

The Occurrence of Calcian Tirodite in the Granite Pegmatite of Kamiotomo, Iwate Prefecture, Japan

By

Akira KATO and Satoshi MATSUBARA

Department of Geology, National Science Museum, Tokyo

Abstract A clinoamphibole from the granite pegmatite of Kamiotomo, Iwaizumi-machi, Iwate Prefecture, is found to be a calcian tirodite, $(\text{Mn}_{1.56}\text{Ca}_{0.54}\text{Mg}_{3.02}\text{Fe}_{1.83}\text{Al}_{0.10})_{\Sigma 7.05}(\text{Si}_{7.74}\text{Al}_{0.26})_{\Sigma 8.00}\text{O}_{23}$ on the basis of $\text{O}=23$. This is a rare example of the occurrence of such a high magnesium ferromagnesian mineral in a granite pegmatite. The associated minerals include pyroxmangite $((\text{Mn}_{0.62}\text{Fe}_{0.22}\text{Mg}_{0.12}\text{Ca}_{0.05})_{\Sigma 1.01}\text{Si}_{0.99}\text{O}_3)$. The assemblage of tirodite and pyroxmangite both compositionally close to above case is also found in a contact metamorphosed manganese ore from Zomeki deposit of the Kusugi mine, Yamaguchi Prefecture. The 2/7 boundary for $(\text{Mn}+\text{Ca})$ contents of these Mg-Fe-Mn clinoamphiboles is extant despite the co-existence with pyroxmangite. One of the materials on 2.5/7 boundary of Nambu *et al.* (1980) occurs as veinlets cutting a wallrock of manganese ore, i.e., in the different mode of occurrence from the present case.

Introduction

During the course of mineralogical studies on manganese silicates from granite pegmatites and metamorphosed manganese ore deposits in Japan, a brownish yellow-green fibrous manganese silicates from the granite pegmatite of Kamiotomo, Iwaizumi-machi, Iwate Prefecture, is found to be calcian tirodite with minor pyroxmangite. This is a rare example of the occurrence of such a high magnesium ferromagnesian mineral in an ordinary granite pegmatite, where magnesium contents of ferromagnesian minerals are generally low.

Also, the studies demonstrate the occurrence of tirodite-pyroxmangite assemblage both compositionally very close to above two, respectively, in a contact metamorphosed manganese ore from Zomeki deposit of the Kusugi mine, Yamaguchi Prefecture.

In both tirodites so-called 2/7 boundary of the manganese (precisely manganese plus calcium) content of octahedral cations in Mg-Fe-Mn clinoamphiboles (KLEIN, 1964) is extant, despite the co-existence with pyroxmangites of higher $(\text{Mn}+\text{Ca})/(\text{Mn}+\text{Mg}+\text{Fe}+\text{Ca})$ ratios than the associated tirodites. The alternative 2.5/7 boundary of NAMBU *et al.* (1980) is seen in dannemorite from the Moichi mine, Iwate Prefecture, where it occurs as veinlets cutting wallrocks of manganese ore, suggesting that this boundary is for the materials formed under a hydrothermal condition.

Occurrence and Description of the Studied Material

The granite pegmatite of Kamiotomo, Iwaizumi-machi, Shimohei-gun, Iwate Prefecture, is located about 7 kilometers east of Iwaizumi Station, Iwaizumi Line, Japan National Railway, and was formed for quartz and feldspar down to the middle of 1950's. It is a lenticular body standing with a steep angle in a granodiorite mass, and elongated along N-S direction to more than 20 meters long and flattened to E-W direction less than 5 meters thick (OMORI and HASEGAWA, 1955). At present no trace of pegmatite is left except for a small dump scattered in a granitic debris.

The mineral was firstly noted by NAGASHIMA and NAGASHIMA (1960), who found it as coarse-grained aggregate with pyroxmangite, spessartine and quartz along the southern margin of pegmatite. The studied material was collected by A. K. in 1954 and regarded to be identical with the above reported one by them. It is a small piece of aggregate of greyish yellow-green blady prisms to fibers of tirodite of more than 20 millimeters long and partially coated by a chocolate brown manganese dioxide which is amorphous to X-ray. The mineral is embedded in quartz accompanied by minute grains of pyroxmangite and magnetite.

Under the microscope, the prisms form subparallel aggregates in coarse-grained quartz and small grains of pyroxmangite and magnetite occur in direct contact with tirodite (Fig. 1). It is colourless in thin section. Between crossed polars a lamellar twinning with a twinning plane $\{100\}$ is very common. The maximum extinction angle is about 18° for Z' . The refractive indices measured by the immersion method are: $\alpha=1.652(2)$, $\beta=1.664(2)$, $\gamma=1.676(2)$. Observed $2V$ is nearly 90° , which is essentially equal to the calculated value, $(-)2V=88.54^\circ$. Dispersion is indiscernible. Besides above stated minerals, very minute colourless flakes of chlorite are found as interstitial aggregates to tirodite prisms. Some of prisms are partially coated by orange brown clayey material.

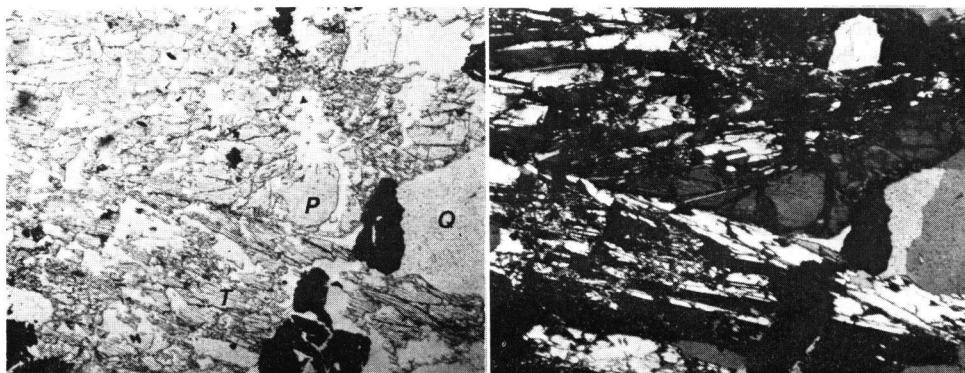


Fig. 1. Photomicrographs of calcian tirodite(T) in association with pyroxmangite (P), quartz (Q) and magnetite (opaque). Field view: approximately 1.9×1.5 mm. Left: one polar. Right: crossed polars.

Table 1. X-ray powder diffraction patterns of calcian tirodite and manganian cummingtonite.

1.				2.			1.				2.		
I	d(obs.)	d(calc.)	hkl	I	d(obs.)	hkl	I	d(obs.)	d(calc.)	hkl	I	d(obs.)	hkl
20	9.09	9.09	020	80b	9.034	020					30	1.6768	551
100	8.32	8.32	110	90vb	8.296	110	2	1.672	1.671	391	60	1.6494	461
				vf	5.179	001	15	1.658	1.660	550			
3	5.10	5.08	130	20b	5.040	130			1.656	461	40	1.6189	1.11,0
3	4.84	4.84	111	20	4.834	111	15	1.627	1.628	481	30	1.5877	531
5	4.71	4.68	200						1.627	1.11,0			
12	4.54	4.54	040	50	4.516	040	2	1.595	1.594	601	25	1.5566	600
30	4.16	4.16	220	40	4.150	220	1	1.579	1.580	133	vf	1.5311	620
				vf	4.054	111	9	1.561	1.561	600	10	1.5139	570
4	3.877	3.866	131	35	3.856	131					40	1.5068	0.12,0
				vf	3.602	221	6	1.514	1.514	0.12,0			
5	3.437	3.432	131	60b	3.426	131	1	1.504	1.504	641			
40	3.262	3.260	240	80b	3.251	240			1.503	392			
100	3.081	3.077	310	100b	3.071	310			1.502	551	30	1.4885	481,602
7	2.984	2.976	221	30	2.968	221							
				15	2.932	151							
17	2.770	2.774	330	40	2.766	330	3	1.484	1.484	372	30	1.4541	3.11,0
12	2.739	2.739	151	70	2.726	151	5	1.460	1.460	3.11,0	10	1.4277	4.10,1
2	2.674	2.673	331	20	2.661	331					75	1.4063	661
9	2.618	2.614	061	50	2.6027	061	15	1.410	1.411	661			
10	2.536	2.542	260	50	2.5111	202	5	1.381	1.382	1.13,0	30	1.3766	512
5	2.425	2.430	132	5	2.4205	311,222					vf	1.3495	1.11,2
		2.423	222								20	1.3333	662
6	2.368	2.368	350	20	2.3575	350	5	1.335	1.336	662			
6	2.306	2.306	171	40	2.2959	171			1.336	731			
		2.304	351						1.334	710			
5	2.262	2.261	421	40	2.2525	421			1.344	4.10,2	vf	1.3197	1.13,1
			30	30	2.2312	312					35	1.2921	0.14,0,
2	2.205	2.206	132	20	2.1925	242	3	1.297	1.298	0.14,0			2.12,2
		2.203	171						1.297	353	25	1.2789	751
		2.199	242				2	1.281	1.282	751			
10	2.185	2.183	261	50	2.1742	261			1.280	661	10	1.2671	4.12,0
6	2.105	2.111	332	vf	2.1044	332	2	1.271	1.272	193			
1	2.083	2.084	202	20	2.0799	202			1.271	4.12,0			
		2.081	440						1.270	4.12,1			
		2.080	081										
7	2.033	2.031	222	30	2.0255	351							
		2.030	351										
2	1.997	1.996	370	20	1.9850	370							
4	1.979	1.978	401										
				30	1.9606	402,281							
4	1.864	1.863	510	50	1.8600	510							
1	1.853	1.855	172										
		1.852	460										
				10bb	1.8023	312,0.10,0							

1. Calcian tirodite. Kamiotomo, Iwaizumi-machi, Iwate Prefecture, Japan. Diffractometer method. Cu/Ni radiation.

2. Manganian cummingtonite. Wabash Iron Formation, Labrador, Newfoundland, Canada. Powder camera method. Fe/Mn radiation. After KLEIN (1964). b=broad. f=faint. v=very.

X-Ray Powder Study

X-ray powder diffraction pattern was obtained using Cu/Ni radiation by the diffractometer method as given in Table 1, where it is compared with that of manganoan cummingtonite from Newfoundland (KLEIN, 1964). From the indexing after the reference to the indices of compared pattern, the unit cell parameters are calculated as: $a=9.598$, $b=18.168$, $c=5.315\text{\AA}$, $\beta=102.63^\circ$.

Chemical Composition

The chemical composition of tirodite is determined by Link Energy Dispersion system, together with that of the associated pyroxmangite as given in Table 2. The empirical formula of tirodite calculated on the basis of $O=23$ has a slight excess of cations, which may be due to the presence of ferric iron. If the analysis is corrected in terms of this interpretation and of addition of H_2O provided that all the non-silicate anions are occupied by (OH) only, it requires Fe_2O_3 2.12, FeO 12.57, H_2O 1.98, total 99.06%. Since the calcium content in the empirical formula exceeds 0.50, the material is termed as calcian tirodite (HAWTHORNE, 1983). The chemical composition of the associated pyroxmangite has slightly higher content of manganese and lower one of iron than those of pyroxmangite from the same pegmatite (OMORI and HASEGAWA, 1955). The co-existence of calcian tirodite and pyroxmangite suggests that their manganese content in the former reaches the upper limit of diadochic capacity under the condition of pegmatite formation. Along with the calcium content, all the known calcian tirodites in Japan are in association with calcic amphiboles, *i.e.*, the materials from Wakasugi, Osaka Prefecture (CaO 4.40% in weight) (AIKAWA *et al.*, 1978), the

Table 2. Chemical analyses of calcian tirodite and pyroxmangite from Kamiotomo, Iwate Prefecture.

	1.		2.	
	wt. %	number of atoms ($O=23$)	wt. %	number of atoms ($O=3$)
SiO_2	51.24	7.74	45.42	0.99
Al_2O_3	2.02	0.36	0.00	
FeO^*	14.50	1.83	11.86	0.22
MgO	13.40	3.02	3.69	0.12
MnO	12.39	1.59	33.29	0.62
CaO	3.34	0.54	2.33	0.55
Total	96.89		99.92	

(* total Fe)

1. Calcian tirodite. Empirical formula: $(Mn_{1.59}Ca_{0.54}Mg_{3.02}Fe_{1.83}Al_{0.10})_{\Sigma 7.08}(Si_{7.74}Al_{0.26})_{\Sigma 8.00}O_{23}$.

2. Pyroxmangite. Empirical formula: $(Mn_{0.62}Fe_{0.22}Mg_{0.12}Ca_{0.05})_{\Sigma 1.01}Si_{0.99}O_3$.

Table 3. Chemical analyses of tirodite and pyroxmangite from Zomeki deposit of the Kusugi mine, Yamaguchi Prefecture.

	1.		2.	
	wt. %	number of atoms (O=23)	wt. %	number of atoms (O=3)
SiO ₂	51.26	7.89	46.48	0.99
Al ₂ O ₃	0.10	0.02	0.00	
FeO*	16.86	2.17	13.99	0.25
MgO	12.71	2.92	3.44	0.11
MnO	12.54	1.63	33.76	0.61
CaO	2.86	0.47	2.68	0.06
Total	96.33		100.35	

(* total Fe)

1. Tirodite. Empirical formula: $(\text{Mn}_{1.03}\text{Ca}_{0.47}\text{Mg}_{2.02}\text{Fe}_{2.05})_{\Sigma 7.10}(\text{Si}_{7.89}\text{Fe}_{0.09}\text{Al}_{0.02})_{\Sigma 8.00}\text{O}_{23}$.

2. Pyroxmangite. Empirical formula: $(\text{Mn}_{0.01}\text{Fe}_{0.25}\text{Mg}_{0.11}\text{Ca}_{0.06})_{\Sigma 1.03}\text{Si}_{0.99}\text{O}_3$.

Shimozuru mine, Miyazaki Prefecture (CaO 5.31 % in weight) and the Osotari mine, Miyazaki Prefecture (CaO 6.29 % in weight) (ISHIDA, 1985).

Also, the authors' chemical survey of tirodite disclosed the occurrence of pyroxmangite-tiroidite assemblage both compositionally very close to the described materials in an ore from Zomeki deposit of the Kusugi mine, Yamaguchi Prefecture. The manganese ore deposit of the mine is of contact metamorphosed bedded type and the material was collected by S.M. from the dump. It is a massive grey ore composed of visible light cream grey tirodite fibers of millimeter order, grey yellow spessartine grains of 0.n millimeter order with minor pyroxmangite of light pinkish grey colour. In Table 3 their chemical compositions are demonstrated with their empirical formulae to indicate the compositional proximity to above materials, respectively, despite the entirely different mode of occurrence. The latter tirodite has a slightly lower calcium content than the former, but both of them keep the 2/7 boundary (KLEIN, 1964).

In 1980, NAMBU *et al.* advocated an alternative 2.5/7 boundary from the occurrence of some high manganese Mg-Fe-Mn clinoamphiboles. Among the materials employed for the presentation of this boundary, dannemorite from the Moichi mine, Iwate Prefecture (NAMBU *et al.*, 1974) is best described, and this is also observed by one of the present authors (A.K.). Obviously it forms fracture-filling veinlet in chert forming the footwall of manganese ores, and the X-ray powder diffraction peaks are all weak with broader profile as compared with those of ordinary Mg-Fe-Mn clinoamphiboles, as expected from the asbestiform feature. NAMBU *et al.* (1974) consider this mineral to be the product under a hydrothermal condition. A part of 2.5/7 boundary keepers would be occupied by products under such a condition as distinct from those currently described.

References

- AIKAWA, N., K. MASAOKA & S. MAENO, 1978. Rhodonite and manganoan amphiboles from Wakasugi, Izumi City, Osaka Prefecture. Abstr. Autumn Meeting of Japan Assoc. Petrol. Miner. Econ. Geol., Miner. Soc. Japan, and Soc. Mining Geol. Japan, p. 46. (In Japanese.)
- HAWTHORNE, F. C., 1983. The crystal chemistry of the amphiboles. *Canad. Miner.*, **21**: 173–480.
- ISHIDA, K., 1985. On the co-existence of manganoan actinolite and tirodite from the manganese ore deposits, Japan. *Jour. Miner. Soc. Japan*, **17**: 1–8. (In Japanese.)
- KLEIN, Jr., C., 1964. Cummingtonite-grunerite series: A chemical, optical and X-ray study. *Amer. Miner.*, **49**: 963–982.
- NAGASHIMA, O. & K. NAGASHIMA, 1960. Rare element minerals in Japan. The Commemorative Group for the Acceptance of Shijuhoushou (Purple Ribbon Prize) by Otokichi NAGASHIMA, pp. 292–294. (In Japanese.)
- NAMBU, M., K. TANIDA & T. KITAMURA, 1974. Mineralogical study of manganese silicate ores in northeastern Japan, (XVI). Manganoan grunerite from Moichi mine, Iwate Prefecture. *Bull. Res. Inst. Miner. Dress. Metallurg., Tohoku Univ.*, **30**: 69–78. (In Japanese.)
- , ———, & ———, 1980. Chemical composition of manganese bearing amphibole in Japan and its classification. *Jour. Miner. Soc. Japan*, **14**, Special Issue No. 3: 98–116. (In Japanese.)
- OMORI, K. & S. HASEGAWA, 1955. Chemical composition of perthite, ilmenite, allanite and pyrox-mangite occurred in pegmatite of vicinity of Iwaizumi Town, Iwate Prefecture. *Jour. Japan Assoc. Miner. Petrol. Econ. Geol.*, **39**: 91–98. (In Japanese.)