I.J.S.N., VOL.5 (1) 2014: 161-169 ISSN 2278 – 9103

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

Case Study

OCCURRENCE AND DISTRIBUTION OF MANGANESE ORE TYPES IN SHIMOGA AREA

Chinnaiah
Department of Studies in earth science, University of mysore, Manasagangotri, Mysore-6, India.

ABSTRACT
The present Investigations carried out on the mining blocks of Shimoga area brought to light the following aspect with regard to the distribution of various ore types of manganese. The Manganese and ferromanganese ores of the study areas were classified based on their mode of occurrence and genesis into i) metasedimentary manganese ore and ii) lateritoid manganese ore. The metasedimentary ore in almost all the mining blocks of the study area (namely Kumsi, Shankaragudda-Harnahalli and Kumudvathi in Shimoga area) have been subjected to lateritic alteration, resulting in the formation of lateritoid manganese ores.

KEYWORDS: Mining block, Shimoga, lateritoid manganese ores.

INTRODUCTION

Precambrian terrains, the world over, are bestowed with metasedimentary manganese mineralization belonging to oxide, silicate, carbonate or mixed facies. In several such terrains, the metasedimentary manganese ores have been subjected to lateritization, which brought about changes in texture, mineralogy and chemical composition of manganese ores. Further, lateritization caused dissolution of metasedimentary ores and consequent release of manganese and other metals to the circulating waters, which later reprecipitated at new locales within the weathered profile and on the contemporary land surface as mangcrete (Dorr, 1973; Lelong *et al*., 1976; Perseil & Grandin, 1978, Roy, 1981). In some regions, late- to post-lateritization events involved mechanical disintegration and short distance movement of near-surface and surficial mangcrete ores and their subsequent burial in the transported soils as palaeofloat and float ores. Although earlier workers recognized the diversity in the manganese ore types in the study area, they failed to provide details on their distribution, textural and mineralogical features. A brief review of the previous work on the manganese ores of the Shimoga area is provided below, prior to proposing a convincing classification of ore types.

manganese ores of Shimoga area has attracted the attention of many workers, including Fermor (1909), Jayaram (1917), Karunakaran (1956), Sreenivas (1957), Sreenivas and Srinivasa Rao (1964), Naganna (1971), Harinadha Babu *et al*.(1981), Roy (1981), Krishna Rao *et al*. (1982), Janardhana (1991). Fermor (1909) examined the manganese ores in the shallow mining pits of the Shimoga area and reported the occurrence of lateritoid, concretionary and cavernous manganese ores. He indicated the possibility of encountering massive ores at deeper levels in the mines. Roy (1981) classified the manganese ores of the region into: (a) syngenetic ores hosted in phyllite and quartzite and (2) remobilized ores occurring in the weathered zone. He did not emphasize the role of lateritization in the formation of extensive new manganese ore types at the expense of pre-existing metasedimentary manganese ores. Krishna Rao *et al*. (1982) reported the following four types of manganese ores in the Shimoga area: (a) reworked metasedimentary ore, (b) sedimentary oolitic ore, (c) cavity filling - replacement type ore and (d) float ore. The occurrence of sedimentary oolitic manganese ore, as suggested by Krishna Rao *et al*. (1982) is questionable, as there are no clear evidences in support of this view. Janardhana (1991) classified the manganese ores of the Shimoga area broadly into: (a) late Archaean metasedimentary ore and (b) lateritoid ore, but did not elaborate on several manganese ore types developed during lateritization event.

The above attempts by earlier workers at classifying the manganese ores of Shimoga area were thus neither based on genetic considerations nor on the field setting and morphological features of the ore bodies. They are therefore not tenable and fail to accommodate the various ore types encountered in the Shimoga area. To overcome the above shortcomings in the earlier works, a new scheme of classification of manganese ores of the study areas is proposed in the present work.

Shimoga Schist Belt

Shimoga region is known for rich manganese deposits where economically important deposits occur at Gangur, Shankaragudda-Harnahalli, Siddarahalli, Kumudvathi, Tuppur, Channagiri, Shikaripura, and Kumsi areas. Among them, mining blocks at Kumsi, Shankargudda-Harnahalli and Kumudvathi mining blocks have well exposed mine pits suitable for detailed investigations (Fig. 1). After a reconnaissance survey, the present investigator selected three mining blocks *viz.*, Kumsi, Shankaragudda-Harnahalli and Kumudvathi for detailed investigations, as other areas were not found suitable for detailed geological investigations. The following section provides details pertaining to the occurrence of different ore types in Kumsi, Shankaragudda – Harnahalli and Kumudvathi mining blocks of the Shimoga region. However, mining activity in the Shimoga region has been suspended during recent years due to encroachment of mining activity into the forest limits.

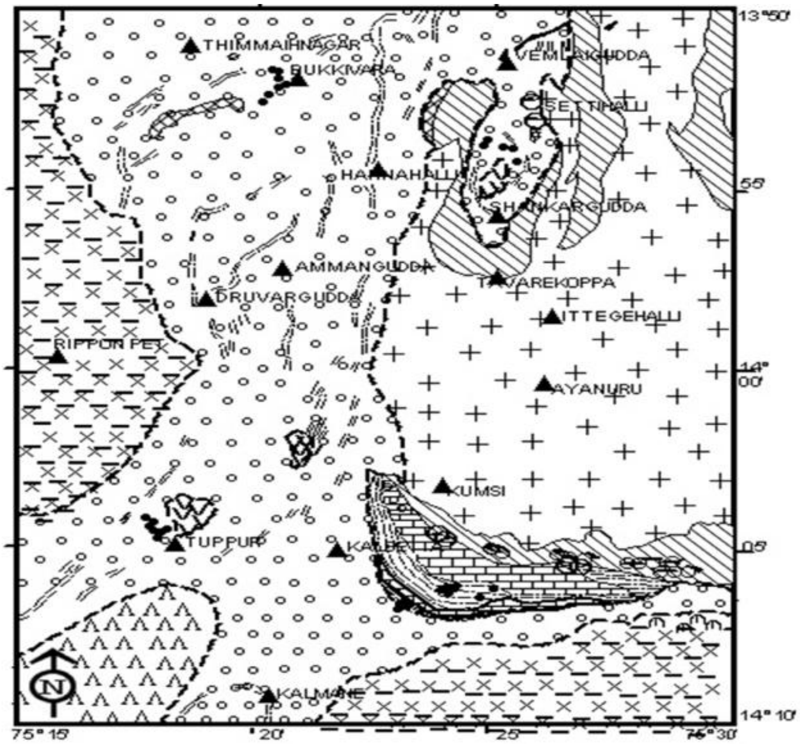
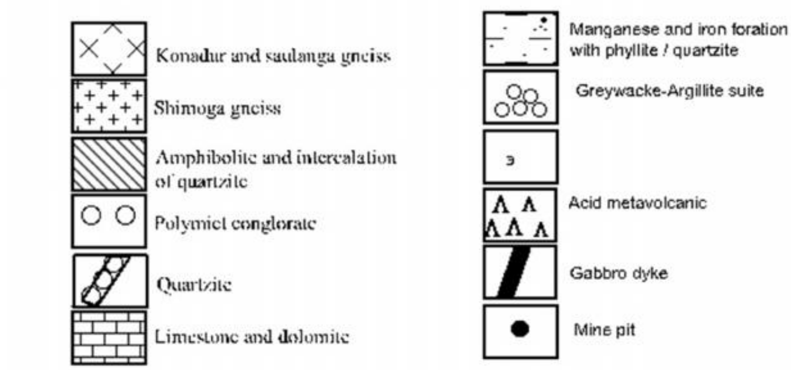


Fig.1. Geological map of Shimoga area showing locations of Manganese deposits



Kumsi mining block

Kumsi mining block is one of the oldest mining blocks in Shimoga region. Kumsi block forms a rugged terrain and the hills of the region rise to elevations of about 900 m, from the general ground level of about 650m. Gange–Gowri halla is a small tributary draining the Kumsi region and it joins the Kumudvathi River.

Precambrian metasedimentary manganiferous formations in the Kumsi region are variably weathered and the lateritic crust has not been preserved insitu anywhere. The manganese ores in the area at places are covered with sandy clay formation and red soil. The lithostratigraphic succession of the rock formations of the Kumsi mining block is as follows.

Sandy-clay formation and soil.

CHITRADURGA GROUP — Acid volcanics
Greywacke and argillite
Banded ferruginous (BIF)
Manganese formation inter banded with chert and phyllite
Limestone and Dolomite
Quartzite
Polymict conglomerate
…………………………………………………
BABABUDAN GROUP — Metabasalt interlayered with quartzite
……………………… Shimoga gneiss (Peninsular gneiss)

In the Kumsi mining block, all the varieties of metasedimentary and lateritoid type manganese ores are encountered. These ores are recovered by open cast mining from several mining pits namely, Vinayaka, Gange – Gowri, Bisonmatti, old Segematti, new Segematti, Python, Kalbetta and Laxmi pit. Mine exposures suited for the present investigation are encountered at Vinayaka, Bisonmatti, old Segematti and Gange-Gowri pits. Metasedimentary manganese ore bodies occur as conformable beds, lenses and bands within the manganiferous formation (Fig.2 A). At several places, these ores exhibit varying degree of (residual) supergene alteration. However the present investigator could trace patches of unaltered metasedimentary ore horizon in deeper section of several mining pits. Distinction between the altered and unaltered varieties of metasedimentary manganiferous formation was evident by ore microscopic studies.

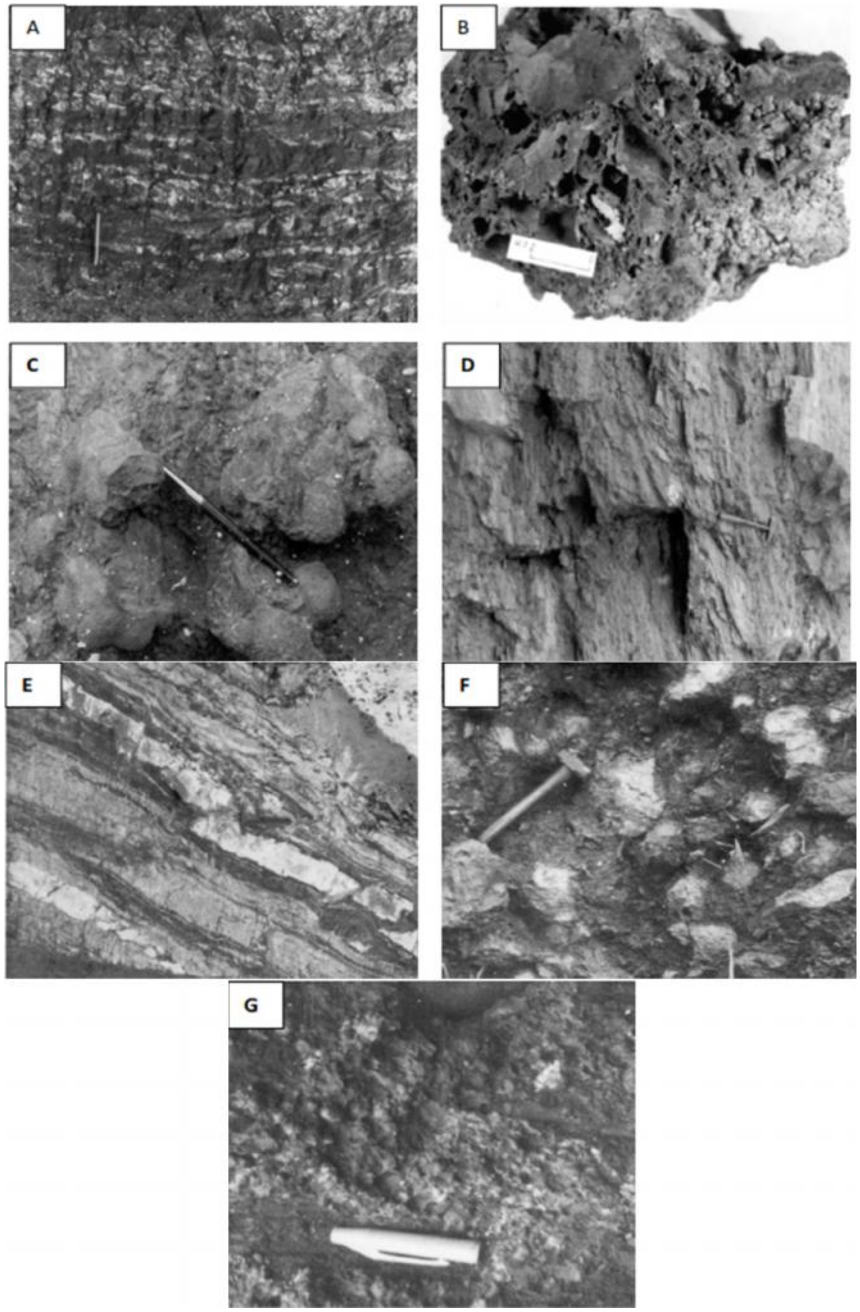


FIGURE 2. A. Metasedimentary manganese ore inter bands with quartzite, Kumsi block, Shimoga area, B. Lateritoid manganese ore of Non-colloform type exhibiting Structure, Kumsi block, Shimoga area, C. Lateritoid manganese ore of colloform type, Kumsi block,Shimoga area, D. Metasedimentary ore bed alternating with phyllite, Shankar pit, Kumudvathi block, Shimoga area, E. Metasedimentary ore bed alternating with quartzite, Balaji pit, Kumudvathi block, Shimoga area, F. Manganese ore boulder bed of palaeofloat type, G. Irregularly strown boulders in recent float (Kumsi block, Shimoga area)

The unaltered metasedimentary ores in the form of patches are encountered in the lower benches of the mine pits and are essentially composed of pyrolusite, as will be described in the forthcoming chapter. On the other hand, the altered metasedimentary ores that extends for a few meters to several kms contain minerals of both metasedimentary and supergene origin, the latter represented by manganese- and iron- minerals. The altered metasedimentary ores encountered at relatively shallow depth are confined to the late Archaean manganiferous formation. Infiltration-type manganese ores are found within the residually altered metasedimentary formations both in the phyllite and quartzite. Within the weathered profile, infiltration type ores occur as cavity fillings along cracks, network of joints, schistosity planes, crevices and vugs. The size and shape of the infiltration-type ores vary greatly and quite often they exhibit a discordant relationship with the structural fabric of the weathered supracrustal rocks. Being a product of dissolution and reprecipitation, the infiltration-type manganese ores exhibit specific textural and mineralogical features that are unlike those of metasedimentary ores.

Majority of the manganese ore bodies belonging to the infiltration-type contain manganese (± iron minerals). These ores occur largely as irregular patches, permeations, pockets, box works (Fig. 2B), thin veins and stringers in the weathered phyllite and quartzite. Some ore bodies however exhibit botryoidal texture (Fig. 2C), wherein colloform bands of varying crystallanity composed of manganese and iron minerals occur. Based on the textural and structural features, infiltration-type ores have been further subdivided into (1) Non-colloform and (2) Colloform types. Palaeofloat ores, derived from denudation of lateritoid manganiferous crust in Kumsi block are encountered mainly in Vinayaka, old Segematti, new segematti and Laxmi pits. Palaeofloat ores consist of beds of closely packed boulders and pebbles exhibiting oolitic/pisolitic and textureless/finely laminated fabrics. In the Vinayaka pit, boulders and pebbles of massive oolitic / pisolitic and occasionally texture less to finely laminated ferromanganese ores occur. The constituent boulders and pebbles exhibit close packing and are sub-horizontally disposed, attaining a thickness of about 12m. A difference in the packing density is discernible, with the lower layer (~ 10m thickness) composed of densely pack boulders and the upper horizon (~ 2m thick) made up of less densely pack boulders. A sandy clay formation (~6m thick) overlies the ore boulder bed and the former exhibits a fine vermicular fabric indicating its residual alteration. The sandy clay formation is in turn covered by a horizon of red soil (~ 2m thick). The two distinct layers in the ore boulder bed possibly indicate two distinct cycles of sedimentation. At places in the Vinayaka pit, massive manganese ore boulders of texture less/finely laminated and oolitic/ pisolitic types are found randomly distributed in a horizon consisting of red soil. This ore belongs to the recent float and were possibly derived from the erosion of the palaeofloat ores.

In old Segematti pit, the ore boulder bed consists of oolitic/pisolitic and textureless/finely-laminated ores and as in the Vinayaka pit, a difference in packing density of the constituent boulders and pebbles is observed. The lower ~ 10 m thick layer is made up of densely packed ore boulders**,** while the upper ~ 2 m thick layer is composed of sparsely distributed ore boulders. This layer is overlain by about 2m thick sandy clay formation. In this pit also evidences in support of two distinct cycles of sedimentation exist.

In the New Segematti pit, massive ferromanganese ore boulders and pebbles (showing oolitic/pisolitic texture) are randomly distributed within loosely held ooliths/pisoliths**.** The ore boulders in this pit were possibly derived in a few cycles from a highly fragmented source. Details on the structural and textural features of these manganese ore types will be described in the succeeding chapters.

Shankaragudda – Harnahalli mining block:

This mining block is located in survey of India toposheet No. 48 0/5 and bound by Latitudes 13°53’38” and 13° 56’38” and Longitudes 75°22’55” and 75°26’20”**.** The Shankaragudda-Harnahalli block constitutes an almost N-S trending hill with the peak altitude reaching 1031 m above mean sea level. The supracrustal rocks of the Precambrian exhibit E-W strike with southerly dip, but rocks are not clearly visible due to thick soil and vegetation covers. Numerous small rivers drain the area.

The sequence of rock types encountered seen in the mining block is as follows.

Soil Sandy – clay formation

Ultramafite
Greywacke – Argillite
Banded ferruginous formation
Chert and phyllites
Manganiferous formation
Limestone / Dolomite
Quartzite
……………………
Amphibolite
……………………
Shimoga gneiss

In the Shankaragudda – Harnahalli block, the altered metasedimentary manganese ores constitute the major ore type followed by infiltration-type, palaeofloat and float manganese ores.

The metasedimentary ore bodies are being mined to a depth of more than 40 meters in Triveni, Raghavendra and Krishna D pit areas. Manganese ores of the banded type extend for more than 1 km and alternate with similar bands of quartzite or phyllite. The manganese ore bodies exhibit varying degrees of lateritic alteration along with the associated rocks such as quartzite and phyllite. Due to alteration processes a compact quartzite has been transformed to sacchroidal quartz and the phyllites to argillitic clay.

The infiltration-type manganese ore is essentially of the non- colloform variety and is encountered in Raghavendra (No.1), Krishna D and Shankara top pits. This type of manganese ore is encountered as pockets in the adjoining phyllite and quartzite formation. The manganese ores are exclusively confined to the structural weak planes of the associated rocks. This type of ore constitutes the commercial variety of ore of this mining block.

Palaeofloat ores are quite common in the Shankaragudda – Harnahalli block and are encountered in many pits including Raghavendra, Triveni and Krishna A pits. They occur as boulders at the base of the 2 m to 10 m thick bed composed of loosely held ferromanganese pisoliths/ooliths. The thickness of the ore boulder bed differs and it generally attains a maximum thickness of 3 m. The ore boulder bed is overlain by loose ooliths and pisoliths, which in turn are overlain by 3 to 7 m thick sandy clay formation exhibiting vermicular fabric, as seen in the Raghavendra pit**.**

Kumudvathi mining block:

This mining block derives its name from the Kumudvathi river that drains the area. The mining block is located 1 km NE of Dr. Thimmaiahnagar and lies between Latitudes 13°51' and 13° 53' and Longitudes 75° 19' and 75° 21' (Fig. 4.10). All the mining pits are located at the top of hills that rise to elevations of over 900 m from a general regional level of about 650m.

The lithostratigraphic sequence of rock formations exposed in the mining block of Kumudvathi is as follows.

Soil

…………………………

Gabbro dyke

Ultramafite

Greywacke – Argillite

Banded ferruginous formation

Manganiferous formation

Phyllite and Quartzite

…………………………

Basement not exposed

Unlike other mining blocks in the Shimoga region, the Kumudvathi mining block is characterized by rich concentrations of metasedimentary ores, followed upwards by infiltration-type ores. Palaeofloat ores derived from lateritoid manganese ores are typically absent in this block.

Metasedimentary manganese ores occur as a few cm to a few m thick beds, alternating either with phyllite (Fig.2 D) or quartzite (Fig. 2 E) of similar thickness. These manganese ores are encountered in Balaji, Shankar, Gem and Rama pits, exhibiting NNW to NW trend with an easterly dip. In all the mining pits where metasedimentary ore is exploited, the ore is residually altered and nowhere fresh or even the least altered metasedimentary manganese ores are encountered.

In Shankara, Nandi, Rama and Vinayaka pits, both varieties of infiltration types ores viz., colloform and non-colloform ores are encountered. The infiltration type manganese ores occur as fillings in cavities, fractures, joints, vugs and schistosity planes. In many of the pits, the ore is largely confined to the highly weathered quartzite.

Basis for the present classification

Manganese ores of the Shimoga area may be broadly classified based on their mode of occurrence and genesis, into: (1) metasedimentary ores and (2) Lateritoid ores. The characteristic features of these ores are described below.

Metasedimentary manganese ore

The metasedimentary manganese ore bodies occur as conformable beds, layers, lenses and bands within the manganiferous formation (generally made up of quartzite and phyllite/shale interbedded with manganese ores). The manganiferous formation sometimes extends laterally for 2-3 km and the thickness of the individual manganiferous layers/bands/lenses varies from a few cm to 1 m or more. Manganiferous layers encountered in quartzites are usually thin (few mm to 1-2 cm thick) and such layers alternate with quartzite layers of similar thickness (Fig. 2A). Manganiferous formation commonly exhibits various degrees of lateritic alteration. Very rarely, unaltered metasedimentary manganese ores are encountered in the deeper sections of the mines. The difference between unaltered and altered metasedimentary manganese ores is not evident in the field, but can be made out by ore microscopic studies.

Lateritoid manganese ore

Lateritoid manganese ores, which owe their origin to lateritization processes due to the tropical to subtropical weathering of the Precambrian metasedimentary ores, are encountered both within the weathered metasedimentary rocks (quartzite and phyllite/shale) as well as in soil horizon of sub recent and recent origin.

Lateritoid manganese ores in the weathered supracrustal rocks (phyllite and quartzite) occur as fracture-/cavity-fillings along cracks, network of joints, schistosity/ bedding planes, crevices and vugs. This type of ore will hereafter be referred to as 'Infiltration-type ore', as they resulted from the precipitation of Mn- ± Fe- rich meteoric waters percolating through the metasedimentary rocks undergoing weathering. Replacement of the weathered metasedimentary rocks by manganese-rich material is also noted. Within the weathered supracrustal rocks, the infiltration-type lateritoid ores extend down to the level of the (palaeo) water table. The infiltration-type ores generally exhibit discordant relationship with the weathered supracrustal rocks.

Based on their textural and mineralogical characteristics, infiltration-type manganese ores can be subdivided into colloform and non-colloform ores. Colloform ores occur as few cm to few tens of cm wide bodies in cavities and crevices of weathered metasedimentary rocks and exhibit botryoidal structures (Fig. 2C). They are essentially composed of colloform bands of manganese- and iron - minerals. Non-colloform ores occur as irregular patches/permeations, pockets, vein-network and stringers and box-work (Fig. 2B) in the weathered phyllite and quartzite. Weathered fragments of phyllite and quartzite in varying proportions are often encountered in the non-colloform manganese ores.

Lateritoid mangcrete ores (hereafter referred to as ferromanganese crust) resulted from lateritic weathering of metasedimentary ore under favorable tropical/subtropical conditions on the contemporary land surface. The lateritoid mangcrete ores contain significant amounts of iron (as goethite) in addition to manganese. Their origin is comparable to the formation of ferricrete over Banded Iron Formations (BIF) and the mechanism attributable to its formation include: (a) evapotranspiration, (b) precipitation from ascending-/downward- percolating and laterally circulating Mn- (± Fe-) rich meteoric waters under waterlogged conditions in the manganiferous weathered zones and precipitation of manganese in ponds or swamps. The resulting lateritoid ferromanganese ores, mixed with variable amounts of fine rock components, exhibit varied textures including massive, textureless to finely-laminated, oolitic/pisolitic and porous earthy mass. The ferromanganese crust has not been preserved insitu in the study areas due to late- to post- lateritic geomorphological evolution of the terrain that resulted in the fragmentation of ferromanganese crust (mangcrete). In the present day, fragmental remains of the ferromanganese crust ore are encountered as boulders and pebbles buried and admixed with in a thick sandy-clay formation (Fig.2 F) and soil. The ore boulders and pebbles in the sandy-clay formation exhibit both normal and reverse graded bedding (Plate.4.3 A) and may be regarded as 'palaeofloat ores', while ore boulders in the soil are irregularly strewn and may be considered as 'recent floats' (Fig.2 G). Further, it can be visualized that recent floats may be derivates of palaeofloats that resulted from destruction and soil creep of the latter during the geomorphologic evolution of the terrain. Based on textural features, the ferromanganese crust ores may be further subdivided into: (1) ferromanganese crust ores exhibiting oolitic/pisolitic texture and (2) ferromanganese crust ores exhibiting textureless/finely laminated texture.

To sum up, the following are the types of manganese ores identified in the study areas:

I. Metasedimentary manganese ore

i) Unaltered metasedimentary ore and ii) Altered metasedimentary ore

II. Lateritoid manganese and ferromanganese ore.

Infiltration type ore: Non-colloform ore and Colloform ore.

Ferromanganese crust ore: Textureless/finely laminated ore. Oolitic/pisolitic ore.

Genesis of manganese mineralization

Details on the field setting, morphology, structural/textural and mineralogical aspects of manganese ores of the Shimoga area have been provided. The above results have led to propose the following genetic model for the manganese deposits of the study areas.

Manganese ore precipitation and their distribution can be related to three major events of evolution in the study areas. They are:

Late Archaean ore-forming event, Lateritic ore-forming event, and

Late- to post- lateritization event.

Of these three events, the first two events respectively produced metasedimentary and lateritoid manganese ores. These two events have contributed to the formation of all the observed types of manganese ores encountered in the Shimoga area. The third event, which involved large-scale mechanical disintegration minor dissolution of the lateritoid manganese ores and near-surface metasedimentary and infiltration-type ores, is however restricted to manganese ores of Shimoga area. The salient geological features pertaining to the formation of different manganese ore types and the post-ore modifications are provided below.

Late Achaean ore-forming event

The crustal evolution of the Karnataka craton include: (a) the development of ancient supracrustal rocks (Sargur group) between 3.5 and 3.1 Ga., (b) invasion of tonalite-trondhjemite around 3.0 Ga.,(c) development of younger supracurstal rocks of the Bababudan group (~2.9 Ga) and Chitradurga group around 2.6 Ga., and (d) termination of Archaean activity by 2.4 Ga granite intrusions. Manganese mineralization is restricted to the volcano-sedimentary sequence of ~ 2.6 Ga Chitradurga group, both in the western and eastern blocks of the Karnataka craton.

The manganiferous terrains of different schist belts exhibit several common features with regard to their genesis, indicating their similarity with one another. These features include geological setting, supracrustal rock association, spatial association with banded iron formation (belonging to oxide and to a lesser extent carbonate, silicate and sulfide facies) and most important, the association of stromotalitic limestone/dolomite. These features not only suggest a common mode of origin for manganese mineralization in all the schist belts, but also for the other spatially and temporally associated metalliferous mineralization in the Karnataka craton.

The scenario of manganese mineralization in the Shimoga schist belt is identical to that of North Kanara schist belt. Here also, the manganiferous horizon is spatially associated with stromotalitic carbonates, banded iron formation, phyllites and ripple marked quartzites. The chemical analysis data of the metasedimentary manganese ores indicate their derivation from a volcanogene-hydrothermal source. The manganiferous formations are considered to have been deposited in a near-shore environment (Janardhana, 1991).

From the above discussion, it can be said that the late Archean manganese mineralization of the Shimoga schist belts find similarities with other manganiferous formations of the Karnataka craton and have a common mode of origin from a volcanogene hydrothermal source, followed by deposition under a near shore environment.

Lateritic ore-forming event

Lateritic ore-forming event, involved:

(i) Residual alteration of the pre-existing metasedimentary manganiferous formation and associated BIF, and

(ii) Late Archaean ore-forming event, Development of new ore bodies composed entirely of supergene ore minerals.

The above events produced three types of manganese ores. They are: (a) altered metasedimentary ore, (b) infiltration-type ore and ferromanganese crust ore.

Residual alteration of metasedimentary ores

During the lateritization process, late Archaean metasedimentary manganese-rich bodies have been variably altered and the alteration effects are noticed in almost all the ore bodies exposed in the mine workings. Lateritic alteration of the metasedimentary manganese ores involved introduction of considerable quantities of cryptomelane, minor amounts of goethite and insignificant quantities of hollandite and ramsdellite by the process of low-temperature metasomatic replacement of the metasedimentary pyrolusite. Thus, in the altered metasedimentary ore, replacement texture is common apart from structures and textures generally found in the metasedimentary manganese ore. Based on the mineralogy, it can be said that the supergene minerals of these altered metasedimentary ores precipitated from Mn-Fe- alkali- rich solutions, migrating within the weathered profile above the level of palaeo water table.

Development of supergene ores

The late-Archaean metasedimentary manganese ores of the Chikkanayakanahalli and Shimoga areas have been subjected to supergene (lateritic) alteration. Structurally and texturally this alteration is discernible by the development of infiltration-type (colloform and non-colloform) and ferromanganese crust ores. Among the supergene ores, the infiltration-type ores are mainly composed of cryptomelane and considerable amounts of pyrolusite and goethite and lesser amounts of nsutite and lithiophorite. Ferromanganese crust ores are made up essentially of cryptomelane and goethite and lesser amounts of pyrolusite and lithiophorite.

To decipher the mode of formation of supergene ores, it is necessary to evaluate the nature of ore forming solutions, the source of Mn and Fe of the ore forming solutions, their migration and the mechanism of precipitation.

Chemical composition and nature of the ore forming solution can be evaluated from the textural features of the ores, mineralogical composition and their site of deposition. In the study areas, infiltration-type manganese ores are encountered at shallow depths localized along the secondary structures of the associated rock formations. Ferromanganese crust ores, which formed on the contemporary land surface of the weathered supracrustal rocks now occur as boulders and pebbles in the sandy clay formation of the Shimoga area. The mineral composition and the cryptocrystalline nature of the minerals of these two types of supergene ores suggest that the majority of the lateritoid ores were derived from colloidal solutions rich in Mn, Fe and alkalies.

Regarding the source of Mn and Fe for the formation of supergene ores, it can be visualized that the Mn- and Fe-content of the circulating meteoric waters were derived essentially from the weathering of the metasedimentary manganiferous and iron formations of the study area. The other associated late Archaean supracrustal rocks of the study areas cannot be considered as a potential source of these metals, because only formations containing 100 times the Clarke value of Mn and Fe can account for the metals required for the formation of supergene Mn- and Fe- ores (Lelong *et al*., 1976).

In a weathering environment, Mn is leached from the source rock after alkaline and alkaline earths, and just prior to or directly with iron (Crerar *et al*., 1980). In the study areas, during the lateritization process, dissolution of late Archaean Mn- and Fe- ores by the reaction with acidic surficial and near-surface waters may not have occurred on a major scale, as the late Archaean metasedimentary Mn- and Fe- formations are composed respectively of pyrolusite and magnetite. Dissolution of such higher oxides in acidic waters can occur only to a limited extent.

The manganese released into the near-surface and surficial waters was present probably as simple and complex ions, organo-metallic complexes and colloids. Divalent Mn and Mn-rich colloids precipitate faster. Mn- and Fe- rich meteoric waters permeating through the weathered supracrustal rocks gave rise to infiltration-type ores. Ferromanganese crust ores precipitated probably from Mn- and Fe- rich surficial waters. During wet spells, when the weathering supracrustal rocks were under water-logged conditions, the metal-rich, near-surface waters in the weathering profile, reach the surface. These waters can also reach the surficial layers as a result of evapotranspiration process.

The dissolved Mn and Fe of the near-surface and surficial waters can precipitate by several mechanisms. However, the present author is of the opinion that the higher oxygen content of the circulating meteoric waters in the near-surface zones facilitated precipitation of the dissolved manganese of the circulating waters.

With regard to the site of precipitation of supergene ores, it is clear that the infiltration-type manganese ores are confined only to the weathered portions of the supracrustal rocks and are encountered in the proximity of weathered manganiferous formation. The infiltration-type manganese ores, being confined to permeable zones in the quartzites and phyllites, can be traced to a depth of the palaeo water table.

The precise site of precipitation of the ferromanganese crust ores in the Shimoga area could not be deciphered during the present investigation, because the ferromanagese crust ore has not been preserved insitu and only its fragmentary remnants are encountered as boulders and pebbles within the surficial detrital sandy clay cover and soils. Textural features exhibited by the textureless/finely laminated and oolitic/pisolitic varieties of the ferromanganese crust ore do not provide tangible evidences in support of their origin. The oolitic/pisolitic ores possibly developed in surficial water-bodies as lake deposits. However, certain textural features indicate the possibility of their development in the soil horizon. Thus, it may be said that the ferromanganese crust ore could be either a fresh water deposit or of pedogenic origin. The ferromanganese crust ore is dominated by oolitic/pisolitic variety, which exhibits matrix supported texture. The nucleus of some of the ooids contain pre-formed and broken fragments of ooliths/pisoliths, quartz grains, broken fragments of earlier formed manganese mineral grains, etc. However, majority of the ooliths/pisoliths are devoid of nucleus. The ooliths/ pisoliths of the ore do not exhibit concrete evidences of either concretionary or accretionary growth mechanisms. The development of ooliths and pisoliths under free-rolling aqueous environment points to the accretionary origin of these ores. The textural and mineralogical features of ferromanganese crust ore support their development through sedimentary/diagenetic processes. In the light of the above observations, ferromanganese crust ore may be viewed as a laccustrine deposit. However, manganese and ferromanganese ooliths and pisoliths are commonly found in the weathered profiles of the mangaese deposits, as in the manganese deposits of the Groote Eylandt, Australia. Such secondary concretions are generally considered to be pedogenic origin. The development of pedogenic Mn- and Fe- rich oolitic/pisolitic ore may be attributed to repeated cycles of dissolution of the Mn- and Fe- minerals of the supracrustal rocks, upward migration of the metal-rich waters through several mechanisms and reprecipitation of the same in the soil horizon.

Late- To Post- Lateritization Event

During the late- to post- lateritization period, surficial lateritoid ferromanganese crust was subjected to mechanical disintegration and minor dissolution under pedogenic conditions. During this process, some of the dissolution cavities were partially/fully filled with lithiophorite of pedogenic origin.

The debris of the mechanically disintegrated ferromanganese crust ore accumulated in the low-lying areas as detrital beds of ore boulders and pebbles during more than one cycle, through the action of gravity and transportation by fluvial/pluvial agencies. The ferromanganese ore boulders and pebbles show both normal- and reverse- graded bedding. These ore boulder/pebble beds of subrecent origin, referred to in the present work as " palaeofloat ore" have been buried under a cover of sandy clay formation of detrital origin, the latter being derived from the weathered phyllites and quartzites.

During the continued evolution of the land, several of the ore boulder/pebble beds and the overlying sandy clay beds were subjected to erosion due to surface creep and other denudational processes. In this process, bulk of the sandy clay material was lost and a part of the weathered ore fragments are encountered randomly in the soil horizon. The soil-hosted ore boulders/pebbles, referred to in the present work as "recent float" were thus derived from palaeofloats. In the Shimoga district, the palaeofloat and float ores of the ferromanganese crust are being mined since the beginning of the 20th Century.

SUMMARY

Investigations carried out on the mining blocks of Shimoga area brought to light the following aspect with regard to the distribution of various ore types of manganese. Manganese and ferromanganese ores of the study areas were classified based on their mode of occurrence and genesis into i) metasedimentary manganese ore and ii) lateritoid manganese ore. The above two types have been further subdivided as follows.

Metasedimentary manganese ores i) Unaltered and Altered metasedimentary manganese ore

Lateritoid manganese and ferromanganese ore.

(A) Infiltration type ore (i) Non-colloform ore and (ii) Colloform ore.

(B) Ferromanganese crust ore: (i) Textureless/finely laminated ore (ii) Oolitic/pisolitic ore.

The metasedimentary ore in almost all the mining blocks of the study area (namely Kumsi, Shankaragudda-Harnahalli and Kumudvathi in Shimoga area) have been subjected to lateritic alteration, resulting in the formation of lateritoid manganese ores.

Lateritic alteration is presumed to extend from the surface to the depth of palaeo water table.

Lateritoid mangcrete ore (ferromanganese crust) resulted from lateritic weathering of metasedimentary manganese ore on the contemporary land surface. This ore type is restricted to the Shimoga area. The ferromanganese crust has not has been preserved insitu anywhere in the study area due to late- to post- lateritic geological evolution of the terrain. The mechanically disintegrated fragments of ferromanganese crust ore are encountered as float ores in the soil horizons.

CONCLUSION

In conclusion, the following analogy can be evoked to explain the adage in ore genesis which in the present context seeks to explain the ferromanganese ores are restricted to the Shimoga area. But may have been later destroyed during weathering in a carbonate-rich environment prevalent in the Shimoga area.

Manganese being one of the unique minerals in nature which does not have a substitute in applications and also the fact that no single geological process can account for the observed diversity in the ore, it is pertinent to adopt an approach that seeks to maximize its utility by way of understanding the intricacies involved in its genesis and the present work is one such attempt in the Karnataka craton of Southern India.

REFERENCES

Crerar, D.A., Fischer, A.G. and Plaza, C.L. (1980) Metallogenium and biogenic deposition of manganese from Precambrian to recent time. In: I. M. Varentsove and Gy. Grassely (Eds). Geology and geochemistry of manganese. V. III. Schweizer bastche Verlagsbuch handling, Stuttgart, pp.285-304.

Dorr, J. (1973) Iron – formation and associated manganese in brazil. In proc. Kiev symp. On Genesis of Precambrian iron and manganese deposits. UNESCO Paris, pp. 105-114.

Fermor, L.L. (1909) The manganese ore deposits of India. Mem. Geol. Surv. India, No.37, 109P.

Harinadha Babu, P., Ponnaswamy, M. and Krishna murthy, K.V. (1981) Shimoga belt.In; J.Swaminath and M.Ramakrishnan (Eds), Early precambrian supracrustals of Southern Karnataka, Geol. Mag, V.2, pp.199-218.

Janardhana, M.R., (1991) Geological setting, mineralogy, textural, geochemistry and genesis of Shimoga manganese deposits, Karnataka. Unpublished Ph.D.thesis submitted to University of Mysore, Mysore.

Jayaram, B. (1917) Report on corundum bearing rocks of Arasikere taluk with notes on other localities, Mysore Geol. Dept. v. 15, PP. 63-91.

Karunakaran, C. (1956) Manganese ore deposits of Mysore, India, Proc. Symp. Manganese. Int, Geol. Congress, V.4. pp. 97-113.

Krishna Rao, B., Srinivasan, R., Ramachandra, B. L. and Srinivas, B.L. (1982) Mode of occurrence and origin of manganese ores of Shimoga district, Karnataka. Jour. Geol. Soc. Ind. V. 23, pp.226-235.

Krishna Rao, B., Muzamil, M.M. and Grade. A.A. (1996) Geological and geochemical features of manganese ore deposits of north kanara district, Karnataka, India. International Syposium applied geochemistry, Osmania University, Hyderabad. Pp.437-446.

Lelong , F. Tardy, Y. Grandin, G. Trescases, J. J. and Boulange, B. (1976**)** Petrogenesis, chemical weathering and processes of formation of some supergeneore deposits. In: Handbook of strata-bound and stratiform ore deposits K.H.Wolf(ed.)v.3,pp.93-174.Elsevier Sci. Pub. Co. Amsterdam-Oxford-New York.

Manikyamba, C. and Naqvi, S.M. (1997) Mineralogy and geochemistry of Archaean greenstone belt-hosted manganese formations and deposits of the Dharwar craton: redox potential of pro-oceans. In: Nicholson, K., Hein, J.R., Buhn and Daagupta, S(eds.), Manganese mineralization: geochemistry and mineralogy of terrestrial and marine deposits. Geological Society special publication. No.119, pp.91-193.

Naganna, C. (1971) Origin of the manganese deposits of Mysore State. India proc. IMA- IAGOD meetings 70. IAGOD vol. Soc. Mining geol. Japan, Spec, Issue 3, 454-459.

Naqvi, S.M., Venkatachala, B.S., Manoj Shukla, B., Natarajan, R. and Mukund Sharma (1987) Silicified cynobactiria from the cherts of Archaean Sandur schist belt, Karnataka, India, Jour. Geol.Soc. India. 29:pp.535-539.

Perseil, E.A. and Grandin, G. (1978) Evolution mineralogique du manganese gisement d'afrique de l'ouest: Mokta, tambao, Nsuta. Miner. Deposita v.13, pp. 295-311.

Roy, S. (1981) Manganese deposits, Academic Press Inc. (London) 451P.

Sreenivas, B.L. (1957) Manganese oxide from Mysore, India. Min. Mag.31.

Sreenivas, B.L. and Srinivasa Rao, M.R., (1964) Texture and paragenesis of manganese ores from Kumsi, Mysore. Bull. Geol. Soc.India, v.1, pp. 19-21.

Venkatachala, B.S., Naqvi,S.M.,Chadha, M.S. and 13 others, (1989) Paleobiology and geochemistry of the Precambrian stromotolites and associated sedimentary rocks from the Dharwar craton: constraints on Archaean biogenic processes, Himalayan geology. 13, 1-20.

Venkatachala. B.S., Shukla, M., naqvi, Srinivasan, R. and Uday raj, B. (1990) Archaean microbiota from the Domimalai formation, Dharwar superegroup, India. Precamb. Res. 47. Pp.27-34.