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Occurrence and Distribution oof Manganese Ore Types in Chikkanayakanahalli Area

KEYWORDS

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ABSTRACT *The present study involves detailed geological investigation of the manganese deposits of Chikanayakanahalli area of Dharwar craton, Southern India. Here, the Precambrian manganese ores have been subjected to supergene/lateritic alteration resulting in the development of different ore types. Studies on various aspects of manganese mineralization of these areas have not received due attention. The present study therefore was undertaken to evaluate the field setting, occurrence and distribution of metasedimentary and lataritoid ores on various manganese ore types encountered in the Chikanayakanahalli area.*

Introduction:
Manganese mineralization has been recorded at different periods during the evolutionary history of the earth and its distribution vertically has been irregular. This irregular distribution is attributed mainly to an interplay of multiple parameters like tectonic setting, magmatic activity, climatic condition, geochemical environment and biological activity, all acting independently or in unison to form ore concentrations of manganese. Evans et al., (2001) used paleomagnetic data from samples spanning several grades of enrichment in the Kalahari manganese field, South Africa, in order to assess mineralogical aspects of the ore forming stages, and also to date these stages through comparison to previously existing, well dated paleomagnetic results from the Kaapvaal-Kalahari craton.

Major Precambrian manganese deposits of the world are reported from Brazil, Romania, Czechoslovakia, China, Namibia, Morocco, Guyana, Surinam, Gabon, Zaire, Sweden, Republic of South Africa, Malagasy, Ghana, Ivory coast, Upper Volta and India.

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.

India occupies a prominent position in terms of world's manganese ore reserves. Contributions made by Fermor (1909) during the early 19th century constituted the basis for later investigations on various deposits of manganese deposits of the Indian subcontinent. Several investigators carried out studies on manganese mineralization contributing to a better understanding of the geological aspects of the manganese deposits of India, noteworthy among them being that of Roy (1958, 1960, 1966, 1968, 1971, 1973, 1978, 1981, 1986).

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 Chikkanayakanahalli area is provided below, prior to proposing a convincing classification of ore types. Earliest references to the manganese ores of Chikkanayakanahalli belt were made by the officers of the Karntaka State Geology Department. Sen (1921) and Venkataramaiah (1926) examined the manganese ores of Janehara, Karekurchi and Honnebagi and reported that manganese ores occur as lenses, patches and bands associated with quartz and ferruginous bands in the altered members of the schistose rocks. Naganna (1971, 1976) and Ramiengar (1977) also reported the occurrence of manganese ores in the area but did not provide details on their textural features, mineralogy and genetic aspects. Devaraju and AnanthaMurthy (1976) briefly dealt with the geology, mineralogy and genesis aspects of manganese ores of the area but did not elaborate on the ore types and genetic aspects of the individual manganese ore type in the area.

In the study areas, Chikkanayakanahalli area, metasedimentary manganese ores have been subjected to lateritization resulting in the development of diverse textural, mineralogical and geochemical features. Based on these features, different manganese ore types confined to various locales in the weathered profile and the eroded surface have been recognized.

Geological Setting of Chikkanayakanahalli Schist Belt:
Chikkanayakanahalli schist belt extends between the longitudes 76°37′ 6″ and 76°47′ 37″ and latitudes 13°18′ 37″ and 13°32′ 14″ in the Tumkur district of Karnataka state.

Chikkanayakanahalli schist belt (Fig. 1) represents the southern extension of ~ 460 km long Chitradurga schist belt and it is about 25 km long and 15 km wide. One of the earliest accounts of the geology of the area around Dodguni, which constitutes the area of interest of the present investigation, was given by Jayaram (1917), who assigned the rocks to the "Champion gneiss series". Radhakrishna (1952) subdivided the rocks of the area into an upper ' Dodguni series' and a lower 'metamorphic series'. Srinivasan and Srinivas (1968, 1972) proposed a geosynclinal scheme of evolution for the rocks of the Dharwar group and described the rocks of the Dodguni series, which forms part of the Dharwar Supergroup, as geosynclinal shelf sediments belonging to the second cycle of sedimentation in the evolutionary cycle of the Dharwars. Mukhopadyay, et al., (1981) and Mukhopadyay and Ghosh (1983) carried out detailed structural mapping around Dodguni area and concluded that the rocks in the area have been affected by multiple episodes of deformation.

The rock formations in the Chikkanayakanahalli area can be

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subdivided into two main groups; the older group made up of amphibolite and chlorite schist interbedded with quartzite and the younger group consisting of BIF, marble, pelitic and semipelitic schists with amphibolite. Lateritoid manganese associated with discontinuous exposures of oligomitic conglomerate demarcates the boundary between the two groups. The older group has been correlated with Bababudan group (Swaminath, et al., 1976) and the younger group with the Chitradurga group (Mukhopadyay, et al., 1981).

The lithostratigraphic succession for the rock formations of the area, as proposed by Devaraju and Anantha murthy (1977, 1984) and (Devaraju, et al., 1986) is given in Table. 1. The supracrustal rocks have been folded into antiforms and synforms and have been subjected to greenschist to amphibolite facies metamorphism. The general physiographic trend of the Chikkanayakanahalli schist belt is North – South, whereas the schistose rocks trend NNW to NW and exhibit dips ranging from 30° to 80° (averaging 55°). A brief description of the rock formations encountered in the study area is provided below.

The oldest lithounit is the gneiss, followed upwards respectively by quartzite, chlorite schist, carbonate and dolerite. The quartzite and carbonate are at places associated with manganese and iron formations.

Methodology:
The methodology adopted in the present investigation is provided below.

Compilation of regional geological maps of the mineralized terrain based on published literature and reconnaissance traverses to establish the lithostratigraphic sequence of the study areas.

- Preparation of large-scale geological plans of the mineralized zone using computer-based MapInfo programme.
- Study of the field setting, morphology/structural features of manganiferous mineralized zone and identification of ore types.
- Collection of representative samples of identified ore types for laboratory investigation.
- Ore microscopic investigations involving textural and mineragraphic studies.
- X-ray investigations of manganese mineral phases.
- Evaluation of genetic features of Precambrian and lateritoid manganese ores.
- Studies on redistribution of the near-surface lateritoid ferromanganese ores during the post-lateritization geomorphological evolution of the terrain.

Basis for the present classification:
Manganese ores of the Chikkanayakanahalli 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.

1. 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 A). 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.

2. 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. B). 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. C) in the weathered phyllite and quartzite. Weathered fragments of phyllite and quartzite in varying proportions are often encountered in the non-colloform manganese ores.

To sum up, the following are the types of manganese ores identified in the study areas:
Metasedimentary Manganese ore: unaltered metasedimentary ore and altered metasedimentary ore, Lateritoid manganese ore: Infiltration type ore. Non-colloform ore and Colloform ore.

Distribution of manganese ore types in Chikkanayakanahall :
In the Chikkanayakanahalli area, two types of manganese ores have been identified by the present worker: (1) Altered metasedimentary type and (2) Lateritoid type. The altered metasedimentary manganese ore bodies occur as conformable beds, lenses and bands within the manganiferous formation and are associated with highly weathered phyllite and quartzite. Lateritoid type manganese ore is encountered as infiltration type ore that occurs as permeations along the cracks, joints and bedding/schistosity planes. Palaeofloat and float ferromanganese ores are conspicuous by their absence in the Chikkanayakanahalli area.

Manganese ores in the Chikkanayakanahalli area are sporadically distributed between Dodguni in the south and Janehara in the north (Fig. 1). Commercially important deposits occur around Karekurchi, Shivasandra, Kondli, Doregudda Taggihalli and Kondli. Of these Kondli, Doregudda and Karekurchi blocks have been selected for the present study in view of the availability of mine exposures for detailed investigations. Mining activity in these blocks too have now been suspended.

Kondli mining block
This block forms part of the village Kondli is located 15 km to the SE of Chikkanayakanahalli. The study area consists of two parallel ridges trending NW - SE, rising to altitudes of above 967 m above mean sea level.

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The supracrustal rocks of the Kondli mining blocks are highly weathered. They exhibit a general N60°E to S50°W trend, with dips ranging from 60° to 70° NW. The lithologic sequence exposed in the mining block is as follows:

Soil
……………………………………………
Banded iron formation
Manganese formation
Limestone
Chlorite schist / Amphibolite
…………………………………………………
Granitic gneiss (peninsular gneiss)

The Kondli mining block is being worked by M.S. mining company and there are two mining pits in this block viz, Balagudda pit and Pooja pit. In these pits both metasedimentary and infiltration type manganese ores are encountered. The metasedimentary ore body extends discontinuously for about 200 m in the Pooja pit, whereas in Balagudda pit, it extends for about 1km. In the above pits, the manganese ores occurs as beds, bands and thin layers interlayered with beds of quartzites/cherts (Fig. D). The manganese ore bands, along with the interlayered quartzites, have been subjected to lateritization and they do not preserve the original texture, mineralogy and therefore these ores have been designated as altered metasedimentary ores. The weathered quartzites are composed of loosely held sacchroidal quartz, which is very well noticed in the Pooja pit (Plate 4.4B).

The lateritoid, infiltration-type, non–colloform manganese ore is also very well exposed in Pooja pit where precipitation of manganese-rich solutions occurred along the joints in weathered quartzite (Fig. E). The recovery of manganese is very poor as the ore body occurs as thin stringers.

Karekurchi mining block

The Karekurchi block forms part of the mining block consists of a series of more or less parallel hills trending NW-SE separated by nallahs and gently undulating valleys. The hills are not very high or steep. Manganese workings are located on the hill slopes and plains and the mining pits are generally shallow.

As in other parts of the study area, even in Karekurchi mining block, the associated rocks are highly altered due to supergene processes, as evidenced by the presence of sacchroidal quartz and intense permeations of iron- and manganese- rich solutions along the primary and secondary structures of the associated quartzite. These formations are overlain, and at places, associated with lithomarge and yellow ochre.

The lithostratigraphic sequence of the Karekurchi mining block is as follows.

Laterite
…………………………………………………
BIF / Ferruginous quartzite
Manganese formations
Chlorite schist / Amphibolite
…………………………………………………
Granitic gneiss

In this block, both metasedimentary and infiltration-type lateritoid ores are encountered. The altered metasedimentary ore is encountered as irregular patches interbanded with quartzite and phyllite. Lateritic weathering of the host rocks has yielded sacchroidal quartz and ochres as noted in Pooja pit of the Kondli block. Infiltration-type manganese ore, which is closely associated with the metasedimentary manganese ore, is the dominant ore type in the area. The infiltration-type manganese ores are associated with wad (an intimate mixture of iron and manganese rich material admixed with lithomarge and ochre). Among the infiltration- type manganese ores, non-colloform type ores are predominant in this mining block. At some places, infiltration-type manganese ores of the colloform type, exhibiting botryoidal and stalactitic features composed of concentric layers of iron and manganese rich material (as will be depicted in the succeeding chapter), are also encountered.

Doregudda mining block

The Doregudda mining block forms part of the mining block consists of NNW – SSE trending hills reaching altitudes of 986 m above mean sea level.

The mining area is covered for the most part by soil and only in the northeastern and southern slopes of the hill, there are outcrops of intensely weathered outcrops of schist and quartzite. However, the mining pits are located on the top and the southeastern slopes.

The lithostratigraphic sequence in the mining block is as follows.

Soil
…………………………………………………………………
Ferruginous quartzite
Manganiferous formation
Limestone
Chlorite schist / Amphibolite
…………………………………………………………………
Granitic gneiss

Mining for manganese ores in the Doregudda is restricted to shallow pits. Manganese ore is essentially in the form of wad, the latter composed chiefly of manganese oxides and exhibiting black to snuff brown colour and is associated with ochreous clay (Fig. F). In the mine pits, wad is usually encountered in intensely altered, friable supracrustal rocks.

At places, concentration of iron is encountered in cavities within boulders of rocks, which may be attributed to precipitation of iron – manganese from percolating ferruginous and manganiferous solution. Such ore bodies assume cavernous appearances are occur at shallow depths in the mining pits (Fig. G).

Summary:

Investigations carried out on the mining blocks of Chikkanayakanahalli and Shimoga areas 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: unaltered metasedimentary manganese ore and altered metasedimentary manganese ore

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

The metasedimentary ore in almost all the mining blocks of the study area (namely Kondli, Karekurchi, and Doregudda in Chikkanayakanahalli 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. The ferromanganese crust has not has been preserved insitu anywhere in the

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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:
Manganese ores of the Chikkanayakanahalli 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 Chikkanayakanahalli 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.

The late Archaean manganese mineralization in the Chikkanayakanahalli region of the Chitradurga belt is spatially associated with stromatolitic carbonates, The manganiferous formation and the associated BIF and carbonates of Chikkanayakanahalli region are stratigraphic equivalents of Fe- and Mn- bearing sedimentary sequence of the central part of the Chitradurga schist belt and hence the source of manganese in both the regions should be attributed to volcanic activity.

Lateritic ore-forming event, involved: Residual alteration of the pre-existing metasedimentary manganiferous formation and associated BIF, and Development of new ore bodies composed entirely of supergene ore minerals.

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

From the above discussion, it can be said that the late Archean manganese mineralization of the Chikkanayakanahalli 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.

The late-Archaean metasedimentary manganese ores of the Chikkanayakanahalli area 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. 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.

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.

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.

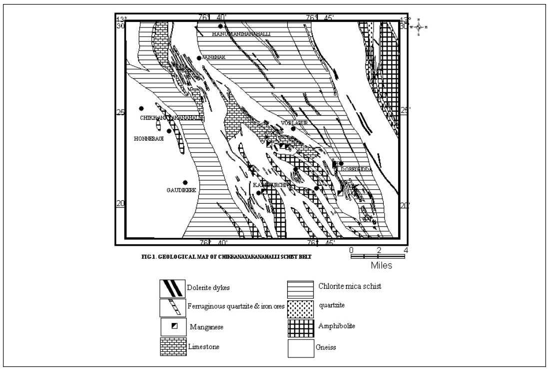

FIG 1. GEOLOGICAL MAP OF CHIKKANAYAKANAHALLI SCHIST BELT

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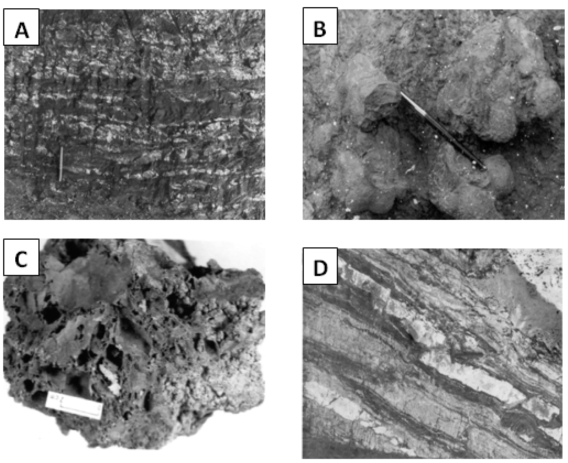
Precursor	Geological processes	lithologies / Present lithologies	petrographicdetails
	Basic igneous intrusion	Dolerites	Quartz,olivine,orthoproxene Poikilitic dolerite and metadiabase.
MAINLY CHEMICAL SEDIMENTS	Ferruginous sediments.	Iron formations	Oxide, mixed oxide-silicate, mixed oxide-silicate-carbonate and carbonate facies iron formations
	Manganiferous sediments.		Manganiferous formation, phyllites and quartzites.
	Carbonate sediments	Carbonates	Limestone, dolomite, calc-schist and ankerite.
DETRITAL SEDIMENTS	Aluminous sediments	Chlorite schist	Chlorite quartz-, biotite Chlorite quartz-, Chlorite biotite carbonate plagioclase-, biotite Chlorite plagioclase and garnet biotite chlorite & grunerite chlorite quartz schist.
	Siliceous sediments	Quartzites and some metaarkose paragneiss	Sericite-, biotite sericite-, fuchsite-, cherty hematite quartzites and orthoquartzite, crushed & sheared muscovite-biotite gneiss.
	GRADATIONAL UNCONFORMITY		
	Granitic intrusion/early Precambrian granite crust	Gneisses	Kandikere gneiss and Honnebagi-Hagalvadi gneiss.

Table 3.1: Lithostratigraphic succession and classification of CN Halli schist Belt (Modified after Ananthmurthy, 1980).



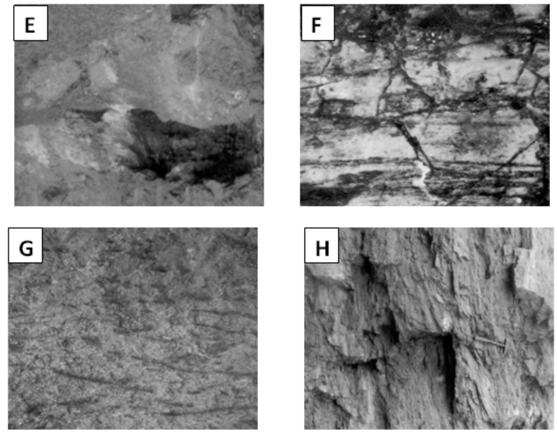


FIG.2.

A. Metasedimentary manganese ore inter bands with quartzite,
B. Lateritoid manganese ore of colloform type,
C. Lateritoid manganese ore of Non-colloform type exhibiting Structure.
D. Metasedimentary manganese ore bed inter bedded with quartzite
E. Weathered and friable quartzite found associated with alter metasedimentary ores.
F. Permeation of manganese-rich solution along joint and weathered quartzite.
G. Wad-type manganese ore associated with ochreous clay.
H. Cavernous type of iron-manganese rich ore boulders.

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