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[*Manuscript received 31 October 1994: revised 13 February 1996*]

KEYWORDS: matlockite, crystal structure, Baratti (Italy).

MINERALOGICAL MAGAZINE, OCTOBER 1996, VOL. 60, PP 836–840

Stichtite [$Mg_6Cr_2(OH)_{16}CO_3{\cdot}4H_2O$] in Nausahi ultramafites, Orissa, India – its transformation at elevated temperatures

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STICHTITE, the rare hydrated magnesian chrome carbonate, has been reported from only a few places in the world e.g. Dundas, Tasmania (Petterd, 1910); Barberton, Transvaal, South Africa (Hall, 1922); Cunningsburgh, Shetland Islands, Scotland (Read and Dixon, 1933) and the Black Lake area of Quebec, Canada (Poitevin and Graham, 1918). This is the first reported occurrence from India. The present work is mainly based on the physical (including optical) and chemical characteristics of stichtite and its transformation to other phases at elevated temperatures substantiated from XRD-peaks of the different mineralogical phases.

Geology

Stichtite occurs in the chromiferous ultramafites (mainly serpentinized dunite and peridotite) and chromite units of the Nausahi Ultramafic-mafic Complex (21°16′N, 86°20′E) in the Keonjhar district of Orissa, which belongs to a part of the Eastern Indian Shield. This ultramafic-mafic complex has intruded the Precambrian Iron Ore Group along a north–south tectonic lineament. The chromite ore bodies mainly occur as lenticular bands and *en échelon* pockets within the serpentinized dunite and peridotite host. The younger suite comprises enstatolite, lherzolite, fresh dunite, gabbro, norite, anorthosite and dolerite. The earlier ultramafites are metamorphosed under lower greenschist facies and a weak but persistent regional schistosity is very prominent in the serpentinized rocks. In places chromite ore bands are co-folded with meta-ultramafites and both have undergone post-crystallization shearing and faulting. Recently Das *et al.* (1994) reported the presence of platinum, gold and silver in the chromite-sulphide association of the ores, the sulphides being mainly of Fe, Cu and Ni.

Properties

Megascopically, stichtite in the present area occurs as purple or lilac massive aggregates or veinlets, mainly within chromitite and some within serpentinized ultramafites. In places it is weakly foliated or fibrous in character. Its hardness is $\leqslant 2$. Lustre is sub-pearly and it has a characteristic greasy feel. Cleavage {0001} is distinct.

It is strongly dichroic from light pink (E) to pink (O). Refractive indices, as determined by liquid immersion, indicate minor association of barbertonite (hexagonal polymormph of stichtite). Stichtite gives N_O = 1.545 and N_E = 1.521 whereas barbertonite has N_O = 1.559 and N_E = 1.526. Frondel (1941), by X-ray study, proved that the materials from Dundas (Tasmania) and Barberton (Transvaal) were intimate mixtures of hexagonal barbertonite and rhombohedral stichtite. The Dundas stichtite had N_O = 1.545 and N_E = 1.518 (Frondel, 1941) and N_O = 1.542 and N_E = 1.516 (Himmelbauer, 1913). Barbertonite of the Transvaal had N_O = 1.557 and N_E = 1.529 (Frondel, 1941) and that of Cunningsburgh, Scotland, had N_O = 1.559 and N_E = 1.543 (Read and Dixon, 1933). Some portion of the material from Barberton, Transvaal, also gives N_O = 1.547, which clearly indicates the presence of stichtite along with barbertonite (Frondel, 1941).

The rock which is mainly composed of stichtite and chromite is also crudely foliated where stichtite surrounds the chromite grains. In meta-dunite, chromite is pseudomorphed by stichtite or partly replaced by it, but in serpentinite stichtite occurs as distinct veinlets along the fractures of the chromite grains (Figs. 1 and 2). Stichtite is occasionally transgressed by very thin magnesite veinlets.

When treated with concentrated HCl stichtite breaks down with evolution of CO_2 at room temperature:

$$\underset{\text{stichtite}}{Mg_6Cr_2(OH)_{16}CO_3 \cdot 4H_2O} + 12\,HCl \rightarrow 6\,MgCl_2 + Cr_2O_3 + CO_2 + 18\,H_2O \quad (1)$$

$MgCl_2$ being soluble in water goes in the filtrate during filtration and Cr_2O_3 remains as an insoluble residue. Antigorite and magnesio-chromite are the main associates of stichtite in the rock and these two remain unaffected during treatment with HCl. Cr_2O_3 thus formed helps to enrich the magnesio-chromite component at higher temperatures and even to form the high-temperature phase eskolaite (Cr_2O_3), as described later.

Table 1 shows the chemical analyses of stichtite from various localities. Columns 6, 7 and 8 show the chemical composition of stichtite from the present area. Column 6 gives the composition of the mineral based on modal analysis, whereas columns 7 and 8

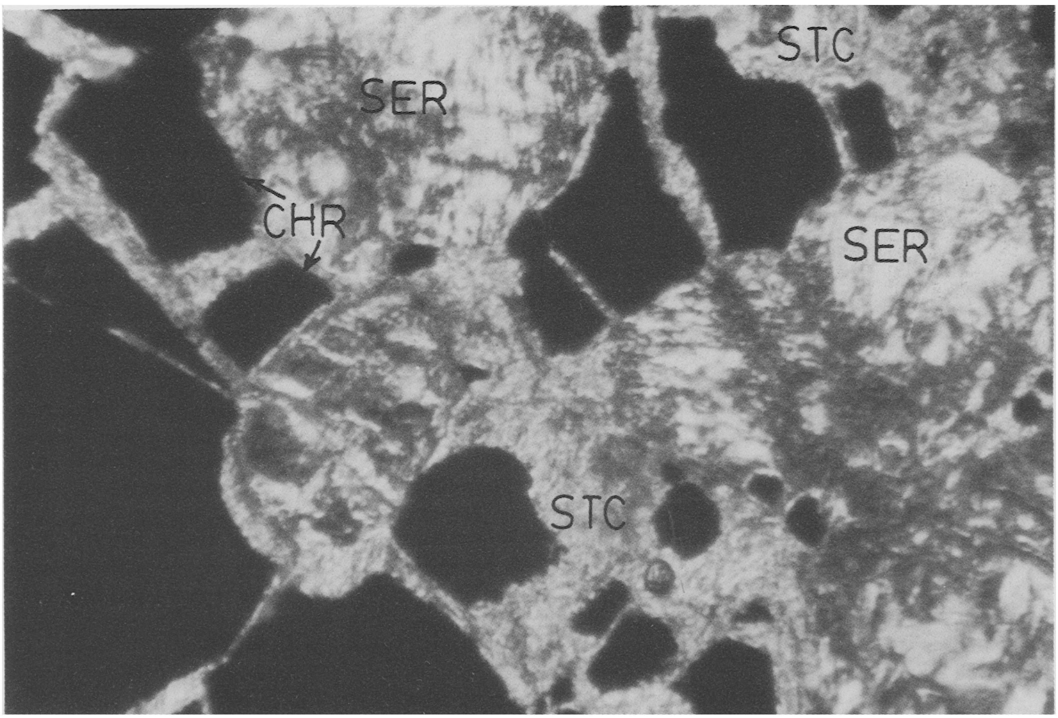

FIG. 1. Photomicrograph showing fracture-filling stichtite in association with chromite and serpentine. Under crossed polars. Length of the figure is 1.6 mm. (STC = Stichtite, CHR = Chromite and SER = Serpentine).

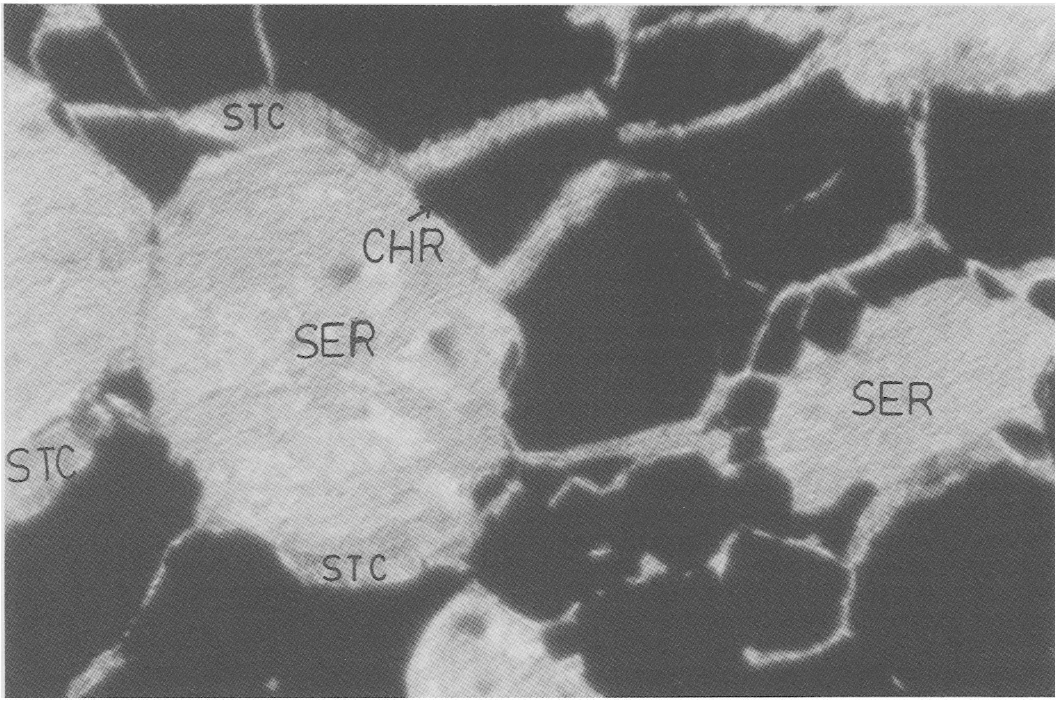

FIG. 2. Photomicrograph showing interstitial stichtite in association with serpentine and chromite. Under plane polarised light. Length of the figure is 1.6 mm. (STC = Stichtite, CHR = Chromite and SER = Serpentine).

give the bulk composition of the stichtite-dominant assemblage, containing minor amounts of antigorite and chromite by wet chemical analysis, following Scott (1939).

X-ray diffraction data of stichtite from Nausahi, at room temperature, with minor association of antigorite, magnesio-chromite and magnesite are given in Table 2 (Philips XRD Model No. PW-1730/1710, Cu-$K\alpha$, Ni-filter, 40 kV, 20 mA).

The strongest peaks around 7.76, 3.88, 2.86 and 2.58 Å characterize the dominance of the mineral stichtite in the assemblage. The characteristic peaks of the minor associates are though much less dominant than those of stichtite but their presence is established.

XRD studies of the different mineralogical phases were done by heating stichtite in air at different temperatures. Periclase and magnesio-chromite appeared when powdered stichtite was heated between 600 and 650°C for an hour and subsequently cooled.

$$Mg_6Cr_2CO_3(OH)_{16}{\cdot}4H_2O \xrightarrow{600-650°C} 5\,MgO + MgO.Cr_2O_3 + 12H_2O + CO_2 \quad (2)$$

stichtite magnesio-chromite periclase

Stichtite undergoes dehydration and calcination with evolution of CO_2 from the structure and formation of periclase and magnesio-chromite.

On heating to 760–820°C in air for an hour stichtite breaks down to periclase and magnesio-chromite as above, and the associated minor amount of antigorite transforms to forsterite and quartz.

$$2\,Mg_3Si_2O_5(OH)_4 \xrightarrow{760-820°C} 3\,Mg_2SiO_4 + SiO_2 + 4\,H_2O \quad (3)$$

antigorite forsterite quartz

When the stichtite-chromite rock after treatment with concentrated HCl was heated to 1000°C in air for an hour, and subsequently cooled to room temperature, eskolaite (Cr_2O_3) and magnesio-chromite became the dominant phases along with a very minor amount of forsterite and quartz. By acid treatment the sample became relatively enriched with a Cr_2O_3 component, by reaction (1) for which at high temperature excess Cr_2O_3 formed the mineral eskolaite, the natural analogue of which is reported only from a very few occurrences (Kouvo and Vuorelainen, 1958; Cassedanne and Cassedanne, 1980). Chatterjee *et al.* (1982) have synthesized corundum-eskolaite, α-$(Al,Cr)_2O_3$, crystalline solutions with compositions in tbe range $0 < X_{Cr_2O_3} < 1$ at 25 kbar P_{H_2O} and 1070°C.

TABLE 1. Chemical analyses of stichtite from various localities. (No.1 to 5 data from Palache *et al.*, 1944)

	1	2	3	4	5	6	7	8
MgO	36.98	36.0	37.12	36.59	36.70	36.977	18.96	20.71
FeO	–	–	1.10	0.28	0.85	–	13.15	14.66
Fe_2O_3	–	9.0	–	4.04	10.60	–	0.93	1.11
Al_2O_3	–	–	–	2.24	0.90	–	4.38	4.78
Cr_2O_3	23.24	11.5	20.44	14.08	8.90	23.236	19.68	11.21
CO_2	6.73	7.2	10.45	6.94	6.90	6.727	9.64	10.83
H_2O	33.05	36.1	27.26	33.01	30.45	33.044	10.37	11.32
SiO_2	–	–	3.87	2.09	4.50	–	20.33	22.71
Rem	–	–	–	trace	0.15	–	1.76	1.91
Total	100.00	99.80	100.14	99.27	99.95	99.984	99.20	99.24

1. $Mg_6Cr_2(OH)_{16}CO_3{\cdot}4H_2O$ – Ideal composition.
2. Dundas, Tasmania. Contains chromite and probably barbertonite (Wesley, analysis in Petterd, 1910).
3. Dundas, Tasmania (chrom-brugnatellite). Contains chromite, serpentine and probably barbertonite. H_2O^+ 26.31; H_2O^- 0.95 (Hezner, 1912).
4. Dundas, Tasmania. Probably contains serpentine and barbertonite with trace amount of CaO (Foshag, 1920).
5. Barberton, Transval. Contains chromite, serpentine and probably barbertonite. Rem. is NiO 0.10; Na_2O 0.05; K_2O trace (McCrae and Weall, analysis in Hall, 1922).
6. Stichtite from Nausahi, India, based on modal analysis of the stichtite – chromite – barbertonite – antigorite assemblage.
7. Stichtite with minor association of serpentine, and chromite (sample no. NS-0/3f), Nausahi, India. Rem. is CaO 1.07; K_2O 0.37; and Na_2O 0.32. Wet chemical analysis by B.P. Gupta & Sons, Calcutta.
8. Stichtite with minor association of serpentine, magnesite and chromite (Sample no. NS-O/3h), Nausahi, India. Rem. is CaO 1.16; K_2O 0.41; and Na_2O 0.34. Wet chemical analyses by B.P. Gupta & Sons., Calcutta.

Acknowledgements

The financial assistance of the Council of Scientific and Industrial Research, New Delhi, for the present research work is acknowledged. Thanks are also due to Mr D.K. Ghosh, Department of Geological Sciences, Jadavpur University, for his kind assistance during XRD-work.

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TABLE 2. XRD-data of stichtite from Nausahi, Orissa, India, at room temperature, with minor association of antigorite, magnesio-chromite and magnesite

Sample No.	Stichtite		Antigorite		Magnesio-chromite		Magnesite	
	d-values in Å	I	d-values in Å	I	d-values in Å	I	d-values in Å	I
	7.7553	100	7.2190	100	4.7918	<10		
	3.8801	100	4.2669	<10	2.5197	15		
	2.8642	60	4.0753	<10	2.4024	<10		
	2.5829	35	3.6375	70	2.0718	<10		
	2.3160	<10	2.5829	35	1.5963	<10		
NS-O/3h	1.9592	10	2.4306	15	1.4689	<10		
	1.8574	30	2.5197	15				
	1.7746	10	2.3719	10				
	1.6570	<10	2.2020	20				
	1.5428	10	2.1867	10				
	1.5120	10	1.8574	30				
	1.4901	<10	1.7957	10				
	1.4316	<10	1.6287	<10				
	7.7609	100	7.2366	55	4.7940	15	2.7484	10
	4.2972	<10	6.4082	<10	2.5027	55	2.3186	<10
	3.8817	100	4.6113	<10	2.9350	10	2.1085	<10
	2.8748	30	3.6145	30	2.3967	<10	1.9424	<10
	2.5882	15	2.6656	<10	2.0760	15	1.7064	<10
	2.3186	<10	2.5882	15	1.7064	<10		
NS-O/3h$_1$	1.9694	10	2.5027	55	1.5989	20		
	1.8606	10	2.4548	<10	1.4692	10		
	1.6973	<10	2.3967	<10				
	1.5419	<10	2.1998	<10				
	1.5139	<10	2.1849	<10				
			1.7940	<10				
			1.7064	<10				
			1.6973	<10				
			1.5989	20				
	7.6880	100	7.2190	100	4.7536	10		
	4.3078	<10	3.6085	70	2.4959	30		
	3.8635	100	2.6883	<10	2.9284	10		
	2.8648	<10	2.6233	<10	2.4055	<10		
	2.5829	20	2.4959	30	2.0718	10		
NS-O/3f	2.3132	<10	2.3840	<10	1.9395	<10		
	1.9632	10	2.1994	<10	1.6908	<10		
	1.8538	10	2.1841	<10				
	1.7539	<10	1.8124	<10				
	1.6598	<10	1.7493	<10				
	1.5417	<10	1.6908	<10				
	1.5120	<10	1.5963	<10				

[*Manuscript received 3 March 1995: revised 11 December 1995*]

KEYWORDS: stichtite $[Mg_6Cr_2(OH)_{16}CO_3 \cdot 4H_2O]$, chromite, phase transformation, Nausahi, Orissa, India.