Motorgrader	275 hp	5
12.	Drill IDM 20 (IR)	6 inches	2
13.	IR Grawlair Drill	4 inches	5
14.	Water sprinkler BEML 35 t Chasis	28000 Litres	6
15.	Tata Hitachi Hydraulic Excavator	3 m^3	2
16.	BEML Haulpak 35 t	380 hp	6

The drill cuttings are sampled on a daily basis and the results are plotted on the quality plan which is essentially based on the area of influence of each blasthole. The daily shovel advance is plotted on this quality plan so that the next day's quality could be forecast. If it becomes necessary, shovels are shifted from one place to other, depending on the shipping priority. In addition, occasionally, face samples are also collected to check results.

Entire production of the mine is exported. The controls on Fe content, and silica, phosphorus, sulphur and other impurities, are of extreme importance as these have to be within the limits stipulated in the contract. The orebody is of low grade and the export requirements stretch its quality obligations to the buyers. Therefore, extreme care is required at every stage.

The plant is designed to work on a twenty-four hour setting basis. Variations beyond $\pm 3\%$ total Fe can cause lower recovery or quality problems. At the plant, the feed ore is sampled every half an hour and reported every four hours after averaging. Thus, constant monitoring is done. The final product collected in the agitator tanks before pumping upto loading point is also sampled, and after dewatering, the concentrate is piled in the sheds and it is sampled again in addition to a third party sampling requirements.

One area of problem has been that the plant is not getting uniform grade of ore every day. It was thought that the ore as it is blended from the faces would get mixed in the crusher hopper and gets further mixed as it is rehandled in the surge pile and silos. As a result, the plant would get a nicely blended mix. But it has been seen that the ore reports to the plant in discreate grades and violent fluctuations in grade are met with. Sequential dumping at the mine has been tried but has not practically succeeded. Some kind of mixing arrangement at the surge pile has been thought of but not implemented due to cost implications.

6.8.3.9 Environment

Since the mine is located in high rainfall area, the erosion of working faces, road surfaces and other exposed areas is substantial. On an average, 7,000 mm rainfall per annum carries down about 1 Mt of ore and waste. To prevent this material from polluting the river systems in the area, two of the principal valleys in the orebody have been dammed and the drains, both natural and created, are diverted through these dams. The silt is arrested in these dams, and every year, nearly 1 Mt ore is recovered and fed back into the concentrator through the sewege pile for processing. Extensive plantations of Eucalyptus, Accacia and Bamboo have been made on mined out areas and elsewhere within the lease area.

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