Petrographical Characters of Some important host rocks in Vizianagarm Manganese Ores Belt (A.P.), INDIA.

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Abstract

Petrographical study of various rocks types has been carried out in the present study area with the discovery of a new rock type- Crystalline algal Limestone. An attempt has been made to describe the petrographical characters of the following rock types encountered in the present study area.

1. Calc-granulite
2. Garnet-sillimanite-feldspathic gneiss
3. Garnetiferous gneiss
4. Feldspathic quartzite
5. Crystalline algal limestone
6. Shale
7. Hypersthene gneiss.
8. Granitic gneiss.

The older Khondalite Group mainly consists of calc-granulite, garnet sillimanite gneiss, feldspathic quartzite and garnetiferous gneiss. The occurrence of crystalline algal limestone and red and green shales have been

reported for the first time. The younger Charnockite Group mainly consists of hypersthene gneiss (porphyrroblastic and non-porphyroblastic) and granitic gneisses. Granite and pegmatite occur as intrusive bodies in this group of rocks. The Khondalites and Charnockites show a complex structural pattern resulting from repeated periods of deformation. The general strike of rocks is NW-SE with local swings at places. These rocks at places show relict banding.

Stratigraphically these are included within a thick succession of Pre-Cambrian rocks belonging to the Khondalite and Charnockite Groups of Dharwar Supergroup, that form a part of Eastern Ghat Complex of India. The manganiferous rocks that have been encountered in the Vizianagarm Manganese Ore Belt (A.P.) India are known as Kodurites. At different places the rock types constituting the host rocks of manganese are essentially garnet sillimanite gneiss (Chipurupalle and Garbham), quartzite and garnetiferous quartzite (Garbham, Koduru, Perapi & Avagudem) and calc granulites and gneisses (Koduru).

Key Words: Pertrography, Vizianagram, Manganeses Ores, Khondalite, Charnockite, Calc-granulite, Garnet Sillimanite Gneiss, Felspathic Quartzite, Crystalline Algal Limestone.

1.0 INTRODUCTION

Numerous types of rocks occur in Vizianagarm Manganese Ore Belt (A.P.), India which belongs to Eastern Ghat Mobile Belt of the Indian Precambrian shield. (Figureure 1 & 2). The host rocks encountered in the present study area are mainly low to medium grade meta-sedimentary rocks. (Acharya and nayak, 2002).

The geology of the area was earlier worked out by Krishna Rao (1954 a, b 1964) and Venkatarmaiah et al. (1978), Rao (1969) and Sharma et al. (1974) have marked three manganese bearing horizons within the Khondalite group. In this area the base is Biotite gneiss (Siddiquie 1986, 2000 & 2003); (Rao, 1969). Venkataramailah et. al., (1978). also recorded two new horizons comprising of crystalline algal limestone, and red and green shales have been identified within the Precambrian sequence of Khondalite and Charnockite groups of Dharwar Supergroup that forms a part of Eastern Ghat complex of India. (Siddiquie, 1986, 1988a, 1988b; Siddiquie and Raza, 1990, 2001; Siddiquie, 2000; Siddique and Meraj, 2001; The Times of India 2002, Siddiquie, 2003) and gritty sandstone (Miocene) in the form of rubble and laterite capping.

So far, no systematic approach to study the host rock has been made in an attempt by earlier workers. The present investigation is proposed to describe a detailed petrographical charecters of the host rocks. In general, the manganese ores in the area occur primarily associated with clac-granulites, less often with quartzite and still less with quartz garnet +/- sillimanite+/- graphite gneiss (Khondalite). These rocks have in turn been intruded by granite and pegmatite. The general disposition of the ore bearing rocks is NW-SE. The manganese ore bodies essentially follow the trends of the host rocks.

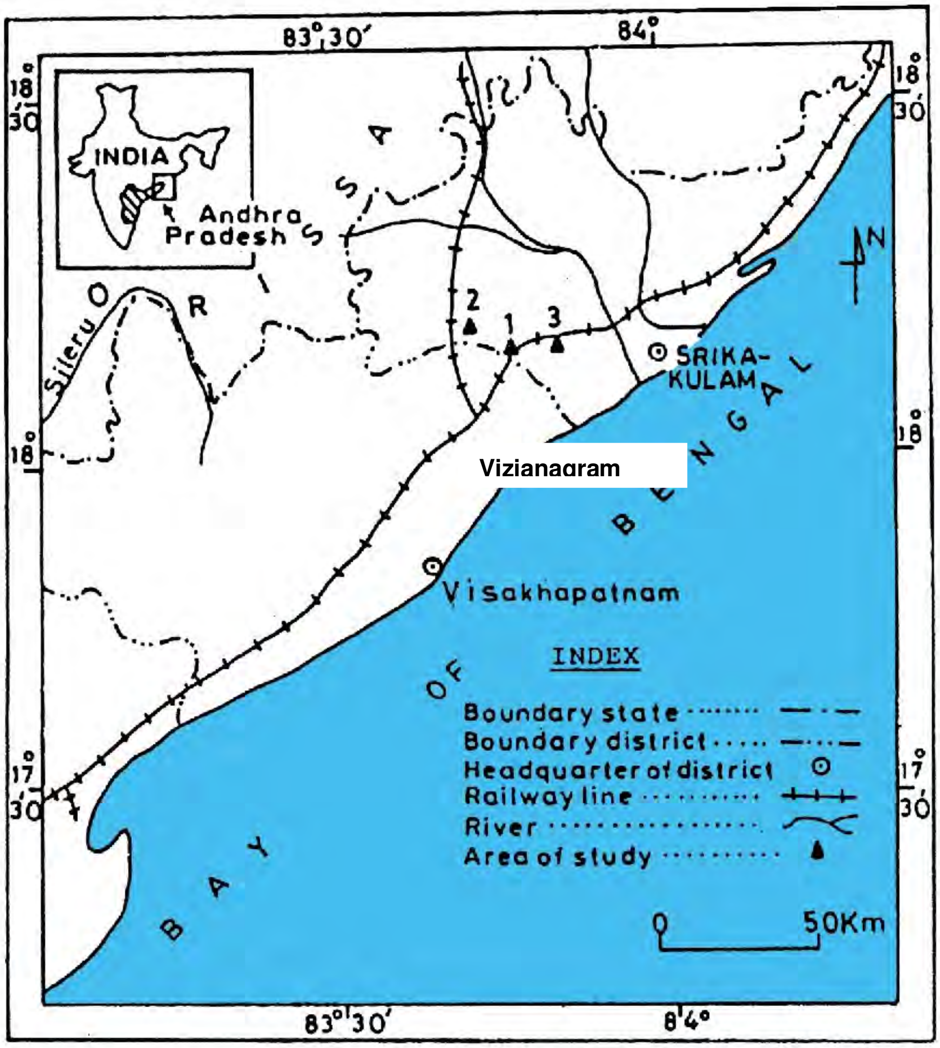


Figure 1: Location Map of 1. Garrividi,2. Garbham and 3.Chipurupalle mangnaese deposits, Vizianagram Manganese belt (A.P-INDIA.)

2.0 GEOLOGY OF THE AREA UNDER STUDY

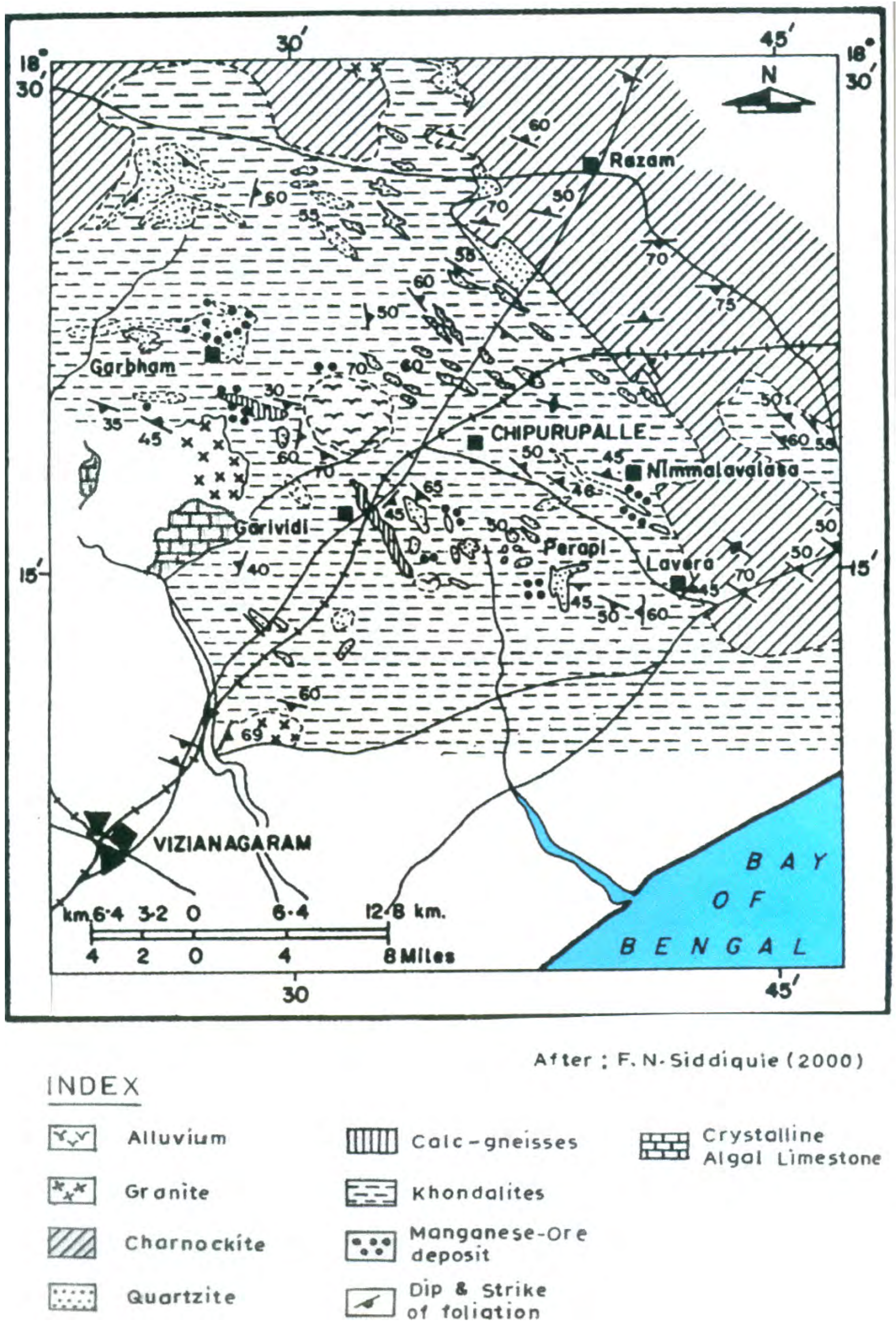
The manganiferous rocks that have been encountered in the Vizianagarm Manganese Ore Belt (A.P.), India belong to Kodurite Series which are typically exposed at Koduru (18° 16': 83° 36'), a locality about 80 km north of Vishakhapatnam, the rock series which constitute an integral part of the Eastern Ghat complex of India. The rock series are composed of an intimate assemblage of metamorphosed argillaceous (garnet-sillimanite gneisses) as at Chipurupalle, Rayagada and Garbham, arenaceous (Quartzite and garnetiferous quartzite) as at Garbham, Koduru, Perapi and Avagudem and calcareous sediments (calc-granulites and gneisses) as at Koduru and Gadabavalasa areas, this sequences belonging to granulite facies. The manganese ores in the area occur primarily in association with calc-granulites, less often with quartzite and still less with the quartz garnet ± sillimanite ± graphite gneiss (Khondalite).

According to Sarkar, 1968, who made radiometric determination of the Precambrain rocks of India, the Eastern Ghat Complex was included in the Precambrain-II (2,500-3,000 m.y.) of the classification of Indian Precambrain rocks. The calc-granulite, quartzite and Khondalites being syn-sedimentary rock bodies, are conformable and co-folded with the associated lithic units such as garnetiferous quartzite, gneisses and gamet-sillimanite gneisses, etc. (Roy, 1966).

Subsequently, granitic and migmatitic activities of different intensities played their respective roles on these metasediments, transmuting their earlier textural and mineralogical characters. However, their impact on quartzite and manganese ore is minimal, probably because these units are considered to be the resisters during migmatisation (Mahnert, 1968). At places, hypersthene gneisses (Charnockite) occur as intrusive bodies in the synsedimentary rock units. All these rocks have in turn been intruded by granite, pegmatite and quartz veins (Rao, 1969). Fermor (1909) recognised several rock types ranging from ultra basic to acidic in the mineralogical composition of Kodurite and ascribed them to differentiation prior to intrusion. Middlemiss (1914) indicated that the Kodurite series might be due to hybridism on a large scale in which a granitic intrusion bodily assimilated the manganese of the Khondalites.

3.0 METHODOLOGY ADOPTED

The authors visited all the mines at Vizianagram District. About hundred samples (both of ores and rocks) have been collected following grid method, out of which fresher and unweathered samples were selected for geochemical analysis, petrographic and mineragraphic studies of the thin section of rocks and polished blocks of ores were carried out under ransmitted and reflected light respectively.



Figureure 2: A generalised geological Map of Garividi, Garbham and Chipurupalle manganese deposits, Vizianagram district A.P

4.0 PETROGRAPHY

4.1 Calc-granulite

The calc-granulite samples were collected from Faccor Hill, Devada Hill, Peroxide quarry (Garividi) and one from the Central Garbham quarry.

The calc-granulite is an equigranular and medium grained rock that exhibits granulitic texture. It is composed mainly of scapolite, orthoclase, diopside, hornblende, quartz, garnet, calcite and wollastonite. The accessory minerals identified included piedmonite, epidote, apatite, zircon, microcline and sphene.

The diopside is an important and a constant mineral occurring in all thin sections of calc-granulite. It is green in color, irregular in form having a moderate relief with well-developed one set of cleavage. Some of the grains are faintly pleochroic. This shows characters similar to manganese pyroxene.

The scapolite is tabular in form with moderate relief. It is colorless in thin section and has straight extinction and the polarization colors are pink and yellow of second orders. The wollastonite is shining, long, thin, flat needles having an oblique extinction. It is generally in association either with calcite or with quartz. Calcite shows characteristic rhombohedral cleavage and twinning in plain polarized light.

Quartz shows undulose extinction and some of the quartz grains are fractured. Orthoclase which shows Carlsbad twinning sometimes occurs as porphyroblasts.

Scapolite, quartz and orthoclase are the dominating minerals of calc-granulites. Garnet is pink in color, somewhat, fractured and the crystal boundaries are occasionally replaced by quartz (**Figure 6**), few garnet grains are altered to hydrated manganese oxides along the cracks. They are pitted presenting high relief and are isotropic. The piedmonite is orange colored with relief higher than Canada balsam, and having one set of cleavage. Occasionally there are inclusions of manganese ores in orthoclase and quartz in which they appear as multi-central replacement bodies (**Figure.7**).

4.2. Garnet-sillimanite-feldspathic gneiss

The garnet-sillimanite-feldspathic gneiss samples were collected from Garbham, Central Garbham mine and from Udikimeta hill areas. The rocks which is medium to coarse grained, shows gneissose structure and consists mainly of orthoclase feldspar as the dominating mineral with sillimanite, garnet, quartz, graphite and biotite. Magnetite, apatite and rutile are the common accessory minerals.

Garnet is generally is very characteristic constituent of this Group of rocks. It is light pink in color, isotropic and refractive index is high. It is generally diablastic frequently shows inclusions of quartz, magnetite and needles of sillimanite where the garnets are altered manganese is found as incrustation over it. Feldspars, which are mostly orthoclase and plagioclase, occur in subordinate amounts. The plagioclases occur as minute grains.

Sillimanite occurs as long stout needles and arranged in a parallel disposition conforming to the general gneissosity of the rock. It has high refractive index and polarizes in second order green and pink. The quartz is colorless and constitutes a major part of the rock. It shows undulose extinction and fracturing. The graphite occurring in this rock in varying amounts is opaque and usually occurs in the form of small flakes.

The rock collected from Central Garbham quarry (**Figure. 8, 9**) contains feldspar and garnet which are rounded to sub rounded and elliptical in shape. The rock samples collected from Udikimeta hill and Central Garbham areas (**Figure.10, 11**) is composed of feldspar, quartz and garnet which are anhedral, broken, sharp-edged and angular in shape. These shapes indicate some brecciation of the rock which may be due to effect of faulting.

4.3 Garnetiferous gneiss

The garnetiferous gneiss, collected from East Garbham quarries. The rock is medium to coarse grained. It is composed largely of garnet with variable amounts of orthoclase, plagioclase, microcline, quartz, chloritoid, spinel and some opaque ore mineral (**Figure 13**). Garnet is euhedral, relief is high and occurs as porphyroblasts. Plagioclase is twinned, quartz usually shows wavy extinction. Spinel is light brown in color, relief is high. There are clusters of fine tadpole-like inclusion of spinel in orthoclase with preferred orientation of the grains along the cleavage direction of the minerals. Chloritoid is characterized by the presence of strain slip cleavage (**Figure 12**), the color of chloritoid is light gray and showing slight Pleochroism. Cleavages perfect in one direction and extinction almost parallel.

4.4 Feldspathic quartzite

The feldspathic quartzite, collected from East Garbham quarries and from Udikimeta, is medium grained. In East Garbham quarries it occurs in the form of lenses and pockets within the calc-granulite. It is mainly composed of quartz, feldspar (microcline and plagioclase), augite and uralite. The augite is of brown color, showing moderate to high relief. Augite alters into uralite (**Figure 14**), (Siddiquie, 1986). Manganese ore is occasionally associated with orthoclase in the form of small inclusions.

4.5 Crystalline algal limestone

The crystalline algal limestone samples were collected from Koduru quarry. The rocks is coarse grained and equigranular. It is composed of calcite (showing polysynthetic twinning), dolomite (showing polysynthetic twinning but the lamellae are thick, **Figure 4**), piedmontite, orthoclase, scapolite and Lucite in addition to quartz. The common accessories include sphene and some opaque ore minerals.

The limestone is partly dolomitized. Idiomorphic crystals of quartz are occasionally found replacing the carbonate minerals (**Figure 5**).

The presence of some algal bodies in all the thin sections of the rock is important feature, (Siddiquie, F.N. 2000; Siddiquie and Meiraj 2001c; The Indian Express 21st march 2003 & Siddiquie 2003). One of the edges of the algal body shows cylindrical outline facing the arrow formed of calcite (**Figure 15**). This filament like body has got distinct cellular outline and suture (**Figure 16**). Thus it is not a mineral, as it looks like structure of an algal body (Horowitz, A.S. & Potter, P.E., 1971) belonging to Precambrian age (**Figure 21**). The rock appears to be a low grade metamorphic product of Calcareous sediment.

The thin section study of the crystalline limestone of the Koduru Main Quarry exhibits preservation of the algal structures which are referable to Cholorphyta. Unicellular green alga *Lepocinclis* (Palmer, 1980) and some thalloid bodies with fibrous structure are recognized from the hitherto unfossiliferous crystalline limestone.

***Lepocinclis*:** The unicellular alga with elliptical shape has been observed in the crystalline limestone of Koduru Main Quarry (**Figure 17**). In the sub apical region, photomicrograph, of the protubrant structure is probably an eye spot of the green alga. The modern *Lepocinclis* bears two long flagella (Palmer 1980). Being a delecate structure, flagella had been lost during lithification and metamorphism and are not well preserved.

Thalloid Bodies: Organic structures (**Figure 15, 16**) are seen as dark brown features under thin section which are sub-polygonal to sub-rounded in outline. Under higher magnification, these structures exhibit fibrous algal features (**Figure. 18**). The preservation of cellular structures suggests that these are remnant of some thalloid bodies. The algal bodies have been partially replaced by calcification and silicification.

4.6 Shale

In the manganese mines of Garividi village, small pockets and lenses of green shale near Vibhu soda plant and a few pockets of red shales in Dhobi pit were recorded for the first time by the author (Siddiquie, F.N. 2000; Siddiquie and Meiraj 2001c; The Indian Express 21^{st} march 2003 & Siddiquie, 2003). These lenses and pockets of shale are found in association with calc-granulite and manganese ores.

The shale is ferruginous and alters into lateritic soil at the surface. It often shows thinly bedded appearance. The minerals identified include quartz, mica, sericite, kaoline and some ferruginous materials arranged in different regularly defined lithic planes. Along with the ferruginous material few patches of dark gray substance are also found which may possibly be the manganese ore. Quartz is generally inequigranular and the crystals are angular to sub-angular and distributed evenly exhibiting typical wavy extinction.

There are a few porphyroblasts of medium grained quartz. The smaller quartz grains often show pressure shadow. The lighter bands of quartz alternate with bands of micaceous minerals (**Figure 19**).

Sericite occurs mostly as fine fibrous aggregate. It shows either pale green or white color. It is present in the rock in close association with muscovite and quartz. Occasionally the shale appears as phyllite with the increase of micaceous minerals.

4.7. Hypersthene gneiss

It occurs in the vicinity of Koduru area. In Jai Bhavani pit (Garbham) it occurs a lenticular bands within calc-granulites. In Peroxide pit (Garividi), the color of hypersthene gneiss is light to dark gray. On weathered surface it is buff and cream colored. In general, the rock exhibits spheroidal weathering and rhomboidal jointing.

The texture of hypersthene gneiss is equigranular, medium grained, composed mainly of quartz, potash feldspar, sodic plagioclase, hypersthene, garnet, biotite and hornblende. The accessory minerals identified include some opaque ore minerals and apatite (**Figure 20**) with occasional presence of zircon.

Orthoclase is some what cloudy. The hypersthene is pale green in color, shows greenish to pale reddish Pleochroism, the crystals of hypersthene are subhedral to prismatic, relief is high. Garnets are dull red in color and having inclusions of opaque ore minerals. Hornblende is green colored, prismatic; relief is high and shows pale green pleochroism.

5.0 CONCLUSION

Petrographical studies of various rock types are carried out. The mineralogical assemblages of important rocks are identified as follows:

S.No.	Rock Type	Mineral Assemblages
1.	CALC-GRANULITE	Scapolite, Orthoclase, diopside, hornblende, quartz, garnet, calcite, wollastonite, piedmontite, apatite, zircon and sphene.
2.	GARNET-SILLIMANITE-FELDSPATHIC GNEISS	Orthoclase, sillimanite, garnet, quartz magnetite, apatite and rutile.
3	GARNETIFEROUS GNEISS	Garnet, orthoclase, plagioclase, microcline, quartz, chloritoid and spinel.
4	FELDSPATIC QUARTZITE	Quartz, microcline, plagioclase, augite and uralite.
5	CRYSTALLINE ALGAL LIMESTONE	Calcite, dolomite, piedmontite, orthoclase, scapolite, leucite, quartz, sphene and some opaque ore mineral.
6	SHALE	Quartz, mica, sericite, kaolin and some opaque ore minerals.
7	HYPERSTHENE GNEISS	Quartz, feldspar, hypersthene, garnet, biotite, hornblende, apatite and occasionally zircon.

In calc-granulite some garnets show alteration to hydrated manganese oxides along the cracks. However, in garnet-sillimanite-feldspathic gneiss, garnets are altered and manganese is found as incrustation over them. Occasional inclusions of manganese ores in orthoclase and quartz appear as multicentral replacement bodies. In feldspathic quartzite manganese ore is occasionally associated in the form of small inclusions. The mineralization of manganese ores is confined to both Khondalites and Charnockites.

As already mentioned, the author has found two pockets of crystalline algal limestone, one lens of red shale and one pocket of green shale. The sediments in the provenance were consisting of immature material of red and green shale which were laid towards the last phase of calc-granulite deposition. The chances are that at this stage, i.e., at the time of sediments deposition, while the sediments were coming from the main source having calcareous provenance. Sediments from another source also started coming into the basin, and these were deposited as red and green argillaceous lenses and pocket, m the early stages, the two provenances were supplying both arenaceous and calcareous sediments and contributed equally for the formation of present day rock types. However, in the last stage there had been reduction in the supply from arenaceous source and an increase in the supply of calcareous source.

Figure 4*:* *C*oarse grained crystalline limestone showing dolomite (polysynthetic twinning) calcite (also polysynthetic but lamellae are thin) and a small grain of scapolite, Koduru quarry, Garividi Vizianagrammanganese belt (A.P.) India. (Crossed Nicol, x25)

Figure 5: Coarse grained limestone showing replacement of Calcite by quartz, Koduru quarry, Garividi , Garividi Srikakulam-Vishakhapatnam manganese belt (A.P.) India. (Crossed Nicol, x25)

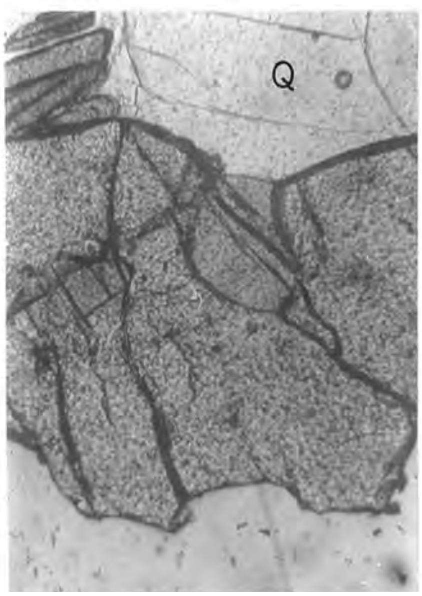


Figure 6: Calc-granulite, showing partial replacement of garnet by quartz Devada hill, Devada, Vizianagrammanganese belt (A.P.) India. (x63)

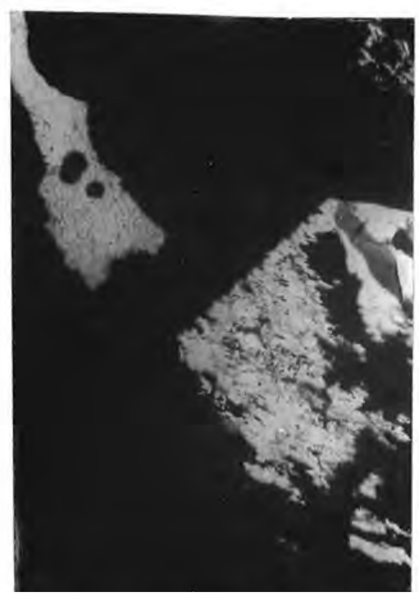


Figure 7*:* *C*alc-granulite, showing isolated angular fragments of quartz and orthoclase (lighter tone) in manganese ore (dark), "Perroxide quarry", Garividi Vizianagrammanganese belt (A.P.) India.
(Crossed Nicols 63)

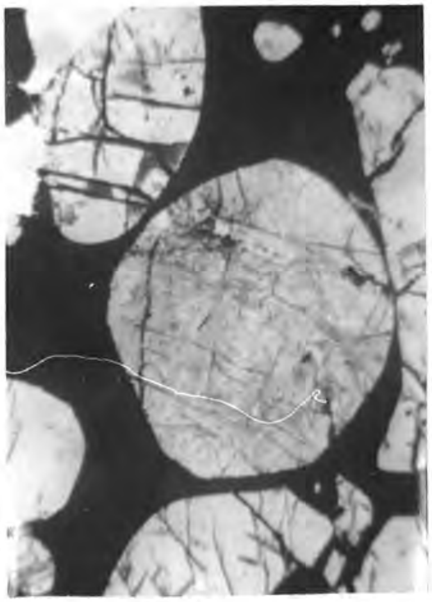


Figure 8*:* Khondalite, showing, elliptical and sub-rounded grains of feldspar, embedded in Mn ore, Central Garbham Vizianagrammanganese belt (A.P.) India. (Crossed Nicols x25)

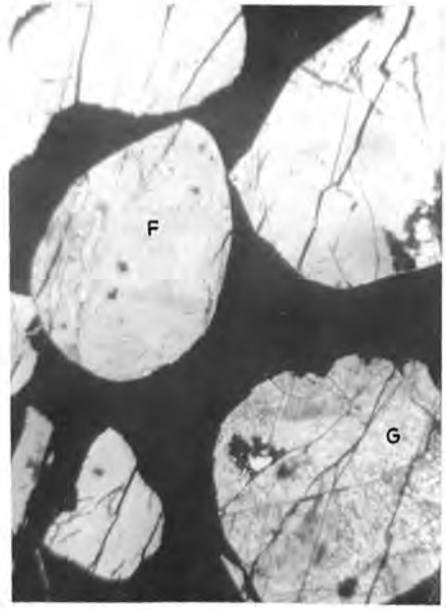


Figure 9*:* Kondalite, showing, sub-rounded garnet (G) and oval shaped feldspar (F), embedded in Mn ore, Central Garbham Vizianagrammanganese belt (A.P.) India. (Crossed Nicols x25)

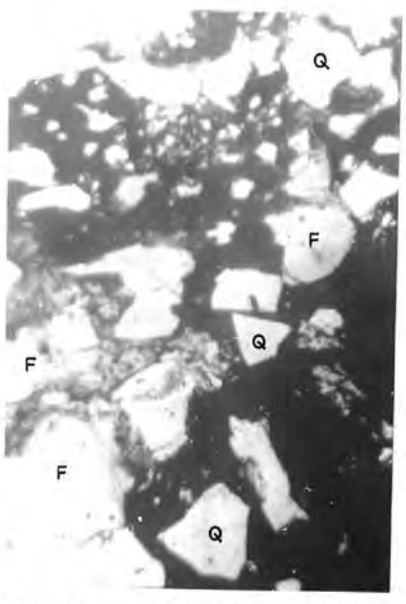


Figure 10*:* Kkhondalite, showing, angular fragments of quartz (Q) and orthoclase (F) enclosed in Groundmass of manganese ore, Central Garbham Vizianagrammanganese belt (A.P.) India. (Crossed Nicols x25)

(A.P.) India. (Crossed Nicols x25)

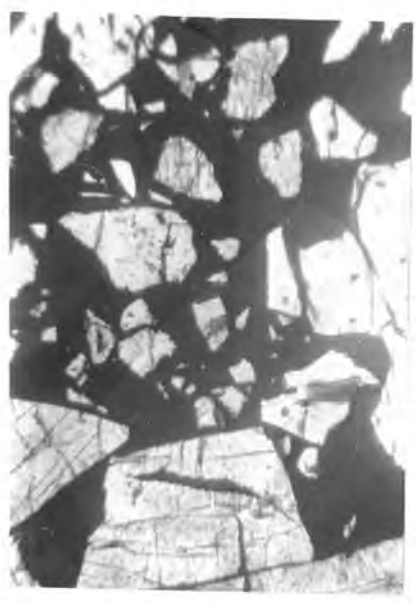


Figure 11*:* Kkhondalite, showing, edged angular fragment of quartz, orthoclase and scapolite in Mn ore (black),Udikemeta Hill Garbham Vizianagrammanganese belt (A.P.) India. (Crossed Nicols x25)

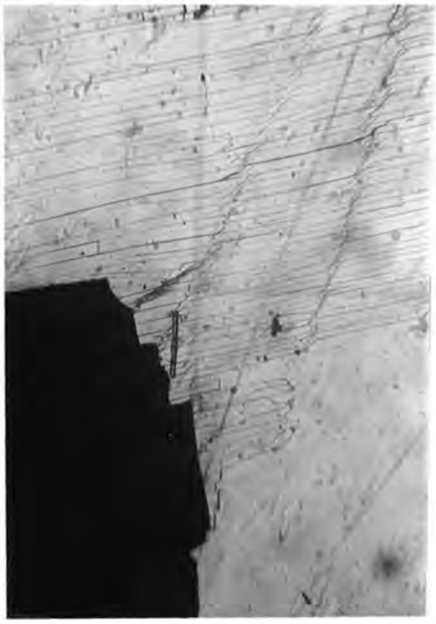


Figure 12*:* Grnetiferous gneiss, showing, strain slip cleavage in chloritoid (lighter tone). 'B quarry' East Garbham Vizianagrammanganese belt (A.P.) India (Crossed Nicols x63)

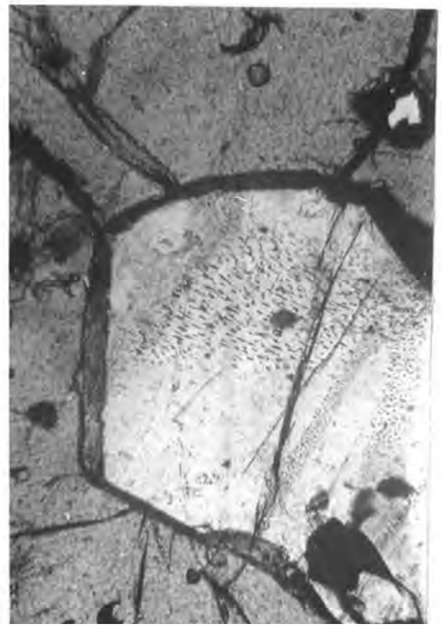


Figure 13*:* Oorthoclase crystal in garnetiferrous gneiss showing very minute inclusions of spinel oriented preferably along the cleavage direction of orthoclase 'B quarry' East Garbham Vizianagrammanganese belt (A.P.) India. (x63)

Figure 14*:* Felspathic quartzite, showing, granoblastic texture and assemblage of quartz (Q) , felspar (F), Uralite (U) and Mn ore Uralite showing alteration from pyroxene. 'A quarry' East Garbham Vizianagrammanganese belt (A.P.) India. (x25)

Figure 15*:* Crystalline algal limestone, two attached algal bodies, one sub-polygonal (upper part) and the other, cylindrical "U " shaped (lower part). Noete the presence of calcite in the circular cross section (arrows marked) Koduru quarry, Garividi Vizianagrammanganese belt (A.P.) India. (x25)

(A.P.) India. (x25)

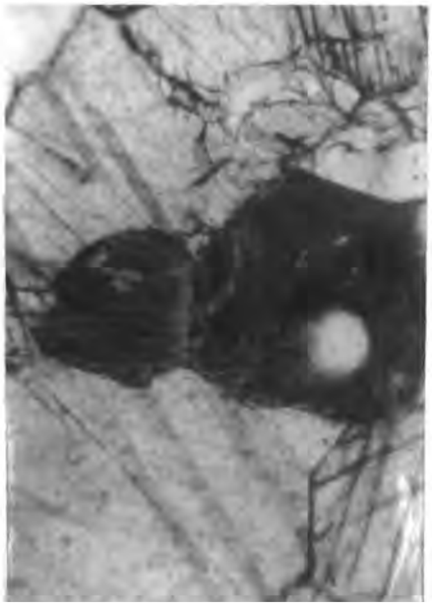


Figure 16*:* Crystalline algal limestone. Two attached algal bodies, one elliptical (upper part) and the other sub-polygonal (lower part) showing a white hollow structure, probably a vacuole of algal cell, Koduru quarry Garividi Vizianagrammanganese belt (A.P.) India.

Figure 17*:* Crystalline algal lime stone showing an algal body: ***Lepocinclis*** showing prominent impression of spiral shaped chloroplast. On the left side of sub-apical region, a dark coloured protuberant structure is supposed to be an eye spot which is meant for perception of light. The alga is embedded in crystalline limestone. Koduru quarry, Garividi, VizianagramMn belt (A.P.) India. (x63)

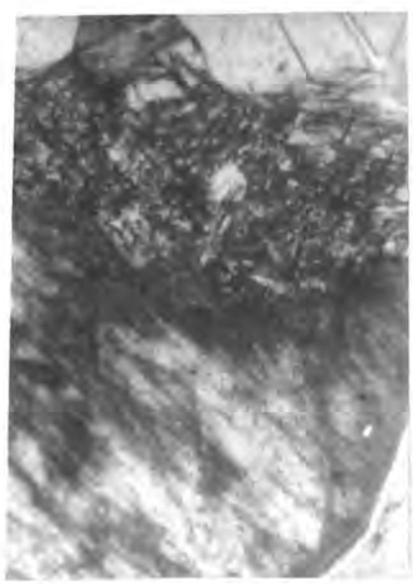
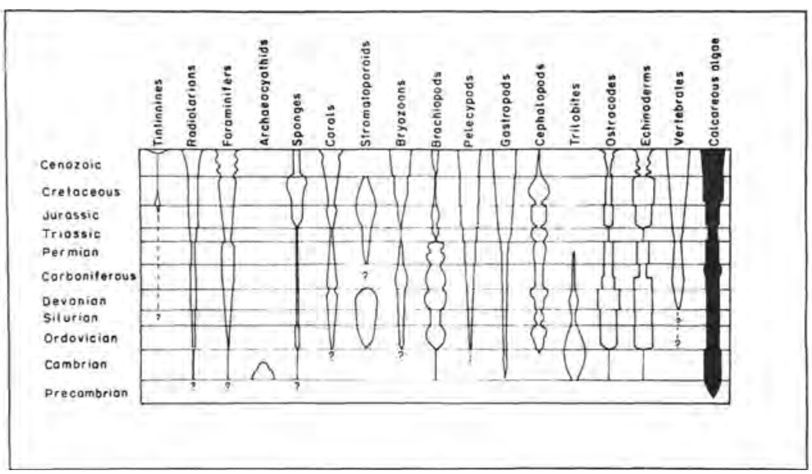


Figure 18*:* Crystalline algal limestone. An akgal body (lower) being partly replaced by cherty, Silica (upper) Koduru quarry, Garividi Vizianagrammanganese belt (A.P.) India. (x63)

Figure 19*:* Fine grained shale showing preferred orientation of quartz and micaceous minerals along the shaly bands Koduru quarry, Garividi, Vizianagrammanganese belt (A.P.) India. (crossed Nicols x40)

Figure 20*:* Hypersthene gneiss, showing laths of hornblende, biotite , hypersthene, plagioclase (exhibit albite twinning) and quartz (angular) Jai Bhawani pit, Garbham Vizianagrammanganese belt (A.P.) India. (Crossed Nicols x75)



Figrure 21: Age range and Taxonomic diversity of fossil groups; also showing distribution of calcareous algae through geological time scale (solid bar) after Horowitz and potter, 1071).

7.0 ACKNOWLEDGEMENT

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