Mineralogy and chemistry of banded iron formations (BIF) of Tiruvannamalai area, Tamil Nadu

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Abstract. The mineralogy and chemistry of banded iron formations (BIF) of Archaean high grade granulite gneiss belt of Tiruvannamalai area are presented here. The BIF of this area is chemically different from those around the world. The iron formations and associated granulites are of different origin namely metasedimentary and metavolcanic respectively.

Keywords. Banded iron formations; granulites; mineralogy; magnetite-quartzite.

1. Introduction

The banded iron formations (BIF) constitute one of the distinct and important components of Archaean schist belts of India. In southern India these formations occur both in granulite-gneiss and in greenstone belts. Although many workers have studied these BIF in detail, the Tiruvannamalai deposit has not received much attention. Based on the mineralogy and chemistry of the BIF and associated granulites their origin, source, and environment of formation as well as their similarities or differences with other precambrian BIF have been discussed. Prasad *et al* (1982) and Radhakrishna (1985) have classified the Indian BIF as follows:

	Region	Type of BIF	Age (Ma)
Proterozoic	Iron ore series of Bihar and Orissa	Superior	2500–1900
	{ Greenstone belts	Algoma	2900–2500
Archaean	{ High grade granulite gneiss belts and Sargurs	Tamil Nadu	< 2900

2. Geology of Tiruvannamalai

This area forms part of the Archaean high grade granulite-gneiss terrain of South India and contains rocks of diverse chemical and mineralogical compositions. BIF in these formations is mainly magnetite-quartzite associated with amphibolites, granulites, metapelites, sillimanite-quartz schists and pyroxenites. The surrounding rocks are granite gneiss and charnockites. These rocks have been subjected to high amphibolite to granulite facies metamorphism and have undergone folding, faulting and shearing. A series of dykes have been cut across the area in SE direction. Magnetite-quartzite occurring in the form of a single band is approximately 10–12 km

long with a width of 10 to 40 m. The band being comparatively harder stands out as prominent ridges.

3. Methods of study

Mineralogical and textural studies of magnetite-quartzite and associated granulites have been made on 29 thin sections and 15 polished ore mounts. Whole rock chemical analysis for 11 samples of magnetite-quartzite was carried out calorimetrically for major oxides using either a Spectronic 20 calorimeter or a Unicam-500 spectrophotometer. FeO was determined by titrimetric method.

4. Mineralogy

The two different mineral assemblages observed in the magnetite-quartzite in the order of abundance are: (i) Quartz-magnetite-orthopyroxene-clinopyroxene-apatite-chlorite-actinolite-grunerite-martite and (ii) quartz-magnetite-orthopyroxene-garnet-apatite-chlorite-hornblende-martite. Magnetite and quartz occur both in granular texture and banded forms with alternate layers of quartz and magnetite. The preservation of banding is conspicuous despite high grade metamorphism, but quartz shows strain, crushing or deformational effects. Fine hair-like cracks in quartz grains are seen filled with iron oxide. Small euhedral grains of hypersthene occur as inclusions within magnetite. They are found in different degrees of alteration giving rise to chlorite, actinolite and hornblende. The clinopyroxene has been identified as hedenbergite. Pink, deep red, or brown garnet is found occasionally. In a few sections apatite is noticed as minute needle-like crystals.

Under reflected light magnetite is grey in colour with brownish tinge. Characteristic octahedral and cubic parting planes are noticed. The cubic nature of the parting plane is indicated by means of triangular pits. Magnetite is martitized to different degrees. Reflectance of magnetite in air in green light ranges from 20.5 to 21.2%. Vicker's hardness ranges from 600 to 625 at 50 g load but gradually decreases at higher loads.

Table 1. Chemical composition (wt.%) of magnetite-quartzite of Tiruvannamalai area.

	V ₁	V ₂	V ₄	V ₆	V ₁₆	V ₂₃	V ₂₅	V ₂₂	V ₁₁	V ₃₄	V ₃₀
SiO ₂	47.01	46.10	42.01	48.84	47.20	43.80	48.08	47.60	44.90	37.40	46.70
Al ₂ O ₃	0.50	0.16	0.30	0.20	0.30	0.25	0.62	0.10	0.36	0.57	0.68
FeO	11.08	8.30	14.31	7.21	9.20	10.75	8.86	7.20	14.84	12.85	7.85
Fe ₂ O ₃	38.80	42.40	43.41	39.48	41.20	43.48	39.40	41.30	37.80	44.80	40.50
CaO	0.11	1.22	0.36	—	0.40	—	0.30	0.90	0.63	0.23	0.42
MgO	0.92	1.50	1.29	1.27	0.50	0.43	1.15	0.95	1.26	2.04	1.80
Na ₂ O	—	0.10	—	0.30	—	0.21	—	0.10	0.35	0.60	0.40
K ₂ O	0.10	0.10	0.40	0.20	0.20	0.10	0.15	0.10	—	0.15	0.48
TiO ₂	0.15	0.20	—	0.40	0.48	0.32	0.25	0.38	0.46	0.35	0.15
MnO	0.20	0.21	0.22	0.22	0.30	0.10	0.24	0.10	0.45	0.20	0.50
P ₂ O ₅	0.15	0.30	0.18	0.12	0.48	0.30	0.68	0.31	0.25	0.40	0.25
Total	98.97	100.59	102.46	99.56	98.78	99.74	99.73	99.04	101.30	99.56	99.73

Table 2. Average major element (wt.%) of Tiruvannamalai BIF and selected types of world BIF.

	Gross and Meleod 1980		Gole and Klein 1981		Kimberley 1979		Chakraborty and Majumder 1986	
	Algoima oxide	Superior oxide	Archaean	Proterozoic	Three environmental types (stated in text)		Eastern India	Tiruvannamalai
SiO ₂	50.50	47.20	47.30	46.90	27.80	38.76	47.02	45.42
Al ₂ O ₃	3.00	1.39	1.25	1.15	1.71	1.82	0.07	0.37
Fe ₂ O ₃	26.90	35.40	22.94	18.08	16.30	22.67	44.16	41.14
FeO	13.00	8.20	20.58	23.11	25.40	16.03	8.28	10.13
CaO	1.51	1.58	2.84	4.43	2.41	1.25	0.17	0.58
MgO	1.53	1.24	3.66	4.41	3.07	3.13	0.13	1.28
MnO	0.22	0.73	0.59	0.59	—	—	0.06	0.25
Na ₂ O	0.31	0.12	0.22	0.29	0.35	0.18	0.10	0.29
K ₂ O ₅	0.58	0.14	0.09	0.48	0.29	0.28	0.13	0.19
P ₂ O ₅	0.21	0.06	0.22	0.14	0.14	0.15	0.07	0.28
CO ₂	1.10	3.00	—	—	—	—	—	—
S	0.29	0.02	—	—	—	—	—	—

Magnetite-quartzite contain mainly magnetite without any ilmenite and the alteration products are Goethite and Limonite.

5. Chemistry

Whole rock chemical analysis of magnetite-quartzite of Tiruvannamalai area is given in table 1. In table 2 their average chemical composition is compared with that of Archaean and proterozoic iron formations of Gole and Klein, (1981), Algoma and superior oxide facies iron formations of Gross and Mcleod (1980), three environmental types (shallow volcanic platform iron formations (SVOPIF) metazoan-poor extensive chemical sediment rich sea iron formations (MECS-IF) and sandy clayey and oolitic shallow inland sea iron formations (SCDS-IF)) of Kimberly (1979) and eastern India BIF of Chakraborty and Majumder (1986). The absence of CO_2 and S in the analysis supplement due to lack of carbonates and sulphides in petrographic observations and low values of Al_2O_3 , CaO and MgO in Tiruvannamalai BIF are noticeably significant in their difference. The proportions of $\text{CaO} + \text{MgO}$, Fe(total) and SiO_2 and the proportions of Al_2O_3 , SiO_2 and Fe_2O_3 , when plotted in triangular diagrams of Lepp and Goldich (1964) and Govett (1966) respectively, the BIF of Tiruvannamalai area clearly fall within the precambrian field (figures 1 and 2).

6. Discussion

Various hypotheses have been put forward to explain the origin of BIF. The trace elements in BIF and associated rocks are often considered reliable to interpret the physicochemical conditions of deposition and to predict the probable source of materials. Anjaneya Sastry and Krishna Rao (1970), Frietsch (1970), Majumdar *et al* (1982) and Davy (1983) reported low proportions of Co, Cr, Ti, V and Ni in iron

Figure 1. Composition of Tiruvannamalai BIF (after Lepp and Goldich 1964).

Figure 2. Composition of Tiruvannamalai BIF (after Govett 1966).

formations of sedimentary origin. Their high concentration in magnetites from known igneous formations has been reported by Wager and Mitchell (1951), Howie (1955), Gjelsvike (1957), Wilkinson (1959), Kisvarsanyi and Proctor (1967) and Schock (1979). Subba Reddy and Prasad (1982) reported low concentration of ferride group of trace elements in magnetites of magnetite-quartzite and their high concentration in magnetites of pyroxens granulites suggesting metasedimentary and metavolcanic origin respectively. The ultimate source of chemical components of BIF is generally attributed to volcano-sedimentary process (Alexandrov 1973; Beukes 1973; Quade 1976) but rarely to magmatism (Alexandrov 1973). The volcanism associated with the formation of acid and basic metavolcanics may be the source of iron and silica of magnetite-quartzite of Tiruvannamalai. Similar exhalative models were given by Simonsen (1985) and Gross (1986). The oldest BIF in the world, Isua of West Greenland were considered to be deposited in a submarine exhalative environment (Appel 1980). Since the Tiruvannamalai BIF occurs in a similar geologic setting as that of Isua (Windley 1984) it is possible that an exhalative process may be involved in their formation.

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