

TIRODITE FROM GANGPUR GROUP OF ROCKS, INDIA

B. K. MOHAPATRA¹ and B. R. NAYAK¹

Regional Research Laboratory

ABSTRACT

Manganese bearing amphibole is recorded in the Mn silicate-oxide rocks of Gangpur Group, India and is identified to be tirodite (Mn-cummingtonite) with the composition $[\text{Mg}_{4.65-4.08}, \text{Fe}_{0.31-0.09}, \text{Mn}_{2.04-1.73}, \text{Ca}_{0.19-0.13}, \text{Na}_{0.42-0.37}] [\text{OH}/\text{Si}_4\text{O}_{11}]_2$. Tirodite, coexisting with rhodonite, occurs without carbonate and pyroxene and developed in a low and unbuffered X_{CO_2} system with $X_{\text{Mn}} < 0.32$. Appreciable hematite in the assemblage and Fe in tirodite structure attests to an iron rich bulk composition and intermediate f_{O_2} in the amphibolite facies condition.

INTRODUCTION

Tirodite, a manganese bearing amphibole, was first described and named by DUNN and ROY (1939) from Tirodi Mn-deposit in India. It was subsequently reported from a number of metamorphosed Mn-deposits of the world such as Nsuta, Ghana (JAFTE et al., 1961), Buritirama, Brazil (PETERS et al., 1977), Balmat, U.S.A. (PETERSON et al., 1984): Precambrian Sausar Group of rocks containing this variety of Mn-amphibole are reported from Chikla (Bhandara dist., Maharastra), Tirodi (Balaghat dist., Madhya Pradesh) and Mansar-Kandri (Nagpur dist., Maharastra) manganese deposits in India (DASGUPTA et al., 1988). Similarly, the presence of tirodite from Gangpur Group, India was first reported by CHATTERJEE (1964). But detail characteristic of this mineral from Gangpur Group of rocks has not been recorded so far. The present note describes the distinctive properties and chemistry of the Mn-amphibole from Goriajhar area in Gangpur Group of rocks with a view to discuss the prevailed metamorphic conditions of the mineral.

GEOLOGICAL SETTING

The manganese belt of Goriajhar area belonging to the Precambrian Gangpur Group of rocks (1700–2000 Ma) occurs over a strike length of about 10 km in the west central part of Sundargarh district of Orissa (*Fig. 1*) and forms a part of Survey of India Toposheet No. 73 B/4. It comprises a volcanic free syn-sedimentary sequence of metapelites and metapsamites which are metamorphosed upto amphibolite facies. This sequence is well known for the occurrence of manganese oxide ores that are interstratified with Mn silicate rocks (ROY, 1966; 1981). Supergene alteration process enriched the manganese concentration and formed these units into workable deposits which were exploited from 1907 to 1933.

¹ Bhubaneswar, India

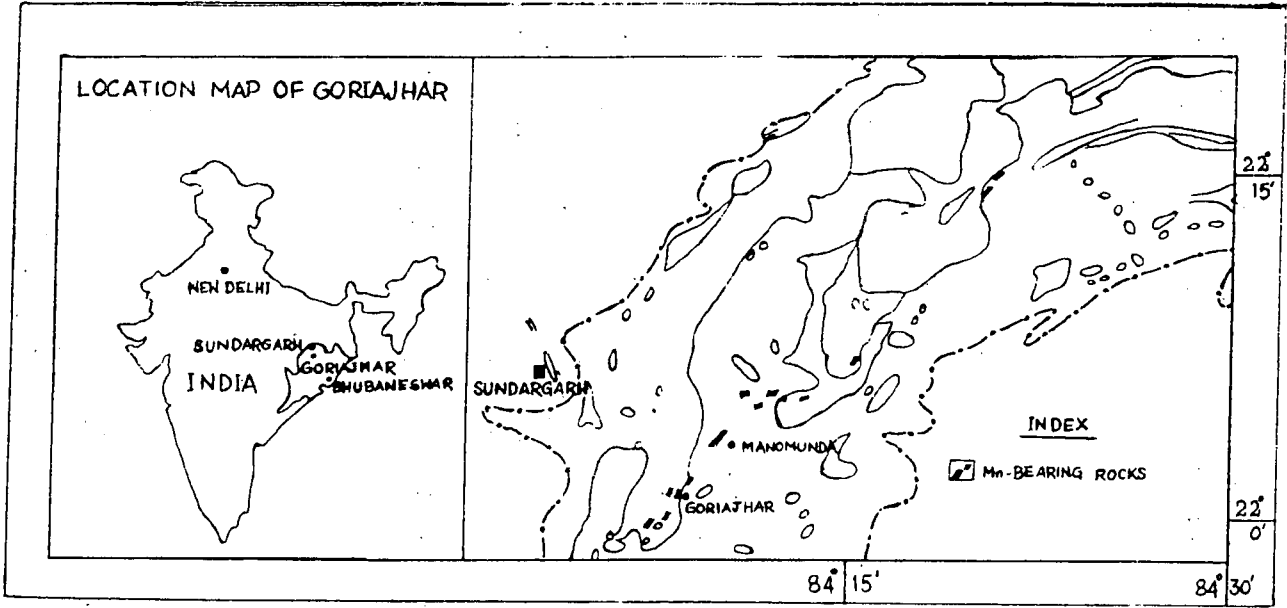


Fig. 1. Outline map of a part of Gangpur Group, India, showing location of Goriajhar and disposition of Mn-bearing rocks/ores

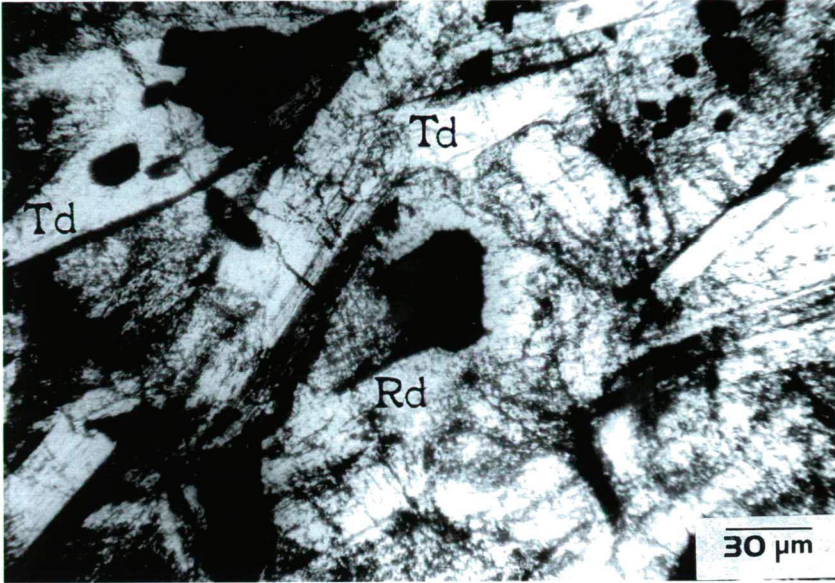


Fig. 2. Tirodite (Td) crystals occurring as clusters in a rhodonite (Rd) base. Black crystals are hematite.

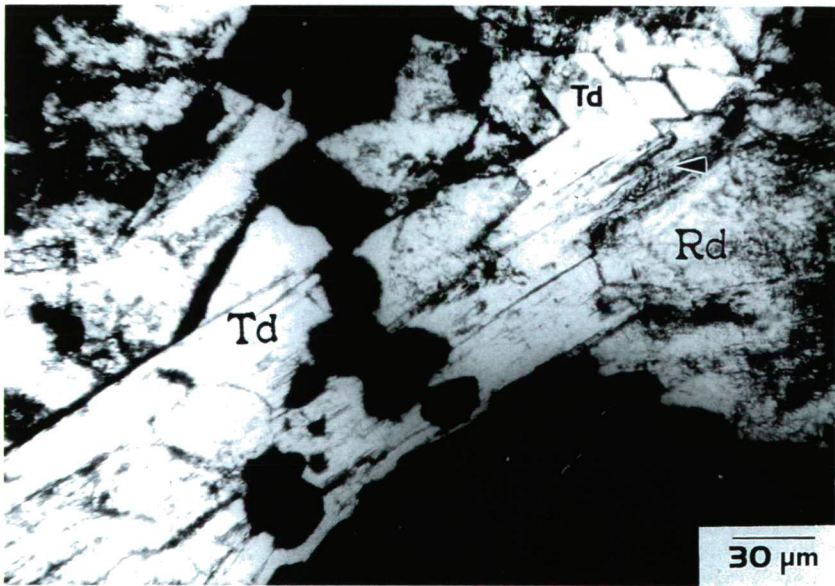


Fig. 3. A large elongated grain of tirodite (Td) along with small prismatic crystals (top right corner) sharing irregular boundary with rhodonite and hematite (black). The other hazy phase is rhodonite. Note the fibrous growth of tirodite (►) at its one end.

The manganese bearing rocks can be differentiated into three major types on the basis of predominant manganese bearing minerals: i) Mn silicate, ii) Mn silicate-oxide and iii) Mn silicate-carbonate-oxide rocks. All these manganese members are conformably interstratified with phyllites, mica schists and metacherts and show imprint of identical metamorphic history (850 Ma). The Mn silicates recorded in the area belong to garnet, pyroxene, pyroxenoid, amphibole, mica and olivine families. Tirodite, the only Mn-amphibole recorded, forms a part of the Mn silicate-oxide facies of rocks.

PETROGRAPHY OF TIRODITE

Tirodite is found to be associated with the Mn silicate-oxide rocks. However, in the field it is not distinguishable from other silicates. The mineral was identified from microscopic observations supported by X-ray diffraction studies. Tirodite looks pale yellow-green under transmitted light and pleochroic from greenish-yellow to dark greenish-brown colours. It is anisotropic and shows high order interference colours. The extinction angle varies between 15 to 21 degrees but most commonly it is 19 degrees. The crystals show varied shape (spindle, prismatic, needle like, bladed) and sizes (10–300 μm) and occur as isolated grains or in clusters (*Fig. 2*). Transverse fractures are recorded in many grains and replacement by secondary oxides (mainly cryptomelane) is prominent in the fracture and cleavage planes. The other coexisting silicate members are rhodonite and quartz. Hematite, with exsolved pyrophanite, is the single oxide phase associated with it. Baryte is recorded in traces. The mutual contact between tirodite and hematite appears irregular. Tirodite, generally, occurs scattered in a rhodonite base. However, inclusions of rhodonite and hematite within tirodite are also recorded. Often larger tirodite crystals develop a fibrous structure due to alteration and show irregular grain boundary with rhodonite (*Fig. 3*). The XRD pattern of tirodite and its associated members are shown in figure 4.

MINERAL CHEMISTRY

Electron microprobe analyses of tirodite crystals (Table 1) show MnO content ranging from 14% to 17% with an average of 15%. MgO (19 to 22%) is always found at a higher concentration level than MnO. Fe_2O_3 in tirodites, though remains below 4%, varies within limits of 2.6 to 4%. The maximum Na and Ca content recorded are 1.51% and 1.23% respectively, which are relatively low in comparison to tirodites reported elsewhere (ROY and MITRA, 1964; YUI et al., 1989). The low substitution of Fe^{3+} , Ca, and Na etc. in the structure results in a higher manganese value in Goriajhar tirodites.

The compositions of Goriajhar tirodites are plotted in the triangle Mg-Fe-Mn and have been compared with the results of KLEIN (1966) and YUI et al. (1989) (*Fig. 5*).

DISCUSSION

The Mn-amphibole in Gangpur Group of rocks, India occurs only in Mn silicate-oxide assemblage. Microscopic and XRD observations support the Mn-amphibole to be tirodite/Mn-cummingtonite. The chemistry of mineral species confirms the identification. LEAKE (1978) has indicated the limits of use of tirodite as $\text{Mn}/(\text{Mn}+\text{Mg}+\text{Fe}^{2+}) > 0.10$ and $\text{Mg} > \text{Fe}^{2+}$. The $\text{Mn}/(\text{Mn}+\text{Mg}+\text{Fe}^{2+})$ value of Goriajhar tirodite has been found to be > 0.25 ,

Fig. 4. X-ray diffraction pattern of Gorralhar tirodite along with other associated phases.

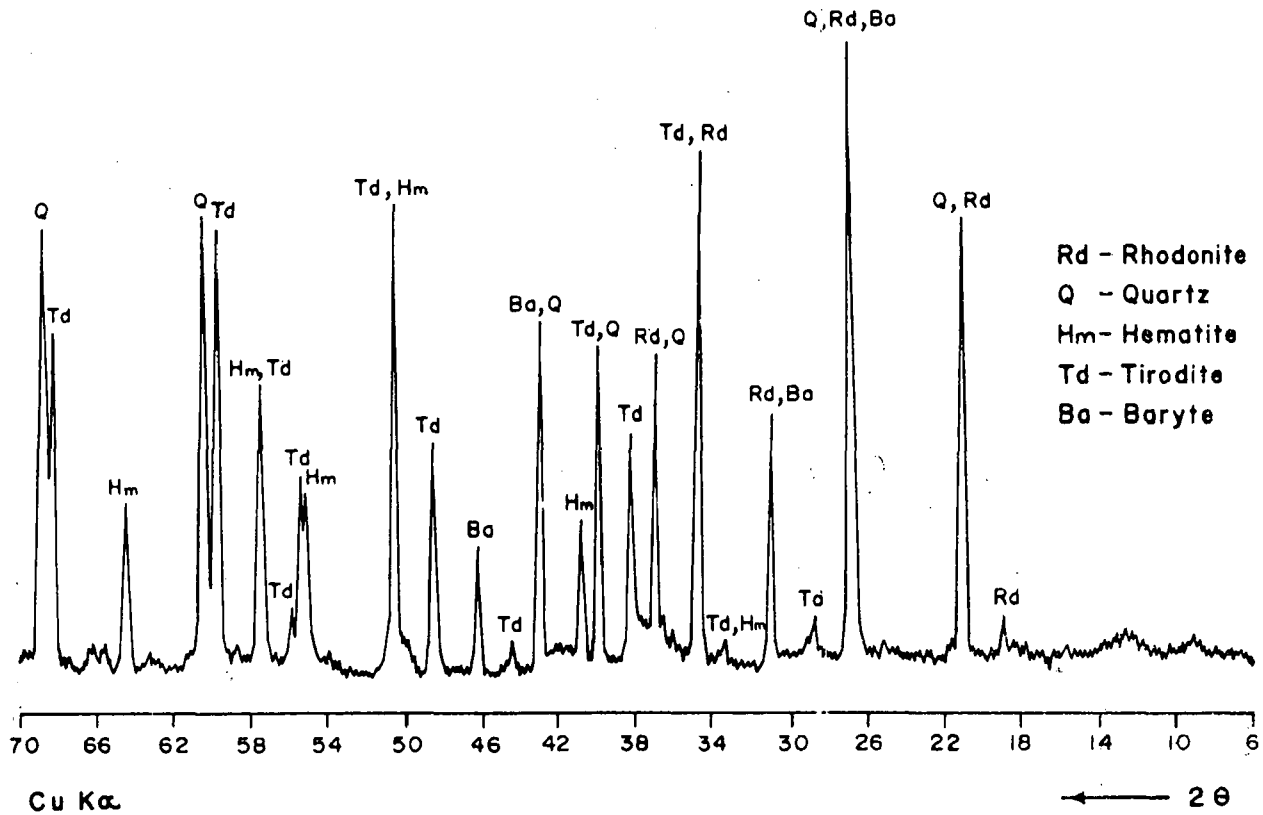


TABLE I

Electronprobe microanalysis (EPMA) of tirodite, Goriajhar, Gangpur Group, India.

	1	2	3	4	5
SiO ₂	55.02	54.11	55.78	56.03	55.41
Al ₂ O ₃	0.55	0.27	0.18	0.27	0.22
Fe ₂ O ₃	2.96	4.00	2.80	2.99	2.60
MnO	14.57	16.08	16.80	17.00	16.57
MgO	22.22	21.04	19.29	19.53	19.02
CaO	0.84	1.07	1.12	1.18	1.23
Na ₂ O	1.36	1.48	1.33	1.24	1.51
H ₂ O (calc.)	2.14	2.13	2.09	2.11	2.08
Total	99.66	100.18	99.39	100.35	98.64
On the basis of 15 cations					
Si	7.720	7.625	7.979	7.945	7.973
Al	0.091	0.045	0.021	0.045	0.027
Fe ³⁺	0.189	0.330	—	0.010	—
Total 1	8.000	8.000	8.000	8.000	8.000
Mg	4.647	4.419	4.113	4.129	4.079
Ca	0.127	0.162	0.172	0.179	0.190
Na	0.370	0.405	0.369	0.341	0.421
Fe ³⁺	0.124	0.094	0.301	0.309	0.281
Mn ³⁺	0.246	0.311	0.059	0.032	0.130
Mn ²⁺	1.486	1.609	1.977	2.010	1.889
Al	—	—	0.009	—	0.010
Total 2	7.000	7.000	7.000	7.000	7.000
Mg End Mb.	66.39	63.13	58.76	58.99	58.27
Mn End Mb.	21.23	22.98	28.24	28.71	26.99
Ca End Mb.	1.81	2.31	2.46	2.56	2.71
Na Fe ³⁺ End Mb.	3.54	2.69	8.60	8.83	8.03
Na Mn ³⁺ End Mb.	7.03	8.89	1.68	0.91	3.71
Na Al End Mb.	—	—	0.26	—	0.29

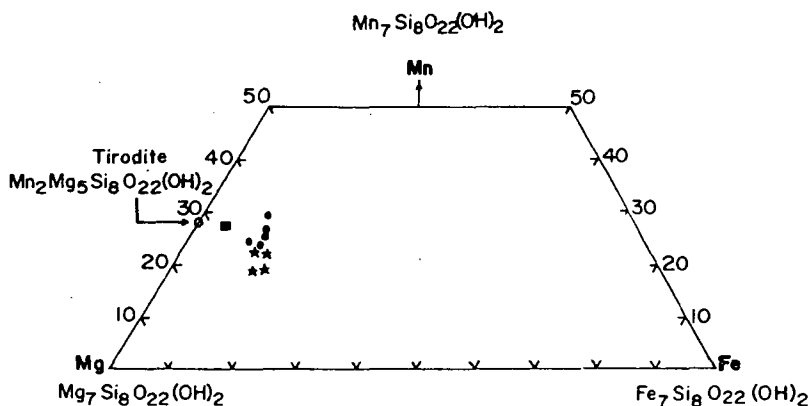


Fig. 5. Compositional plots of tirodite in the triangle Mg-Fe-Mn; Closed circle (●): Goriajhar, Gangpur Group, India, Closed square (■): Southwestern Labrador (KLEIN, 1966), Star (★): Eastern Taiwan (YUI et al., 1989).

which is above the theoretical lower limit given by LEAKE (1978) and MgO content (19 to 22%) is more than FeO (2 to 3.6%). Goriajhar tirodite is similar to tirodite of eastern Taiwan and differs from the Mn-amphibole of Southwestern Labrador in its chemical composition (Fig. 5).

HUEBNER (1986) indicated that in Mn-amphibole structure, Mn occupies sites other than $M(4)$. The Mn-amphibole in the present case generally shows (Table 1) a structure where Mn is mostly greater than 2 (out of the total of 15 cations) and this corroborates the observation made by HUEBNER (1986). This amphibole thus corresponds to Mn-cummingtonite which has been equated to the varietal name tirodite by LEAKE (1978).

In contrast to the Sausar Group of rocks, India, where Mn amphibole is present mainly in the silicate-carbonate rock and locally in the silicate-oxide rock (DASGUPTA et al., 1988), the Mn amphibole in Gangpur Group has been recorded only from the latte assemblage so far. Moreover, rhodonite coexists with tirodite in contrast to pyroxmangite. Presence of appreciable hematite in the assemblage attests to an iron-rich bulk composition. At the same time, the non-appearance of magnetite indicates that the ambient f_{O_2} was above the HM buffer, thus restricting iron to the trivalent state.

The stability of coexisting tirodite and rhodonite was inferred through possible mineral reactions. It is apparent from the modal abundance of different phases in the assemblage that they evolved in rocks which can be represented by Mn-Mg-Fe-(Ca)-Si fluid system. The stabilization of tirodite alone from a bivalent cation-bearing residual unbuffered low to intermediate X_{CO_2} assemblages with $X_{Mn} > 0.35$ have been inferred by DASGUPTA et al. (1988) and HUEBNER (1986). In this context it is worth recording that tirodite-rhodonite pairs at Goriajhar have been stabilized with $X_{Mn} = 0.26$ to 0.32 in a single assemblage. Absence of any pyroxene mineral in this association evidently indicate both low and unbuffered X_{CO_2} in the fluid phase during amphibolite facies condition that inhibit the development of pyroxene. The co-existing rhodonites have a maximum CaO of 3.48%. The association of low calcic pyroxenoids in the absence of any carbonate mineral, is also suggestive of a low X_{CO_2} situation (DASGUPTA et al., 1988) for these tirodites.

CONCLUSIONS

The results of the present study demonstrate that the Mn-bearing amphibole in Gangpur Group of rocks, India in general and Goriajhar Mn-deposit in particular, is tirodite (Mn-cummingtonite) having X_{Mn} (= Mn/Mn+Mg+Fe) less than the theoretical upper limit of 0.35. The general composition of tirodite in Mn silicate-oxide assemblage is observed to be $[Mg_{4.65-4.08}, Fe_{0.31-0.09}, Mn_{2.04-1.73}, Ca_{0.19-0.13}, Na_{0.42-0.37}] [OH/Si_4O_{11}]_2$. Further, the stability of Mn-amphibole and low calcic pyroxenoid pair is influenced by low and unbuffered X_{CO_2} situation and are metamorphosed up to amphibolite facies in an intermediate f_{O_2} condition.

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