Potentials and Availability of Mineral Raw Materials for Ferro Alloy Production in India

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ABSTRACT

With an ever increasing tempo for more and more iron and steel production, the demand for ferro alloys has increased considerably, which would ultimately depend on the mineral raw materials position. With this in view an appraisal has been made in this paper on the potentials and availability of some of the mineral raw materials for ferro-alloy industry. The different raw materials with their specifications, occurrences, distribution, grades, reserves, production, consumption, exports and imports etc. have been discussed.

INTRODUCTION

The name "Ferro-alloys" covers a wide range of metals like chromium, manganese, nickel, cobalt etc. alloyed with iron and containing various percentages of other minor elements such as carbon, silicon, phosphorous and sulphur. With the growth of iron and steel industry, the demand for the ferro-alloys in the country has increased considerably. The estimated demand for ferro-alloys by the end of 1985, is expected to be of the order of 6,43,000 tons. We are having more than 20 manufacturing units holding industrial licence with an aggregate installed capacity of 4,45,000 tons per annum but the actual production in the year 1982 was only about 2,47,300 tons.

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The mineral raw materials required for the production of ferro-alloys can be broadly classified into three groups based on their scale and use, as below :

1) Tonnage ferro-alloy mineral raw materials comprising chiefly manganese ore, quartzite and chromite.

2) Special ferro-alloy mineral raw materials like tungsten, molybdenum, vanadium, titanium, nickel, cobalt minerals etc.

3) Other ferro-alloy mineral raw materials which include phosphorus, boron, zirconium, niobium minerals etc.

In this paper detailed discussion has been limited to the first two categories of raw materials, while others have been dealt with briefly.

TONNAGE FERRO-ALLOY MINERAL RAW MATERIALS

Manganese ore

The important commercial manganese ore minerals are, pyrolusite, psilomelane, cryptomelane, manganite, braunite, hausmanite and rhodochrosite. The suitability of manganese ore is evaluated in terms of manganese and iron contents and their ratio, phosphorus content and slag forming constituents like silica and alumina. The acceptable specifications in general for metallurgical grade ore for production of standard ferro-manganese are as follows [8, 9, 12]:

Grade	Mn %	Fe (max) %	SiO (max) %	P (max) %
1.	48% and over	7.0	8.0	0.12
2.	46% - 48%	7.5	9.0	0.15
3.	44% - 46%	9.0	10.0	0.15
4.	40% - 44%	12.0	12.0	0.15
5. General	48%	6-7%	6%	0.12%
	Al_2O_3 - 4% (max); Size - should be hard lumps between 5mm and 50mm			

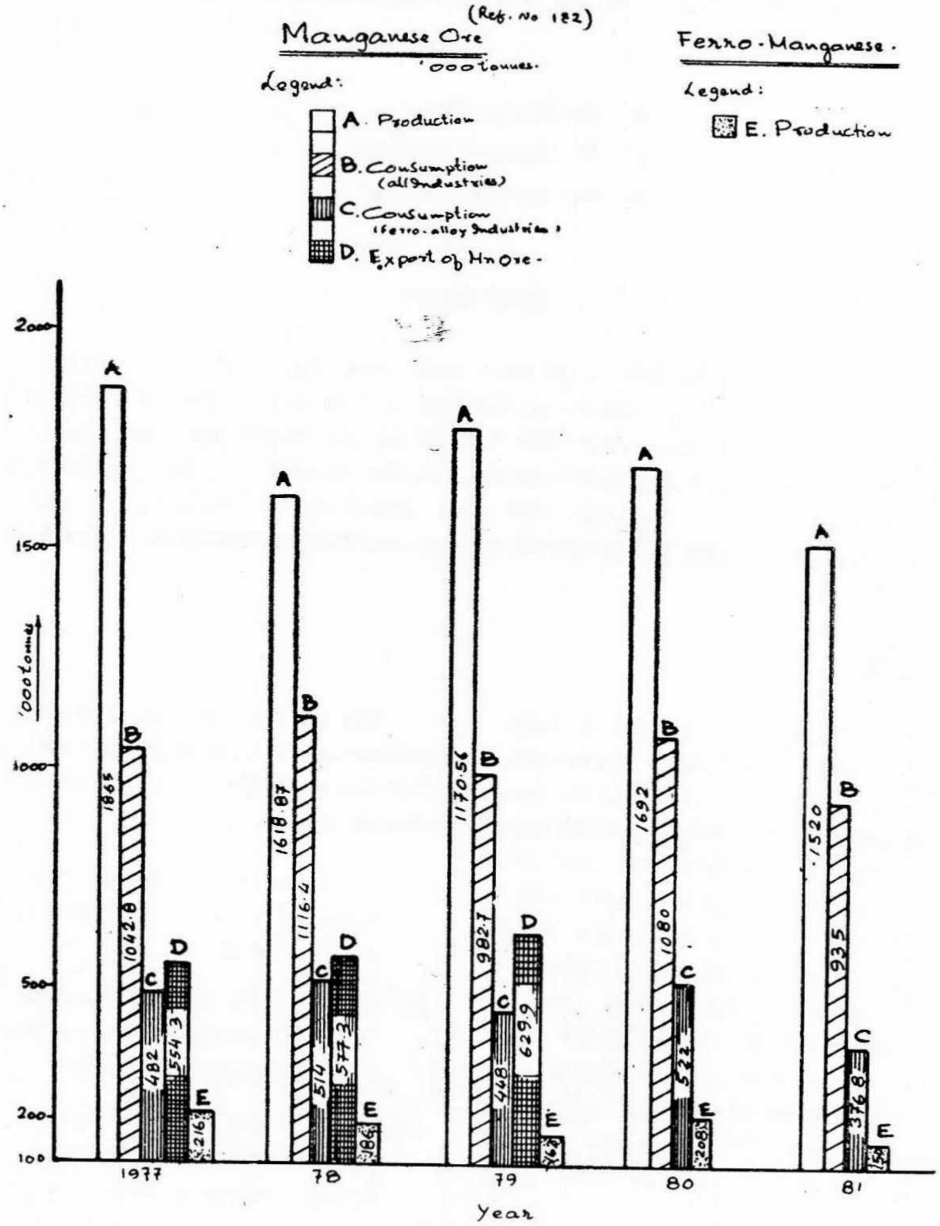

FIG. 1

TABLE — 1

Categorywise reserves of manganese ore in India as on 01-01-1979
(state and gradewise)

(Quantity : in million tons)

State	Measured reserves FMG	Measured reserves BG	Measured reserves LG	Indicated reserves FMG	Indicated reserves BG	Indicated reserves LG	Inferred reserves FMG	Inferred reserves BG	Inferred reserves LG	Unclassified reserves	Total	Remarks (in General)
Orissa	1.02	1,41	3.53	0.93	1.60	3.24	2.68	5.40	11.18	9.26	40.25	Ferruginous ores with low phosphorous.
Maharashtra	2.35	0.69	0.02	2.20	1.18	0.66	0.94	0.34	0.49	2.00	10.87	Siliceous and ferruginous ores.
Karnataka	—	—	—	—	0.81	1.02	—	4.31	13.99	—	20.13	,,
Madhya Pradesh	2.36	0.51	—	1.25	0.40	0.42	3.57	3.20	0.06	5.0	16.77	Ferruginous ores
Goa	—	-	—	—	—	3.29	—	—	—	—	3.29	,,
Gujarat	—	—	—	—	—	—	—	2.90	—	—	2.90	Siliceous ores with high "phosphorous".
Andhra Pradesh	—	—	—	—	—	0.87	—	—	0.37	3.00	4.24	High phosphorous ores
Rajasthan	—	—	—	—	—	—	0 002	0.14	0.18	—	0.322	Garnetic-ferous siliceous ores
India	5.73	2.61	3.55	4.38	3.99	9.50	7.192	16.29	26.27	19.26	98.772	
		11 89			17.87			49.75		19.26	98.772	

N. B. : F. M G. = Ferromanganese grade (46% Mn & above), B. G. = Blendable grade (35% to 46% Mn)
L G. = Low grade (35% Mn and below). (Source I. B. M.)

Production and demand

At present there are eight industrial units produding ferro-manganese, with an installed capacity of 2,40,900 tons per year, but in the year 1982, the production was of the order of 1,50,700 tons. The indigenous demand of course, is related to the quantum of steel produced in the country. It is expected that the demand for manganese ore is likely to go upto more than 5,00,000 tons by the end of 1985. The statistics on production, export are given in Figure 1.

Reserves and distribution

The known reserves of manganese high grade and blendable grade ores suitable for the ferro-manganese, along with low grade ores are given in Table 1. However, recent estimates of the recoverable reserves of all grades of manganese ore are put at 114.4 million tons approximately of which 22.0 million tons are measured category, 21.1 million tons indicated category and remaining 71.4 million tons are of inferred category. The distribution of known reserves of high grade ore suitable for ferro-manganese with manganese content ranging from 42 to little over 46% are by and large confined to Balaghat District of Madhya Pradesh and Nagpur, Bhandara District of Maharashtra and Keonjhar, Sundergarh Districts of Orissa [1,2,9].

Chromite ore :

Chromite, the double oxide of chromium and iron, usually occurs in ultrabasic rocks. The presence of gangue affects the composition of chromite ores by lowering the Cr_2O_3 content as well as Cr : Fe ratio which are the main factors of the chrome ore quality. In general, the acceptable specification of metallurgical grade ore for production of standard grade ferro-chrome, charge chrome, along with other Indian ferro-alloy plant chromite ore specifications are as follows [1,9,16].

Name of the plant	Specifications				
	Cr_2O_3 (min%)	Cr:Fe	P & S (%) max	Al_2O_3 (%) max	Size
1. General					
a) Ferro-chrome	48	2.8:1	0.04 & 0.08%	8-10, SiO_2: 2-6%	Lumpr: 25 to 50 mm fines : 2 to 10mm.
b) Charge chrome	40-44	1.6:1			Both lumpy and friable.
2. Ferro-alloy corporation, Garividi.	48	2:1			1" to 3"
3. Industrial development Corporation of Orissa Ltd., Jajpur.	50	3:1	SiO_2: 6% (max)		lumpy ore.
4. Visvesaraya Iron & Steel Limited, Bhadravati	52		0.01 each		10-50 mm

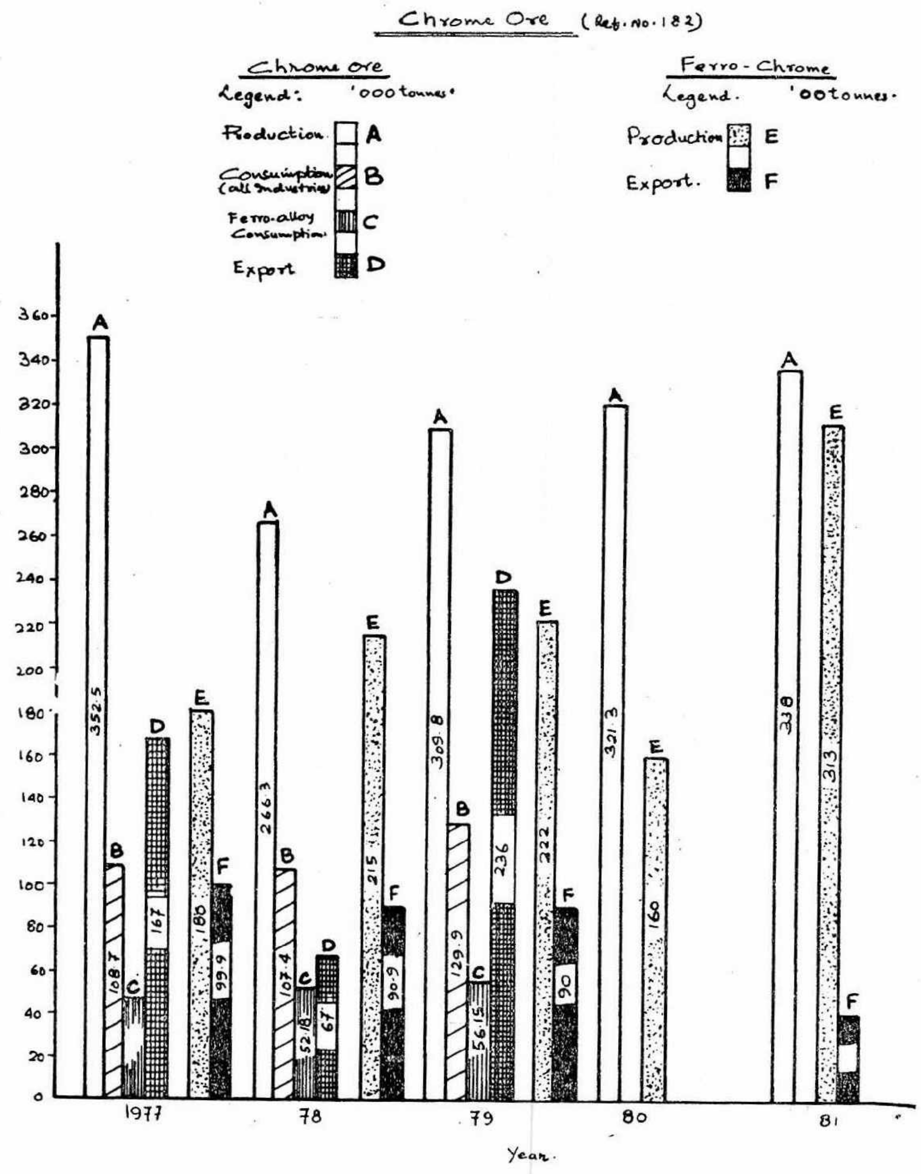

FIG. - 2

Production and demand

There are two units Producing ferro-chrome & silico-chrome with an installed capacity of 31,000 tons per year. Production has also been reported intermittently by VISL, Karnataka. Total production of ferro-chrome and silico chrome from domestic plants in 1982 was 40,244 tons and 4,468 tons respectively. The estimated demand for chromite ore by all industries by 1990, will be about 3,55,000 tons[11,13]. The statistics on production, [1,2] export and consumption of ferro-chrome and chromite ore from 1977 to 1981 is given in Figure 2.

Three charge chrome plants with a total annual capacity of 1,50,000 tonnes are located in Orissa based on the chromite ore available in the state.

TABLE — 2

Detailed distribution of chromite ores along with their chemical analysis and Cr : Fe ratios in India

Location	Cr_2O_3	FeO %	Al_2O_3 %	SiO_2 %	MgO %	Cr/Fe
1. Andhra Pradesh						
Kondapalli area, Krishna (Dt.)	38.89 to 55.6	20 to 23	7.8 to 17.9	0 6 to 8.8	9.2 to 12.2	0.86 to 1.07
2. Bihar						
Roro, Singhbhum (Dt.)	48.4	18.9	4.0	6.1	18.7	1.13
Kakatakuti, Jojohatu	47.2	23.67	11.51	3.0	11.99	0.88
Bichaburu, Kusmita (Dt)	41.1	17.37	11.58	12.4	17.73	1.04
3. Karnataka						
Byrapur, Hassan (Dt.)	45.50	19.54	6.22	5.81	12.77	1.03
Sindhuhalli	48.65	18.63	12.70	2.45	—	1.15
4. Maharashtra						
Pauini, Bhandara (Dt.)	40 to 42	18 to 21	10 to 17	5 to 9	13 to 15	0.88 to 0.98
" "	46 to 48	15 to 21	10 to 17	4 to 8	13 to 15	1.01 to 1.35
" "	48 & above	14 to 16	15	3 to 6	13 to 15	1.51 & above
Vagda, Ratnagiri (Dt.)	32.39	21	12	10	17	0.68
5. Manipur						
Moreh, Tengnopal (Dt.)	40 to 47	—	—	—	—	—
6. Orissa						
Baula, Keonjhar (Dt.)	53.96 to 56.0	12.99 to 18.12	5.24 & above	6.18 to 20.4	16.99 & below	1.36 to 1.83
Saraubil, Cuttack (Dt.)	55.65 to 59.67	11.2 to 11.1	—	2.22 to 4.0	—	2.19 to 2.37
7. Tamil Nadu						
Sitampundi complex	26.73 to 28.2	22.38 to 31.5	24 to 41	6.18 to 14.36	0.32 to 2.4	0.39 to 0.53

Reserves and distribution

Fairly sizeable deposits of chromite ore occur in Orissa, Karnataka, Maharashtra, Manipur and Bihar states. Known occurences have also been reported from Andhra Pradesh, Tamil Nadu, Nagaland, Jammu & Kashmir and Andaman Nicobar islands. The recent estimates of chromite ore reserves are 111.25 million tons, of which 24.19 million tons measured category, 41.58 million tons, indicated category and remaining 45.48 million tons are of inferred category. The detailed[6] distribution of chromite ore along with their chemical analysis and Cr : Fe ratio is given in Table - 2. 90% of the reserves are concentrated in Orissa state only. 1/5th of the total measured category reserves are of metallurgical grade, while the remaining reserves are non-metallurgical grade [1,9,10].

Quartzites :

Quartzite which is the cheapest and rich in silicon is used for the production of ferro-silicon. Dense quartzite seems to be better suited as a raw material than coarse grained or loosely compacted quartzite or sandstone. The suitability of quartzite is assessed primarily in terms of the silica content though maximum tolerable limit for alumina and iron contents are also stipulated. For producing ferrosilicon, the quartzite should have minimum 97 to 99% SiO_2, Fe_2O_3 0.05% to 1.1% maximum, Al_2O_3 0.05 to 0.8% maximum[9,13]. It should also be free from objectionable impurities such as phosphorous and sulphur.

Production and demand

There are six plants for ferro-silicon production with total aggregate licenced capacity of 76,600 tons per year[1]. Production of ferro-silicon in the year 1982 was 36,060 tons[2].

In the same year the demand of ferro-silicon was approximately 21,256 tons, which indicated 100% degree of self-sufficiency. The projected demand for the ferro-silicon and quartzite by the end of 1985 would be of the order of 30,000 tons and 60,000 tons respectively. The production of quartzite in the year 1982 was 3,32,208 tons[2]. Presently the quartzite requirements are met from the deposits of Srikakulam, Khammam and Hyderabad districts of Andhra Pradesh, Shimoga district of Karnataka. Keonjhar and Bolangir districts of Orissa and also from other states like Gujarat, Rajasthan, Madhya Pradesh and Kerala etc. Consumption of quartzite and ferro-silicon during 1977 to 1981 are given in Table - 3.

Reserves

Total estimated reserves of quartzite of all grades would be of the order of 273 18 million tons[1] though the inventory of reserves estimation is not fully available. However reserves of quartzite are known to be substantial, which can meet the requirements of all industries including ferro-alloy industry.

SPECIAL FERRO-ALLOY MINERAL RAW MATERIALS

Tungsten Minerals

The most important ore minerals are scheelite, wolframite, ferbarite and hubrenite. For production of ferro-tungsten, which finds extensive application in the manufacture of high speed steels, magnetic valves etc., the tungsten ore concentrate must contain a minimum of 65% WO_3.

In India, tungsten production is reported mainly from Rajasthan and West Bengal. The present production of this metal is inadequate to meet the domestic requirements. The production figures for the year 1980, 1981 and 1982 being only 44.1 tons, 38.8 tons, 53 5 tons respecpectively. The estimated demand by all industries may rise upto 2400 tons of tungsten concentrate (65% WO_3) by the end of 1985, where one third of it would be mainly consumed by the ferro-alloy industry alone. The production, imports [1,2,12] are given in Table - 4.

The total estimated reserves of the ore are

TABLE — 3

Production, consumption and exports of quartz/quartzite and ferro-silicon in India during 1977 to 1981

(Quantity in tons)

Year	Quartz/Quartzite			Ferrosilicon		
	Production	Consumption by ferro-alloy industry	Exports	Production	Exports	Imports
1977	3,68,451	1,38,439	10,707	44,675	6,424	38
1978	3,90,593	1,42,644	9,541	52,366	9,560	106
1979	3,38,062	1,38,931	16,407	53,087	7,594	179
1980	2,55,404	1,13,000(P)	22,104	54,319	—	8,807
1981	2,91,407	1,23,000(P)	N. A.	60,253	1,000	N.A.

P = Provisional, N. A. = Not available.

TABLE — 4

Production, imports of special ferro-alloys in India during 1977 to 1981

Quantity (in tons)

Name of ferro-alloy	Year	Domestic production	Imports of respective ore & concentrates	Imports of ferro-alloy
Ferro-molybdenum	1977	314.8	* 21	159
	1978	327.7	* 34	127
	1979	302.2	* 32	431
	1980	162.3	19	948
	1981	158.7	N.A.	N.A.
Ferro Tungsten	1977	N. A.	541	1
	1978	12.90	333	—
	1979	21.86	321	—
	1980	21.21	594	10
	1981	12.17	N.A.	N.A.
Ferro Vanadium	1977	N.A.	412	33
	1978	226.0	216	10
	1979	123.0	270	26
	1980	92.26	278	—
	1981	117.9	N.A.	N.A.
Ferro Titanium	1977	N.A.	5,302	—
	1978	75.8	6,145	—
	1979	128.7	6,817	—
	1980	321.2	5,230	—
	1981	170.12	N.A.	—

* indicates molybdenum metal & scrap imports; N.A. = Not available.

about 10.54 million tons (with grades varying between 0.032 and 0.5% WO_3). The different category of reserves with grades[12] are given in Table - 5.

Molybdenum Minerals

The chief ore minerals are molybdenite and wolfenite. Molybdenum is an important alloying element, which, when added to steel in the form of ferro-molybdenum, improves hardness, toughness and strength at higher temperatures.

The production of molybdenum is inadequate to meet the indigenous requirements. The potential areas are Rakha Copper deposits containing on an average 0.11% Mo, Dariba-Rajpura Pb-Zn deposits, Malanjkhand copper deposits and the Karadikuttam area, Madurai district, which contain recoverable percentage of Mo. The reserves with grades are given in Table 6 whereas the ferro-molybdenum production, imports etc. are given in Table - 4. M/s. Uranium Corporation of India at Jaduguda is also producing moly concentrate intermittently as a by-product.

Vanadium Ores

Vanadium occurs in the from of vanadium bearing titaniferous magnetite ores. It is also obtained as alumina sludge by-product with 10-20% V_2O_5 in alumina production from bauxites. Vanadium is a very important alloy metal for the production of various structural, tool and spring steels Ores containing 1.04% V_2O_5 and 53.1% Fe were successfully treated for the production of ferro-vanadium in the VISL plant, Bhadravati.

Regular production of vanadiferous ore has not been reported so far, except some quantity of vanadiferous magnetite ore occassionally mined by VISL from Masanikera deposit, near Bhadravati in Karnataka. But alumina sludge is being produced in some of the alumina plants. Vanadiferous titanomagnetite ores occur in Karnataka, Orissa and Maharashtra. In addition to this, the total estimated 2,403 million tons of bauxite with 0.01 to 0.2% V_2O_5, is a potential source for ferro-vanadium industry in India. The total estimated reserves of vanadium deposits are given in Table 7 and the production and imports of ferro-vanadium are given in Table-4.

Titanium Ores

Both ilmenite and rutile are important ore minerals of titanium, and are commonly found as mineral concentrates in the beach sands on coastal tracks. Ilmenite may also be found as a constituent of basic rocks and in association with magnetite and hematite. Rutile is also found as an accessory mineral in some igneous rocks.

Titanium is used in steel manufacturing as a reducer and alloying element to improve welding qualities and corrosion resistance of steels and also used in refining of high chromium steels[14,15].

India produced 1,84,556 tons of ilmenite and 7,192 tons of rutile in the year 1980. The production is mainly from Quilon district of Keralal and Kanyakumari district of Tamil Nadu. In the year 1979 the exports of ilmenite and rutile were 53,043 Tons and 1,000 tons respectively, whereas the imports of TiO_2 was 5,977 tons. The production of ferro-titanium in the year 1982 was 68.949 tons[2].

The total estimated reserves by Atomic Mineral Division is 138 million tons of ilmenite and 7 million tons of rutile. In addition to that 230 million tons of raw sands with 9.4% ilmenite and 0.4% rutile was estimated in Chattarpur area, Orissa and 4 million tons with 20 to 40% TiO_2 in *Are-Kalbadevi* area in Ratnagiri district of Maharashtra.

The Indian rare earths limited has two processing plants with total annual capacity of 2,25,000 tons of ilmenite and 9,000 tons of rutile. One preconcentration plant at Manavalakurichi has started for enriching heavy mineral content from 50 to 95%. The Kerala Minerals & Metals Limited has one plant at Chavara.

TABLE — 5

Estimated reserves and distribution of tungsten ores.

Sl. No.	Area	Quantity (in million tons)	Grade $\%WO_3$	Equivalent to 65% WO_3 conc. (in tons)
1.	Agargaon area, Maharashtra	2.250	0.064	2215
		0.400	0.271	1676
		0.720	0.161	1774
		0.386	0.048%	288
2.	Rajasthan Deganu vein deposit	0.533	0.54%	444
	Elluvial deposit	3.330	0.04%	3723
	Disseminated deposit	2.700	0.025%	1045
	Sirohi deposit	2.259	0.02 to 0.2	1542
3.	Bankura, West Bengal	0.384	Average 0.1%	228.43
4.	Burugubanda, Andhra Pradesh	—	—	96.17
5.	Karnataka : Kolar Gold Fields tailing dumps.	0 980	0.035 to 0.18%	725.96
	Mysore mines in Bangarpet	0 006	0.43%	25.50
	Hutti gold fields	0.041	0.33%	—

TABLE — 6

Estimated reserves and distribution of molybdenum ores.

(Quantity in million tons)

State and District	Indicated reserves	Inferred reserves	Total	Grade
Madhya Pradesh, Balaghat Dist.	—	8.000	8.000	0.02 to 0.06% Mo
Meghalaya, Khasi Jaintia hills	0.118	—	0.118	0.15 to 0.48% Mo
Tamil Nadu, Madurai Dist.	—	0.519	0.519	0.02 to 0.14% Mo
India (total)	0.118	8.519	8.637	0.02 to 0.48% Mo

TABLE — 7

Distribution and estimated reserves of vanadium ores

(Quantity in million tons)

State	Total reserves	Grade % of V_2O_5	Measured category	Indicated	Inferred
Karnataka	17.67	0.41 to 1.0% of V_2O_5	0.54	4.20	12.93
Orissa	5.25	0.21 to 2.41% of V_2O_5	2.4	0.26	2.59
Maharashtra	6.20	0.88 to 1.16% of V_2O_5	—	—	6.20
Total	29.12	All grades	2.94	4.46	21.72

TABLE — 8

Estimated reserves and distribution of nickel ores

(Quantity in million tons)

State and district	Measured	Indicated	Inferred	Total	Grade
Orissa (Cuttack)	16.674	59.570	65.570	141.791	Cut off 0.7% Ni considering the reserves within each deposit with 1% Ni or above average grade.
Orissa (Keonjhar)	—	—	7.970	7.990	0.2% to 0.7%.
Orissa (Mayurbhanj)	—	—	10.500	10.500	0.8% Ni cut off.
Total (India)	16.674	59.547	84.040	160.261	All grades

Recently I. R. E. L. has set up a beach sand processing plant called "Orissa Sand Complex" in Chattarpur coastal area. Ferro-titanium production, imports are given in Table - 4.

Nickel Ores

Workable deposits of nickel ore occurs in several localities of Sukinda area (where Ni is 0.8% to 1.14% and cobalt 0.06%) as nickel laterites in Kansa, Saruabil. Chrome ore overburden also contains Ni 0.8% and 13000 ppm Co. Occurences are also recorded in Rajasthan, Manipur, Tamilnadu, Jammu & Kashmir, Himachal Pradesh, Andhra Pradesh and Assam. About 9 million tons of nickeliferous magnetite is located in Nagaland[10] shown in Table - 8 with detailed break up. Nickel is being recovered by HCL as by-product in the form of nickel sulphate from the copper ores of Singhbhum copper belt containing Ni 0.05 to 0.13%.

Cobalt Ores

The cobalt mineral occurences were noticed in copper ores of Khetri and other areas of Rajasthan with nickeliferous pyrrhotite ores near Arumanallur in the Kanyakumari district of Tamilnadu, copper ores of Nungon in Manipur and with sulphides in Subansiri district of Arunachal Pradesh. Some of the Indian manganese ores also carry small quantities of cobalt and nickel It also occurs in Sukinda chromite belt of Orissa and in multimetal sea nodules of Indian Ocean[10].

Other Ferro-alloy Mineral Raw Materials :

Zircon is isued in the manufacture of ferro-silico-zirconium which added to steel to reduce the noxious effect of nitrogen and sulphur and as an excellent powerful deoxidiser ("Ferro-silico-zirconium" contains not less than 40% Zr and Si/Zr ratio of not over 0 55). Zircon is found as constituent of the beach sands between Quilon and Kanyakumari and in other coastal tracks of India. Zirconium mineral production in the year 1979 was 10,000 tons. Ferro-silico zirconium produced in the year 1981 was 6.6 tons[1,2].

Columbite, pyrochlore etc , which are chief niobium minerals for the production of ferroniobium are obtained from the weathered portions of pegmatites of Nellore mica belt of Andhra Pradesh, Lekola area in Bhilwara district of Rajasthan, Bihar and Tamilnadu. Ferro-niobium production in the year 1982 was 19.11 tons[2].

India has enough phosphatic ore deposits to meet the requirements of ferro-phosphorous industry.

Conclusions

In conclusion, it may be pointed out that in the case of mineral raw materials, such as quartzite, manganese ore, chromite, titanium and vanadium ore, the potentials and reserves are adequate enough, whereas the molybdenum, tungsten and nickel ore reserves are inadequate to meet the future requirements of industries.

The beneficiation of low grade ores and agglomeration techniques are an absolute necessity, for which there is no substitute in the light of present day economy. Eventhough lot of work has been done in this line by National Metallurgical Laboratory, Jamshedpur and other research organisations, still it calls for sustained efforts to solve some of the following problems :

1. Developing suitable technology to reduce phosphorus content to the acceptable limit in manganese ores.

2. Effective utilisation of chrome ore fines which constitute bulk of the Indian reserves, by beneficiation & agglomeration techniques. Suitable technology has to be developed for utilising the chemical grade chrome ores to make them suitable for ferro-alloy industry.

3. In the case of tungsten ores, R&D efforts should be made to recover the tungsten values, which are lost in the ultrafine stage, by adopting suitable beneficiation processes to get higher recoveries. In addition, fool-proof processes for chemical analysis is also necessary to know the actual grade of ore in the ROM stage.

Nickel, molybdenum and tungsten ores are still in proving stage. After proving, the need is to push speedily to recover the mineral values to augment the domestic production. Recycling of tungsten scrap will improve the availability of tungsten to the industry. In the case of cobalt, potentials are very meagre, calling for substitutes in the ferro-alloy industry. The nickel bearing laterites of Orissa and other potential areas have to be relied upon greatly to substitute a part of nickel imports. The development of suitable technology for the recovery of nickel and cobalt along with manganese from the multimetal nodules of Indian Ocean bed, would meet the future demand of ferro-alloy industry in the country. Further, we can hope new deposits will be investigated by extensive detailed survey in the possible metallogenic provinces to reach self-sufficiency.

Acknowledgement

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Discussion

A. S. Ray, Alloy Steels Plant, Durgapur

1) Can you please give the form and the chemistry of both high grade and low grade manganese ores available in India ?

2) What is the extent of phosphorous removal by beneficiation ?

Answer

Total manganese high grade ores with 46% Mn and above are about 17.3 million tonnes in the form of lumps as well as fines. Low grade ores are about 40 million tonnes.

Extent of phosphorus removal in manganese ores by beneficiation depends upon the mineralogy. If the phosphorus is present in the form of apatite, it is possible to remove it completely, but if phosphorus is present in the lattices of manganese mineral, it is difficult to remove to any extent by ordinary methods of beneficiation.

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1) What methodology can be adopted for recovery of molybdenum and tungsten from industrial wastes ?

Answer

There are so many conventional methods for Mo and W. For tungsten the most versatile process, to my mind, seems to be the zinc distillation process patented by Panul Bernard of U. S. B. M.