FERRIDE GROUP OF ELEMENTS AND THEIR SIGNIFICANCE IN THE GENESIS OF BANDED IRON FORMATION OF THIRUVANNAMALAI GRANULITIC TERRAIN, TAMILNADU, INDIA

C. Sakthivel, A. Thirunavukkarasu, R. Suresh, C. Kasilingam,
C. Ramachandran, M. Sankar
Department of Geology
Periyar University, Salem-11,
Tamilnadu, India.
E-Mail:-Petrosakthi25@gmail.com

ABSTRACT

The study area is well known for its iron formation in the Precambrian high-grade Granulitic Terrain of South India. An attempt is made to understand the ferride group of elements and their significance in the genesis of Banded Iron Formation (BIF). BIF in these formation is mainly of banded magnetite quartzite (bmq) associated with pyroxene granulites, charnockite and granite -gneisses. About 10 rock samples from iron ores and other associated rocks were collected and analyzed for the ferride group of elements. The results of geochemical analyses show the ferride group elements vary much less in iron ore samples than in pyroxene granulites. The proportion of Manganese (Mn) and Titanium (Ti) are high compared to other elements. The depleted ferride group elements banded iron formation indicates that the source might have been derived from weathering of landmasses and not from volcanic sources. Thus, the ferride group elemental study of Thiruvannamalai region shows that the banded iron formations have meta-sedimentary in origin. Also, the FGE correlated with other world iron formation shows their similarities with other well-known meta-sedimentary iron ores.

Keywords: *Banded Iron Formation, Ferride Group Elements (FGE) and Thiruvannamalai region, India.*

INTRODUCTION

The iron formation of Tamil Nadu state occur as bands, enclaves, veins in the districts of Salem, Dharmapuri and Tiruchirappalli (King and Foote, 1864; Holland, 1893; Dubey and Karunakaran, 1943; Krishnan and Aiyengar 1944; Ramanathan, 1956; Saravanan, 1969; and Radhakrishna et al., 1986; Rajendran, 1996; Rajendran and Chandrasekaran, 2000; Rajendran et al., 2007, Thirunavukkarasu, 2009). These banded magnetite quartzite differentiated on the basis of presence of magnetite and quartz and having an iron content of 35- 40% (low-grade iron ores; Radhakrishna et al., 1986). The Iron ore deposits are in the age group of Precambrian iron formation occurring as narrow, highly deformed and metamorphosed belts within the Archaean granulite terrain (Prasad et al., 1982).

These rocks are older than 3,000 Ma (Radhakrishna et al., 1983). Previous work for geochemical studies have been mainly focussed on the low concentration of ferride group of elements as was reported from meta-sedimentary iron ores or in late magmatic differentiates by Landergren (1948), Goldschmidt (1954), Rankama and Sahama (1950), Fripp (1976), Subba Reddy and Prasad (1982), Chakraborty and Majumder (1986) and Thirunavukkarasu (2008). Although, a large amount of literature is available on the general geology, geochemistry, structure, metamorphism, tectonics and age of the iron ore formation of the area (Acharya, 1964; Chakraborty and Taron, 1968; Acharya et al., 1982; Majumder, et al., 1982; Majumder, 1985; Chakraborty and Majumder, 1986; Saha, 1994), very limited work has been carried out on the ferride geochemistry of iron ore. The present work emphasizes on the ferride group of elements concentration and their significance in the genesis of banded magnetite-quartzite iron ore formation of the study area.

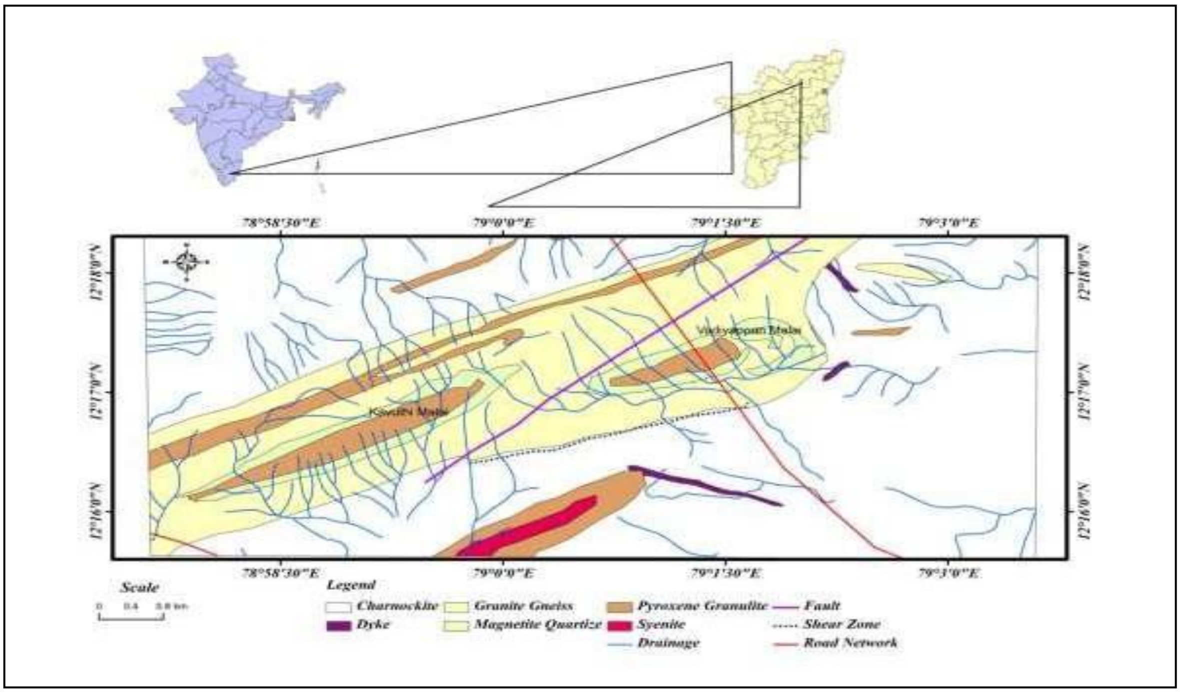


Figure 1. Location Map of the Study Area.

GEOLOGY & STRUCTURE

The rock of the study area includes pyroxene granulite, charnockite, granite gneisses and banded iron formation and are present according to their order of superposition. The pyroxene granulites, charnockite and granitic gneisses show sharp contacts with each other. The charnockite have xenoliths of pyroxene granulites, which indicate the former as younger. The fault zone that had taken place in the NE-SW direction and later metamorphosed.

The banded iron formation of the study area occurs as three discontinuous bands two major hills. These two hills are separated by fault striking NE-SW. The total length of band is approximately 10 km and the apparent width varies from 10 to 23 m. The top of the iron ore ridge is strewn with large loose joint blocks. The iron ore generally exhibits medium grained texture. The width of the band varies from 10 to 45 m and the total length of band is about 9 km.

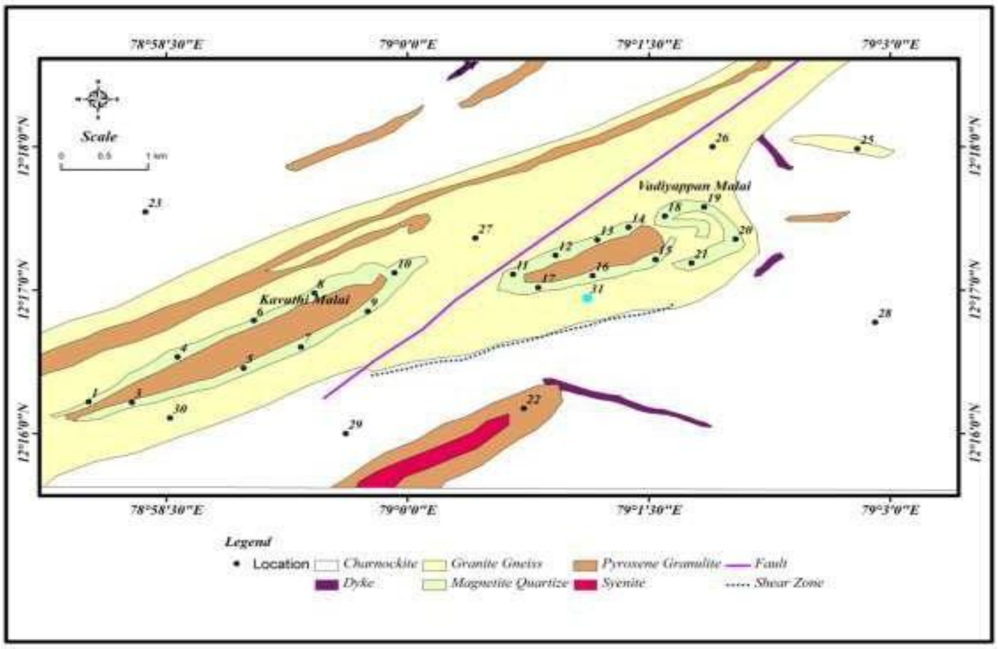


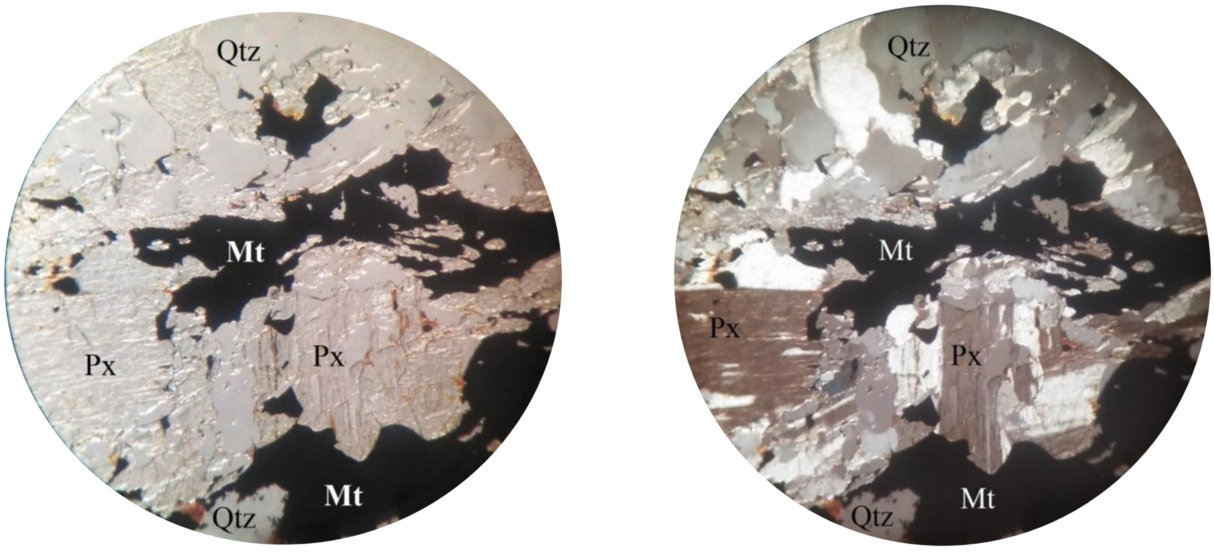
Figure 2. Geological map of the study area

The western portion of the fault occurs as steeply dipping on the top as basin like structure. The eastern end of this hill shows the BIFs on the northern flank is repeatedly folded and is connected with the southern flank at a point near the peak of the hill**.** The rocks are seen with distinct banding, due to the occurrence of thin discontinuous ribbons and laminae of quartz and alternating with those rich in dark iron minerals. The BIFs are well-banded and consisting of millimeter to centimeter thick alternating iron-rich and silica- rich layers. The magnetite crystal in the northern limb shows medium to course grained, while in the southern limb it is usually medium grained, with well developed crystals. In some places, especially in the eastern region of the hill near the (Vediyappan temple) magnetite patches are very coarse grained, with well developed crystals. Also, huge joint blocks occur on the top of the ridge. The width of the individual layers range from a few millimeters to centimeters. The BIF is highly weathered two blocks of different sizes strewn all along the hills. At few places, these are so weathered as to obscure the silica bands. Some boulders of BIF at the top of the two hills are showing the minor folding.

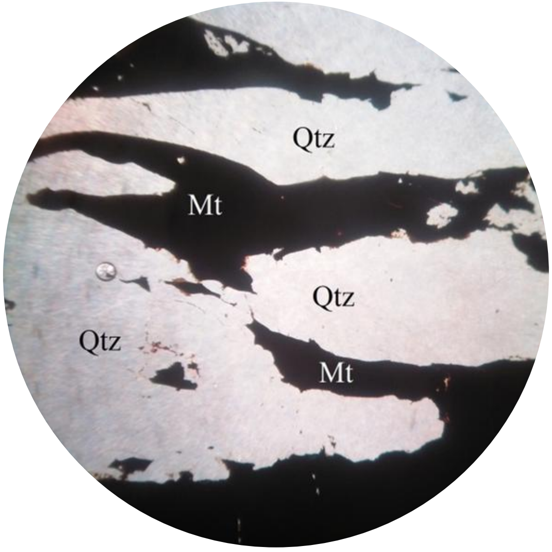
PETROGRAPHY

The petrography of the BIFs is mainly composed of magnetite and quartz with minor proportions of hypersthene, hedenbergite, cummingtonite/grunerite, garnet and apatite. Magnetite occurs as irregular grains or bands. The association of magnetite with quartz ranges from granular to well banded nature with alternate layers of quartz and magnetite. The numerous cracks in the quartz are filled with iron oxide. In some section shows the veins appear to be feeding the iron oxide bands. Also, sections are fine hair line cracks from the iron oxide grains extend in to quartz grins, which form a mesh like network. The ore petrography study of iron ore samples shows light magnetite is grey in color with brownish tinge. The octahedral and cubic parting planes indicated by triangular pits. In some iron ore sections shows faint an-isotropism due to the presence of martite formed by martitistion, along the octahedral parting planes and thus giving rise to a network of triangular lattice pattern. The martite is identified by its high reflectance than magnetite and by its light grey in color with bluish tinge. Quartz is the dominant mineral in many assemblages. It occurs as elongated grains and alternate bands with magnetite. In addition, this mineral is also occurs as inclusions in magnetite. The grain size is to be finer at the contact with magnetite than far off. The deformation effects in quartz are marked by marginal granulation and development of numerous cracks filled with iron oxide. The individual grains of quartz contain dust like numerous inclusions of magnetite.

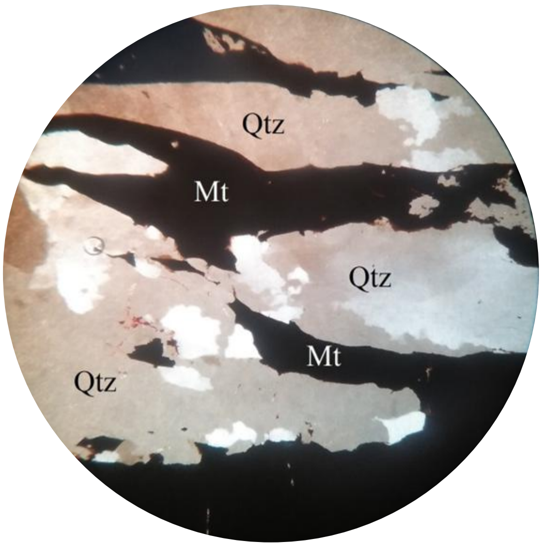
1. PPL (a) XPL (b)



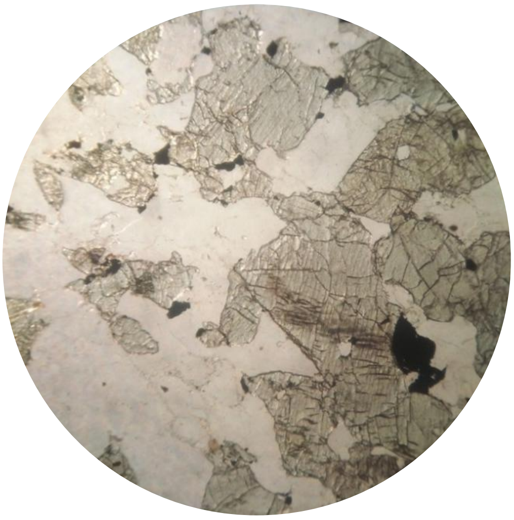
2. PPL (a)



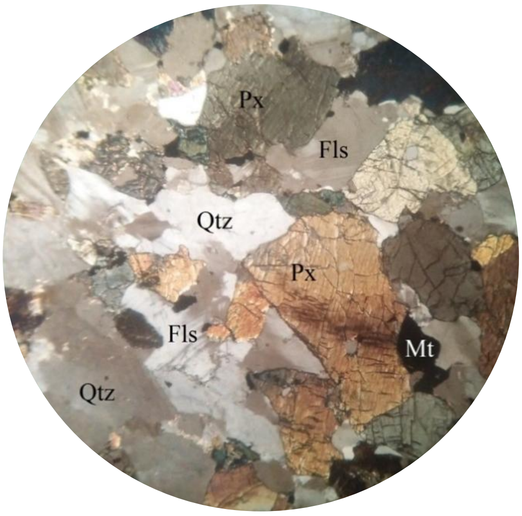
XPL (b)



3. PPL (a)



XPL (b)



3. **Photomicrograph of banded magnetite quartzite in Kavuthimalai.** a) PPL and (b) XPL image shows discontinuous bands of magnetite (Mt) in the center and bottom of the band with quartzite (Qtz) and pyroxene (Px). **2. Photomicrograph of banded magnetite quartzite in Vediyappan malai.** a) PPL and (b) XPL image shows continuous and discontinuous bands of rich magnetite (Mt) and stretched quartzite (Qtz), quartz shows wavy extinction in XPL image. **3. Photomicrograph of banded magnetite quartzite in Kavuthimalai.** (a) PPL shows pyroxene in good cleavage, magnetite in black color and colorless minerals (b) XPL image shows quartz by wavy extinction and feldspar by stripes of black lines, pyroxene in various colors.

RESULT AND DISCUSSION

The analyses of ferride group elements of Thiruvannamalai iron formations are compared and interpreted with other iron formations of Tamilnadu. The maximum, minimum and average values of such elements of iron formation of Thiruvannamalai, Tirthamalai, Kanjamalai, Godumalai regions of Tamilnadu. And are given in Table 1. The Samples of Thiruvannamalai region shows the ranges as Mn (0.10-0.30 ppm); Ni (0.40-0.59ppm);Ti(0.10-0.48ppm);Co(5.00-10.00ppm);Cr(75.00-156.00ppm);V (20.00-56.00 ppm). The Samples of Tirthamalai region shows the concentration of elements in the range of Mn (201.00-627.00 ppm); Ni (20.00-50.00 ppm); Ti (54.00-444.00 ppm); Co (1.00-12.00 ppm); Cr (20.00-20.00 ppm); and V (5.00-17.00 ppm). The Samples of Kanjamalai region shows the concentration of elements in the range of Mn (31.00-140.00 ppm); Ni (8.00-72.00 ppm); Ti (10.00-500.00 ppm); Co (4.00-21.00 ppm); Cr (41.00-202.00 ppm); and V (16.00-32.00 ppm). The Samples of Godumalai region shows the concentration of elements in the range of Mn (255.00-488.00 ppm); Ni (-20.00-62.00 ppm); Ti (30.00- 564.00 ppm); Co (-1.00-5.00 ppm); Cr (20.00-102.00 ppm); and V (-5.00-20.00 ppm).

Table 1. Distribution of Ferride Group of Elements (in ppm) in Thiruvannamalai, Tirthamalai, Kanjamalai and Godumalai regions of Tamilnadu, India.

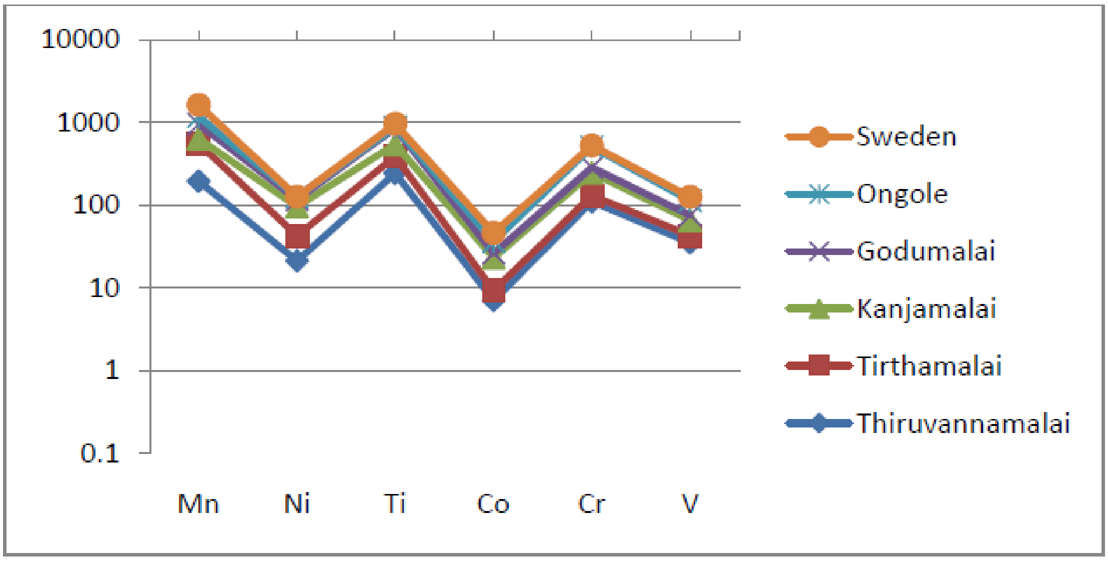
Name of the Regions	Range	Mn	Ni	Ti	Co	Cr	V
Thiruvannamalai	Max	0.30	0.59	0.48	10.00	156.00	56.00
	Min	0.10	0.40	0.10	5.00	75.00	20.00
	Avg	194.60	21.00	240.80	7.00	109.00	35.00
Tirthamalai	Max	627.00	20.00	444.00	12.00	20.00	17.00
	Min	201.00	50.00	54.00	1.00	20.00	5.00
	Avg	356.00	21.00	146.00	2.20	20.00	7.40
Kanjamalai	Max	140.00	72.00	500.00	21.00	202.00	32.00
	Min	31.00	8.00	10.00	4.00	41.00	16.00
	Avg	86.56	53.75	155.81	13.62	115.43	22.43
Godumalai	Max	488.00	62.00	564.00	5.00	102.00	20.00
	Min	255.00	-20.00	30.00	-1.00	20.00	-5.00
	Avg	310.00	20.00	311.00	3.14	38.00	9.80

The results of interpretation of Samples of all regions show not much variation among the formations in the concentration of ferride group of elements and exhibits similar trends. The low concentrations of these elements indicate the source of materials derived from weathering of land masses and not from any volcanic sources. These iron formations are later metamorphosed. Among the elements, the Ti and Cr are enriched compared to other elements are indicating that the iron formation of the study area are of Meta- sedimentary origin (Saravanan, 1969; Krishna Rao and Kosapathi, 1991 and Rajendran 2000,2008). Lander Gren (1948) Suggested that the low concentration of these elements in many iron formations of central Sweden indicating the sedimentary origin. The Average Concentration of ferride group elements of Thiruvannamalai region is compared with iron formations of Ongole, and Sweden (Table 2 and Figure 3).The samples of the study region show similar trend with the other regions of the world and indicating meta- sedimentary origin (Anjaneya Sastry,et al 1970; Rama Rao, 1971; Krishna Rao and Kosapathi,1991).

Table 2. Comparison of Average concentration of ferride group of elements (in ppm) with other iron formation.

Name of the Region	Mn	Ni	Ti	Co	Cr	V
Thiruvannamalai	194.60	21.00	240.80	7.00	109.00	35.00
Tirthamalai	356.00	21.00	146.00	2.20	20.00	7.40
Kanjamalai	86.56	53.75	155.81	13.62	115.43	22.43
Godumalai	310.00	20.00	311.00	3.14	38.00	9.80
Ongole	228.00	10.00	30.19	10.00	222.00	38.00
Sweden	457.00	0.00	75.00	10.00	20.25	13.00

Figure 3. Comparision of ferride group of elements of Thiruvannamalai iron formation with other iron formation of the World.



The samples of study area BIF show the average as Mn (194 ppm), Ni (21 ppm), Ti (240 ppm), Co (7 ppm), Cr (109 ppm) and V (35 ppm). Shows the average values of ferride group elements of iron formations of Kanjamalai, Godumalai, Tirthamalai and Thiruvannamalai regions in which, few samples have very poor concentration compared to the samples of other regions.

Table 3. The mean percentage of Ferride elements (Thiruvannamalai %) standard deviation (S. D.) **Lithosphere % - Mean percentage of element for lithosphere.**

Elements	Lithosphere %	Thiruvannamalai %	S. D
Magnetite quartzite			
Mn	0.17	0.035	0.0131
Ni	0.01	0.0015	0.0003
Ti	0.5	0.014	0.01
Co	0.004	0.0003	0.0002
Cr	0.02	0.0018	0.0002
V	0.015	0.0008	0.0003

Table 4. The mean percentages of trace elements (X %) standard deviation (S. D). (after Subba Reddy et al., 1982). **Lithosphere % - Mean percentage of element for lithosphere.**

Elements	Lithosphere %	X %	S. D
Magnetite from pyroxene granulite			
Mn	0.17	0.2927	0.0842
Ni	0.01	0.1531	0.05054
Ti	0.5	1.048	0.7312
Co	0.004	0.0066	0.00371
Cr	0.02	0.0018	0.03838
V	0.015	0.0814	0.06181

In comparison, Weaver (1980) reported high concentration of Mn, Ni, Co in basic granulites of the Madras area, which are of igneous origin. Similarly, many iron formation of central Sweden are generally deficient in Ni and Co compared to average magmatic rocks. Very high proportions of 500 ppm of Cr in titaniferrous iron ores and 3500 ppm in magnetite from gabbro and low values of V from sedimentary iron ores were reported by Landergren (1948). According to Goldschmidt (1954) the quantities of Ni and Co in sediments are usually in low proportions. Anjaneya Sastry and Krishna Rao (1970) reported lower concentrations of Ni and Co from the Ongole and central Sweden iron ores and 10 to 16 ppm of V. Similarly the values are corresponding with the present study area of Thiruvannamalai region. According to Goldschmidt (1954) the absence of low concentration with Cr in metamorphic iron ores indicates their derivation from oxidated sediments. Hydrothermal solutions also contain low proportions of Cr. Here, the FGE concentration in magnetite iron formation of different areas show that low values are of metasedimentary origin and the high values are of volcanic origin.

CONCLUSION

The present study concludes with the ferride group of elements and their significance in the genesis of banded iron formation of Thiruvannamalai Granulitic Terrain, Tamilnadu, India. The study region are mainly comprised of banded magnetite quartzite associated with pyroxene granulite, charnockite and other granitic gneisses. The structural characters of BIF is well banded, folded and faulted, highly deformed and metamorphosed. The petrography of the BIFs is mainly composed of magnetite and quartz with minor proportion of hypersthene, hedenbergite, cummingtonite/grunerite, garnet and apatite. The geochemical analyses and interpretations of samples show the presence of low concentration of ferride group elements. The average ferride group element compositions are compared with other iron formations, namely Tirthamalai, Kanjamalai, Godumalai, Ongole, and Sweden. It is observed that the iron formation of the present study area is having a similar trend like other magnetite iron formations of meta-sedimentary origin of the world. Hence, it is shown that the various concentrations of Mn, Ni, Ti, Co, Cr, and V in these iron formations may be due to the difference in their origin and especially with respect to the environment. In comparison, the magnetite from igneous or volcano-sedimentary rocks has a high concentration of ferride elements. Hence, it is concluded that the BIFs of study region might be of metasedimentary origin.

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