Mining Geological Studies of Avagudem Manganese Vizianagaram District Andhra Pradesh India

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Abstract: India is the third largest producer of manganese ore in the world. The countries most important ore deposits are Syngenetic, epigenetic and lateritic. Supergene enrichments associated with the first two groups. On the basis of mode of occurrence and association with different kinds of country rocks, the Indian manganese ore deposits have been classified as **Gondites**, **Kodurites** and **Laterite**. Indian manganese ore deposits occur mainly as metamorphosed bedded sedimentary deposits associated with Gondite Series (Archaean) of Madhya Pradesh, Maharashtra, Gujarat, Odisha and with Kodurite Series (Archaean) of Odisha and Andhra Pradesh and Proterozoic sedimentary manganese deposits of Penganga group Adilabad district of Telangana. The subject area is a part of the Archean terrain consisting of Biotite Gneisses, Garnet Sillimanite Gneisses, Feldspathic Quartzites, Calc-granulites, quartz veins etc. The Garnet Gneisses occur individually or intermixed with Kaolin or in Red loam. The lithomarge is generally yellow to brown in colour and at the contacts of the ore body, it is dull grey which is due to the presence of Manganese Oxide and it is termed as Wad. The general strike of the ore body is NNW-SSE with dip 0f 700 towards east.The environmental aspects are being monitored regularly and seasonally by an environmental laboratory. As such the portability of air is fresh and unpolluted in this area.

Key words: Manganese, Gondites, Kodurites and Laterite, Syngenetic, Epigenetic and Supergene Enrichments, Environmental aspects

I. INTRODUCTION

Manganese makes up about 1000 ppm (0.1%) of the Earth's crust, making it the 12th most abundant elementEmsley,John(2001)[1].Geochemically, Mn behaves like Mg, Fe, Ni, and Co and tends to partition into minerals that form in the early stages of magmatic crystallization. Significant quantities of Mn persist, however, in melts and can be plentiful in late-stage deposits such as pegmatites. Mn is readily depleted from igneous and metamorphic rocks by interactions with surface water and groundwater and is highly mobile, as Mn (II), in acidic aqueous systems. Near the Earth's surface, Mn is easily oxidized, giving rise to more than 30 known Mn oxide/hydroxide minerals. These oxides are the major players in the story of the mineralogy and geochemistry of Mn in the upper crust and the major sources of industrial Mn.

Indian manganese ores are preferred by many as they are generally hard, lumpy and amenable to easy reduction[4].In the Indian continent, the deposition of manganese must have taken place in varying environmental settings and by different geological processes but the sedimentary mode of formation far outweighed other methods such as supergene enrichment[3]etc. These manganese ores have been selectively exploited either for direct use or for sweetening the otherwise available phosphor-rich ores. Favorable geological and geomorphological settings, existing well connected rail and road links, easy amenability of ores to beneficiation and liberal Govt. policies make the exploitation of Indian manganese deposits practically a no risk proposition.

The 96% of global production of manganese today is from barely 8 countries viz. China (17%), RSA (15%), Australia & Brazil (12% each), Gabon, India and Kazakhstan (9% each) and Ukraine (8%) in decreasing order of tonnages raised annually. The global resource base is close to 52 billion tones including Indian reserve of about 378 million tones.

Manganese is a vital component of steel and over 90% of manganese produced world over is used for metallurgical purpose. Ore utilization mode and smelting practice vary from Operator to operator but the general world-wide approval is to produce high-carbon ferromanganese. Mn ore deposits are not evenly distributed in geologic time. Instead they cluster in three groups, one in the Palaeo-

proterozoic, the second in the Neo-proterozoic and the third in the Cenozoic. There is also a striking disappearance of sediment-hosted deposits from 1800 to 1100 Ma: The Palaeo-proterozoic peak is by far the largest and corresponds in time to the major episode of Banded Iron Formation deposition. Iron formation is also a common companion for the Neo-proterozoicMn deposits, but the Cenozoic peak, largely confined to the Oligocene, has no associated Fe mineralization. The largest volume of Palaeoproterozoic Mn is in the Kalahari region of South Africa. The largest Neo-proterozoic deposit is in Brazil with many smaller deposits occurring in China. The Oligocene deposits are centred on the Black Sea.

In recent years world manganese production has increasingly come from large sedimentary deposits of shallow marine origin. Stratigraphic units containing valuable manganese concretions consist of carbonates of fine clastic and represent deposition during high sea level stands, particularly on the margins of stratified basins.

II. GEOLOGY

India is the third largest producer of manganese ore in the world. the countries most important ore deposits occur in the form of sedimentary stratified metamorphic deposits in the Dharwar system , the manganese deposits are generally either Syngenetic {Ref.4} (sedimentary) as in Madhya Pradesh and Maharashtra, epige 82-87% manganese (residual enrichment and oxidation) as in Jharkhand, Orissa, Goa and Karnataka or lateritic and supergene enrichments associated with the first two groups. On the basis of mode of occurrence and association with different kinds of country rocks, the Indian manganese ore deposits have been classified as...

A) Gondites ores which are associated with metamorphosed manganiferous sediments: **{Ref.5}.**

B) Kodurites ores which are produced due to reactions the country rocks and an invading magma or composition.

C) Lateriod ores which are produced to metasomatism replacement and residual concentration. Georgia has huge deposits of manganese ore India is the third largest producer of manganese ore in theWorld**{Ref.4}.** The country s most important are deposits occurring (in the form of sedimentary stratified metamorphic deposits in the Dharwar system.

In India, extensive and rich manganese deposits occur in Madhya Pradesh, Orissa, Jharkhand, Andhra Pradesh, Maharashtra and Karnataka **{Ref.6**}. Indian manganese deposits display some distinct geological formations which are...

A) Deposits associated with the Khondalite rocks (garnet, sillimanite, gneisses) found in the Srikakulam district of Andhra Pradesh and in the kalahandi and Koraput districts in Orissa {**Ref.**[8]}

B) Deposits associated with in the iron bearing rocks (schist's) found in Karnataka states in the sandur hills **{Ref.13}.**

C) Deposited associated with limestone and dolomite which occur in the Sausars-manganese –marble and Adilabad manganese ore associated with the limestone .province of Madhya Pradesh ,Jharkhand and Gangapur , Ratnagiri in Maharashtra and Adilabad district in Andhra Pradesh **{ Ref.**[7]**}.**

Indian manganese ore deposits occur mainly as metamorphosed bedded sedimentary deposits associated with Gondites Series (Archaean) of Madhya Pradesh (Balaghat, Chhindwara&Jhabua districts), Maharashtra (Bhandara& Nagpur districts), Gujarat (Panchmahal district), Odisha (Sundergarh district) and with Kodurites Series (Archaean) of Odisha (Ganjam&Koraput districts) and Andhra Pradesh (Srikakulam&Visakhapatnam districts) and Proterozoic sedimentary manganese deposits of Penganga group Adilabad district Andhra Pradesh.

III. GENERAL GEOLOGY

The rock unit exposed in this region of the subject area belongs to Khondalie suite of Rocks of Archean system.

A. Local Geology

The subject area is a part of the Archean terrain consisting of Biotite Gneisses, Garnet Sillimanite Gneisses, FeldspathicQuartzites, calcgranulites, quartz veins etc. In the subject mine the Manganese ore horizon is associated with Garnet Gneisses, Lithomarge. The Garnet Gneisses occur individually or intermixed with Kaolin or in Red loam. The Garnet gneisses with Kaolin or as such are predominant in the area. The lithomarge is generally yellow is yellow to brown in colour and at the contacts of the ore body, it is dull grey which is due to the presence of Manganese Oxide and it is termed as Wad. The Manganese forms intrusive in contact on both the sides by Calc gneisses/Kaolin. The Ore in the pits is generally Psilomalene-brown, brownish black to black in colour and it is friable in nature. The general strike of the ore body is NNW-SSE with dip 0f 700 towards east.

B. *Evaluation of Manganese ore and Classification of deposit as per UNFC*

A total of 5 cross sections (A-A' to E-E') have been drawn across the exposed strike length. The drilled Boreholes (Core bore holes) have been projected on to the respective Cross sections. The interception of the ore zone in boreholes has been plotted on the respective cross Sections. The depth of the ore body is extended from surface to the intercepted depth of the borehole and the same has been placed under the G1 category scale of exploration (Sections A-A' to C-C'). Further in the remaining sections D-D' and E-E' where the ore body is exposed in the pit and to a depth of 8 m has been considered under G3 category of UNFC system. The strike influence of the ore zone is restricted to an exposed length of the ore zone. The respective cross sectional area has been multiplied by the exposed strike length, i.e. strike influence to get the volume. In turn the volume is multiplied by the bulk density to arrive the insitu tonnage. The results of the drill hole and the pit logs are almost synonymous.

A proved Mineral reserve(111) is the economically mineable part of a measured mineral resources that includes diluting factors and allowances for losses, which may occur when mineral is mined and the economically mineability being demonstrated by a feasibility study/actual mining activity which is being aided by detailed exploration. A 75% recovery factor to the insitu reserve has been adopted sincethe loss in recovery is mainly due to the friability nature of the ore. The 25% of recovery loss is attributed to intercalated clayey/Lithomarge and handling losses. The other factor attributed for 25% recovery loss is the waste that is removed while upgrading the ore/value addition for competitive price. Otherwise as such the entire ROM is marketable at low price. This conclusion has been drawn after a thorough exercise carried out on the ROM produced from the mine over a period of time. The reserve catagorised under UNFC of 111 in the present context is being justified up to a intercepted depth of drill hole data in the following manner

IV. ECONOMIC AXIS

1) The Manganese mineralization in the subject mine is strata bound and is confined to Khondalite formation and a detailed exploration by means of Core bore holes with a cumulative meterage of 156 m had been carried out. Thus the detailed exploration parameter has been fulfilled.
2) The mine is in operation continuously since 1968. All the pits are in operation. Even in lean period, the lessee continued the mining operation. Thus the mining of the Manganese ore is viable.
3) So far whatsoever Manganese ore produced from the mine was marketed. The Manganese ore of the mine has very good mineral composition both in respect of elements of Mn and others i.e. Fe and P and put together is 50%. It is best suitable for blending of Manganese ore of the other mines of the lessee which are low in Fe and high P content. The ore is friable in nature and sold to Steel plants with the end use specifications as given below.

Radical	Vizag steel plant	Bhilai steel plant
Mn	26-28%	28-30%
Fe	13-15%	-
Sio_2	14-16% max	30% max
Al	7.5% max	5% max
P	0.3-0.5% max	0.3-0.5% max
size	20-60mm	+25 to -85mm

Table 1

Thus the grade of the ore produced from the mine is marketable, since it is meeting end use specifications of the industry.

Therefore the first digit of economic axis i.e. **'1'** is justified up to a exposed depth of Manganese horizon from the existing surface RL.

A. Feasibility axis

1) As said, the ML area is thoroughly explored through the ongoing mining activity since 1968 and further by means of exploratory drill holes. Thus the geometry/disposition of the ore body has been delineated precisely and shown in the Surface Geological plan and Geological cross sections (Refer Plate – IV & IV A)
2) Mining is done by opencast semi mechanised method and it is meticulously guided by the incidence and behavioral trend of the ore and with which it is continued till date. The mining in the M.L. has witnessed both sides viz the lean as well the boom periods of market and the ore has sustained its tenability since inception of the mining.
3) As said mining is done by semi mechanised means and which does not have much effect on the Quality of present ambient air. Pollution to the air is on account of dust which gets airborne due to plying of dumpers and loading of Manganese Ore and waste. Loading of Manganese ore is generally done by manual means and thus it does not contribute to air pollution. As far as water pollution is concerned there are no rivers, tanks and other perennial water sources in and around area. The present pit has reached about 35 to 40m and as such lot of seepage collected in the sump and it is bailed out.

4) The sump water is analysed and found to be no incidence of toxic elements. The top soil generated during the mining is stored separately and it is utilized for the productive purpose of plantation and raising nursery at the mine.

5. The material produced from the mine is highly friable in nature and disintegrates at each stage of handling. In general it is observed that the ROM consists of 65-75% fines and 25-35%of lumpy material. As the ore is friable, the lithomarge gets admixed with the fines. To separate lithomarge hand picking operation is being done on every day basis from the surface of ore heaped before any fresh material is dumped over it. Secondly the process of hand screening or hand sieving is also being done to prevent the disintegration of lumps during the process of sieving

6. The area falls in survey of India Topo sheet no. 65 / N / 11 is located about 2 kms on North-West from road point on Vizianagaram-GarividiPWD Road, situated at a distance of 1.5km towardsVizianagaram from Garividi Railway level crossing. The villagers mostly on agriculture and mining work. Electricity is available in the area and also in the villages.A main substation located at a distance of about 500m where power is received from Government Electric feeder. The electricity requirement of the ML is met by drawing private feeder lines from this substation. The power is utilized only for the purposes of pumping out the pit water. The lessee is also maintaining pucca structures for office, First aid station and shelters

   Thus the ML area can be considered and provided with all man power, infrastructure and other services.

7. The Manganese ore occurring in the area is found to be good quality and is continued to get good response in the domestic as well as International market in the market scenario. The mining operation has positive impact on the socio economic of the local population. The small scale mining operation in the ML has no effect on the ecology and surrounding environment of the ML area. All the statutory provisions with regards to mining, labour and other taxations have been meticulously implemented since inception of the mining operations. At no point of time any statutory agency or any court has given any adverse directions.

   In view of the above the second digit of Feasibility axis can be assigned as **'1'**

B. Geological Axis

1) A detailed exploration where in the ML area has been mapped on a scale of 1:2000 covering the length and breadth of the ML area (Refer Plate – III Surface Geological plan).

2) A total of 34 exploratory boreholes (Auger holes) with a cumulative meterage of 339.34m had been carried out. During the preceding Scheme period 4 DTH holes with a total meterage of 63.7m were drilled and three deep trial pits were sunk (for details see Litho logs-Annexure IV C and Plate V-Geological cross sections where the Borehole intercepts are projected. Further in the year 2014, Core Boreholes have been drilled. The samples so obtained at a 1m interval from the Boreholes were subjected for chemical analysis for radicals namely Mn, Fe, Sio_2,Al and P(refer Annexure – IVA)

3) The samples so obtained from the Boreholes were composited and subjected for chemical analysis for radicals namely Mn, Fe, Sio_2,Al and P (refer Annexure – IX C)

   In view of the above the third digit of Geological axis can be assigned as **'1'.** Thepossible Mineral resource (333): The ore zone exposed in the pit and in the absence of exploratory data in such ore zone to a depth of 8m has been considered to be possible category with the UNFC codification of (333).

   Considering the above parameters and justification of UNFC system, the Reserve/resource estimation has been done by Cross Sectional method. The details of estimation have been furnished vide Annexure- . The abstract of the reserve/resource is as below:

C. *Grade*

Total 5 core samples of manganese ore from Boreholes Cores are being collected .These samples have been labeled as Sample-1,2 (Borehole no.1), Sample-3 (Borehole no.2), Sample-4 & 5 ((Borehole no.3) were collected for assessment of the grade. The grade of this as follows:

Table -2

Classification	Code	Quantity	Grade (Mn %)
-1	-2	-3	-4
Total Mineral Resources (A+B)		**5,65,082**	
A. Mineral Reserve			
(1) Proved Mineral Reserve	111	**3,90,222**	
(2) Probable mineral reserve	122		Mn – 12.38 to 40.28
B. Remaining Resources		-	Fe – 6.93 to 17.31
(3) Feasibility Mineral Resource	211		SiO_2 – 2.58 to 30.79
(4) Pre-feasibility Mineral Resource	221 & 222	-	P – 0.14 to 1.75
(5) Measured Mineral Resource	331	-	
(6) Indicated Mineral Resource	332	-	
(7) Inferred Mineral Resource	333	**1,74,860**	
(8) Reconnaissance Mineral Resource	334		
		5,65,082	
		-	

Radical	Grade in %
Mn%	14.43- 37.32
Fe%	8.3- 13.74

Table-3

Depending upon the degree of exploration and the geometry of the ore body as exposed in different sections of the mine and the results of core drill holes, the Geological axis has been demarcated and the Tonnages available up to the intercept of the drill holes have been placed under G1 area and the reserve estimated based on the delineation of such G1 area is placed under proved category in terms of other axes like Feasibility as 1 and Economic axis as 1 since the market for such ore from the mine is established and the reserve so obtained is placed under proved category of **111 of UNFC** and the remaining as discussed were placed under G3.The reserves estimated under UNFC are furnished in table 3.

V. UNFC CLASSIFICATION OF RESERVES AND RESOURCES

A. Mining

i) The existing method of mining is opencast method of mining for winning of Manganese. The Mining operations fall under A-other than fully mechanized category. Mining done so far resulted in breaking of the 3.32 ha lease hold. There were 2 pits in the lease area which was merged into a single pit and the present mining is going in the merged pit. The ore being soft and friable, no drilling and blasting is required. Simple implements are used for digging the ore to avoid contamination of clayey material with the ore. The pit reached an average depth of about 26 m from the surface.

ii) Proposed Method of mining: Development and production will go hand in hand as practice in vogue by continuing the opencast method of mining involving removal of overburden and keeping overburden benches well in advance of ore benches to prevent contamination of ore. The removal and handling of overburden done by deploying hydraulic excavator in conjunction with set of tippers and this shall be deployed for a limited period in a year. The removal of ore and excavation of the overburden in juxtaposition of the ore zone is done by manual means only as a precautionary measure against contamination of ore. The ore loading into the tippers is also purely manual. Requisite pumping capacity is provided along with suitable sumps and coursing drains to facilitate the mining operations. The height of over burden

benches shall be 3m, with a width more than the height which will be developed by machinery. The ore benches shall not exceed 1.5m height and width of more than 1.5m for stability and safety.

iii) Working of deposit with design parameters. The mining activities will be essentially in the pit where the manganese ore is exposed. Development of the over burden/side burden benches shall be formed by deploying machinery. The benches in overburden shall be of 3m height and width of 3- 5m. The benches in ore shall be formed manually with 1.5m height & width. As the manganese ore is soft and friable, no blasting is required. This is being the practice in the past and also present. The water that is encountered in the pit shall bail out by deploying suitable pumps.

B. Open Cast Mining

i) Mode of Workings: Opencast method of mining will be continued to win Manganese ore by semi mechanised method. The development shall be carried out by excavator with combination of tippers. The benches in overburden shall be of 3m height and width of 3-5m. The benches in ore shall be formed manually with 1.5m height & width. As the manganese ore is soft and friable, no blasting is required. The ore produced is screened and sorted for up gradation.

VI. ENVIRONMENTAL MANAGEMENT PLAN

A) Baseline Information

i) **Existing land use Pattern**: The subject area is a private patta land it is being used for mining. The details of exiting land use pattern as on date is given below.

a)	Area covered by pits (Pits: 1)	3.2965 Ha.
b)	Area covered by dumps (Dumps: 1)	1.2085 Ha.
c)	Area covered by ore stack yard	0.1327 Ha.
d)	Area covered by roads	0.5321 Ha.
e)	Area covered by site services	0.0156 Ha.
f)	Area covered by plantation	10.426 Ha.
g)	Area covered by storage topsoil	0.0834 Ha.
	Total	**15.6948 Ha.**

Table. 4

ii) **Water Regime:** Generally the ground water table in this locality is below 20m from the ground level. The pit has gained a depth of 25-30m. The rainwater on surface flows through the slopes and drains out the lease area. The water accumulates due to seepage in the pit is being bailed out by deploying a 15Hp pump.

iii) **Flora and Fauna:** The subject area is a palm oil garden. There is no report of existence of wild animals in this region.

iv) **Quality of Air, Water and Ambient Noise Level:** The subject area is away from industries. There is no scope of air, water & sound pollution by industries. The environmental aspects are being monitored regularly and seasonally by an environmental laboratory. As such the portability of water & air are fresh and unpolluted in this area. The environmental monitoring stations are shown in the Environmental Management Plan i.e. Plate –

v) Climatic Conditions: The area has a tropical climate. The peak summer will be in the month of May. Highest temperature of 45oC is recorded in this area during the month of May and the lowest temperature of 16oC is recorded in the month of January. The rainfall in this area is about 1500-2000mm.

vi) **Human Settlement**: The following villages are located within 5km radius of the mining lease area. The population and direction of the villages with respect to applied area are given in the following table.

Name of the Village	Population	Direction
Garividi	11450	E
Sadanandapuram	2500	SE
Devada	1800	SE
Chukkapeta	1700	SW
Vijayarampuram	2150	E
Tatiguda	850	NW
Penubarthi	926	SW
Nallalavalasa	750	S

Table. 5

vii) **Public Building, Places of Worship and Monuments:** There are no Public Building, places of workshop and Monuments within or near by the area.

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