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On 'winchite' from the original locality at Kajlidongri, India

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SUMMARY. A new analysis of the violet amphibole from the original locality where winchite came from agrees with another recent analysis in differing substantially from the original winchite composition and is $(K_{0\cdot17}Na_{2\cdot10}Ca_{0\cdot23})(Al_{0\cdot19}Ti_{0\cdot00}Fe^{3}_{1\cdot27}Fe^{2}_{0\cdot01}Mn_{0\cdot07}Mg_{3\cdot34})Si_{8\cdot01}O_{22\cdot05}(OH)_{1\cdot95}$. It is essentially a magnesio-arfvedsonite. Although it is possible that the original analysis was unreliable, evidence is given to support the alternative view that there is a wide range of blue alkali and soda calcic amphibole compositions at Kajlidongri and the name winchite should be restricted to compositions between ferri-winchite $CaNaMg_5Fe^{3+}Si_8O_{22}(OH,F,Cl)_2$ and alumino-winchite $CaNaMg_5Al\ Si_8O_{22}(OH,F,Cl)_2$. X-ray, density, and optical data on the analysed mineral are given.

WINCHITE, a violet soda calcic ferric amphibole practically free of ferrous iron, was originally found by a Mr. H. J. Winch in manganese ores at the Kajlidongri mine (22° 57′ N., 74° 31′ E.), Jhabua district, Madhya Pradesh, India. He brought it to the attention of Sir Lewis Fermor who described (1904, 1906, 1909) and named it. The first analysis was reported by Fermor in 1909 and is given in Table I. Since then the mineral has been reported from several Indian and other localities (Kilpady and Dave, 1954; Bilgrami, 1955; Byramjee and Meindre, 1956; Sadashivaiah, 1962; Roy and Mitra, 1964; Sadashivaiah and Naganna, 1964; Nayak and Neuvonen, 1963; Sathe *et al.*, 1965). Nayak (1962) investigated the manganese ore deposits of the Kajlidongri area and found that winchite occurs in a variety of rocks and recently Lahiri (1971) has given a summary of the mineralogy and genesis of the manganese oxide and silicate rocks of Kajlidongri and the surrounding areas.

The original analysis of winchite (Fermor, 1909), when calculated on the basis of 23(O) [as the combined water was not determined, only loss on ignition being given, and assuming all the iron occurs as Fe_2O_3] gives a half unit cell formula (Table I) quite close to the theoretical 'end member' $CaNaMg_5Fe^{3+}Si_8O_{22}(OH)_2$, a soda calcic ferric amphibole. Analyses from other localities than the original one have tended to show much more Al with substitution of Al for both Si and Fe^{3+} but usually Si is not far from the theoretical upper limit of eight. Consequently the theoretical 'end members' $CaNaMg_5Fe^{3+}Si_8O_{22}(OH)_2$ (ferri-winchite) or $CaNaMg_5AlSi_8O_{22}(OH)_2$ (alumino-winchite) have usually been called winchite and will be referred to as theoretical winchite. Lahiri (1971) has, however, recently given a new analysis of winchite, the sample probably being derived from the Kajlidongri mine (the locality is not specified but most of the paper is concerned with the relationships at this mine) and this has markedly less Ca than theoretical winchite, containing only $Ca_{0.43}$ with $Na_{1.99}$ $K_{0.16}$ on the basis of 24 (O,OH,F). This raises the question as to whether winchite from the original locality is at all close to theoretical winchite or not. If the analysis reported by Lahiri is recalculated on the basis of 23(O), as the total OH+F of 1·23 is very low for an amphibole, then the Ca, Na, and K values are even more reduced giving $Ca_{0.42}$ $Na_{1.96}K_{0.16}$. Such a composition would be some form of eckermannite or magnesio-arfvedsonite depending upon the precise definition of these terms.

Accordingly, a reanalysis of the blue winchite mineral from the Kajlidongri mine has been made on material obtained by crushing transparent crystals of the amphibole and carefully separating the few inclusions present by heavy liquids. The results (Table I) will be discussed after the occurrence of the mineral in the mine at Kajlidongri has been described.

Occurrence. The mineral occurs in schist containing braunite and calcite, in quartzite, manganiferous quartzite with pyroxene, pyroxene-bearing quartzite, and a lavender to ash-grey friable sandy rock. The amphibole is especially developed in the schist that forms a 1·5 m band conformable with the ore body, and forms one wall in the north-east part of the mine.

The winchite in the schist is best developed in association with calcite, being almost absent from the quartz-rich portions of the rock. Poikiloblastic winchite with quartz and calcite inclusions sometimes occurs. In the manganiferous quartzite, pyroxene occurs within the amphibole and manganese ore is disseminated throughout the rock. In the pyroxene-bearing quartzite the amphibole and pyroxene (probably acmite or blanfordite) coexist together and in the friable sandy rock such abundant calcite occurs within the amphibole that the latter appears to be almost replaced. The accessory minerals in these rocks are biotite, manganophyllite, apatite, muscovite, plagioclase, hematite, calcite, and manganese oxides.

Further details on the occurrence of this and other associated minerals at Kajlidongri are given by Nayak (1962) and Lahiri (1971); the paragenesis is one of low-grade metamorphism corresponding to the chlorite and biotite zones in pelites.

Physical characteristics. Winchite has a striking cobalt blue to bluish-violet colour and occurs as stout prismatic crystals, thin fibres, blades, acicular prisms, and also in rosettes. The longest prismatic crystal measured was 4 cm long. There are also spherulitic forms with cores of pyroxene fibres with peripheral winchite. Prismatic cleavages (110) and ($1\bar{1}0$) are common. The specific gravity of the analysed material is 3·175. The optical properties of an unzoned variety are: α 1·649, lilac to pinkish lilac; β 1·655, paler lilac; γ 1·671 variable sky blue; γ–α measured 0·022; α: [001] 16–28°, $\beta \parallel$ [010]; $2V_\alpha$ 44–56°, dispersion, $r > v$, is very high. Two varieties are known, one with negative elongation (the 'basic' variety of Fermor, 1909) and a low extinction angle is common, and one with positive elongation ('acid' variety) and a high extinction angle, sometimes over 30°, is rare and has not been analysed. The pleochroism is rather variable and strong zoning occurs with the inner part sometimes having a negative elongation while the outer part has positive elongation and striking ultra-blue polarization colours also occur. It is clear from these physical properties that there are variations in the chemical composition of the mineral.

Chemistry. The new analysis (Table I) differs very significantly from the original winchite analysis, principally in being much poorer in Ca and richer in Na, features also shown by Lahiri's (1971) analysis. The present analysis was made on very carefully purified apparently unzoned material and three international standards were simultaneously analysed with the amphibole so that the possibility of substantial error is negligible. The contents of the half unit cell calculated on the basis of 24 (O,OH) showed a slight excess of Si, which is believed to be the result of the non-determination of F, which B. P. Gupta found to 0·28 on the sample reported by Lahiri (1971). If the analysis is calculated to 23(O), in effect assuming that $(OH)_{1\cdot95}$ is accompanied by $F_{0\cdot05}$, then the Si is slightly reduced. The new analysis has the smallest Ca ($Ca_{0\cdot23}$) and the highest Na ($Na_{2\cdot10}$) of any analysis described as winchite, and indeed agrees with Lahiri's analysis in departing so substantially from the original analysis and from theoretical winchite that it is more appropriately named a magnesio-arfvedsonite. It differs from the analysis reported by Lahiri mainly in possessing smaller Al, Mn, and Ca contents and larger Si and Fe^{3+} contents.

As both the modern analyses of the blue amphibole from Kajlidongri are substantially different from the original analysis the question arises as to whether the original analysis is reliable or whether there is substantial variation in the chemistry of the blue amphibole from this locality. The evidence clearly favours the second view for a wide range of amphiboles have been described from this locality; tremolite (Nayak, 1962), pale pleochroic and deep violet-red amphiboles (Nayak, 1962), juddite (Nayak, 1961), tirodite (Lahiri, 1971), in addition to the presence of zoned winchite crystals with a range of optical properties that demonstrates that some chemical variation certainly occurs. The differences between the present analysis and that reported by Lahiri (1971) are far outside likely analytical error (e.g. 8·02 and 1·19 % Al_2O_3, 4·02 and 0·62 % MnO, and 6·00 and 12·09 % Fe_2O_3) and in the writers' opinion the original analysis by T. R. Blyth reported by Fermor (1909) is unlikely to be erroneously high in both CaO and MgO such that total CaO and MgO would be nearly 12 % too high. On the other hand, the original analysis has a seriously low Z group total and an excessively high Y group total even when calculated to 23(O), to avoid the excessively high loss on ignition value influencing the formula as combined water. Accordingly, the status of the original analysis is somewhat uncertain but the most likely elucidation is that there is substantial variation in the chemistry of the blue amphiboles at this locality and clearly a detailed microprobe study of all these amphiboles is called for.

This is particularly necessary as the range of amphiboles being described as winchite is being enlarged in a quite bewildering fashion with no apparent consideration of the crucial features of the original analysis. Thus Sadashivaiah and Naganna (1964) have described as winchite an amphibole with as much Ca as typical calcic amphiboles contain (Table I, analysis 7). The amount of Mn in both the original sample and the present one is really quite trivial and clearly Mn is not necessarily abundant.

TABLE I. *Chemical analyses of some amphiboles described as winchite*

	1	2	3	4	5	6	7
SiO_2	57·31	55·64	54·12	55·14	52·84	50·58	47·41
Al_2O_3	1·19	1·08	8·02	1·14	7·32	0·58	1·16
TiO_2	0·01	0·00	0·32	0·50	0·42	0·15	0·34
Fe_2O_3	12·09	7·06	6·00	4·59	3·36	16·04	6·98
FeO	0·10	—	0·13	1·25	tr	0·59	0·78
MnO	0·62	0·77	4·02	1·38	1·74	2·37	0·66
MgO	16·04	22·09	14·96	22·16	21·02	13·16	18·94
CaO	1·52	7·64	2·86	7·37	8·68	7·21	10·82
Na_2O	7·74	2·89	7·31	2·88	2·51	6·43	4·48
K_2O	0·95	0·98	0·90	1·24	0·94	2·34	6·67
H_2O+	2·09	3·09	1·18	1·98	0·64	0·32	1·02
H_2O-	—	0·14	0·18	—	0·16		
F	—	0·00	0·28	—	0·05		
	99·66	101·00	100·16	99·63	99·66	100·04	99·26
Atoms to 23(O) or 24(O, OH)							
Si	8·01	7·70	7·49	7·70	7·22	7·36	7·04
Al	0·19	0·17	0·51	0·18	0·78	0·10	0·20
Al	0·00	0·00	0·80	0·00	0·40	0·00	0·00
Ti	0·00	0·00	0·03	0·05	0·04	0·02	0·04
Fe^{3+}	1·27	0·73	0·62	0·48	0·35	1·76	0·78
Fe^{2+}	0·01	—	0·02	0·14	0·00	0·07	0·10
Mn	0·07	0·09	0·47	0·15	0·20	0·29	0·08
Mg	3·34	4·55	3·08	4·62	4·28	2·85	4·19
Ca	0·23	1·13	0·42	1·11	1·27	1·12	1·72
Na	2·10	0·77	1·96	0·78	0·66	1·81	1·28
K	0·17	0·17	0·16	0·21	0·16	0·44	1·27
OH	1·95			1·84			
O	22·05	(22·00)	(22·00)	22·16	(22·00)	(22·00)	(22·00)
ΣZ	8·01	7·87	8·00	7·88	8·00	7·46	7·24
ΣY	4·88	5·37	5·02	5·44	5·27	4·99	5·19
ΣX	2·50	2·07	2·54	2·10	2·09	3·77	3·27

1. Violet amphibole from the NE. part of the Kajlidongri mine (80 m SSW. of Mata Hill), Jhabua district, Madhya Pradesh, India. The host rock is a winchite schist with calcite, braunite, biotite, manganophyllite, and sometimes apatite and plagioclase. Analyst, A. Kemp in the Department of Geology, University of Bristol.
2. The original analysis of winchite from the above locality, Fermor (1909). State of oxidation of the iron not determined and assumed here to be entirely as Fe_2O_3. H_2O+ not determined but loss on ignition given as 3·09.
3. Deep-blue amphibole from the same mine (?) (Lahiri, 1971). Analysis total includes a subtraction of 0·12 for O ≡ F.
4. Amphibole from Chikla, Bhandara, India (Bilgrami, 1955).
5. Amphibole from Tirodi, India (Roy and Mitra, 1964). Total includes a subtraction of 0·02 for O ≡ F.
6. Amphibole from Goldongri (Sathe *et al.*, 1965).
7. Amphibole from Jothvad (Sadashivaiah and Naganna, 1964).

X-ray pattern. The mineral was examined with a 5·7-cm camera with filtered Fe-$K\alpha$ radiation and gave *d* 8·30 Å ms, 4·78 w, 4·44 m, 3·37 s, 3·25 m, 3·100 s, 2·952 w, 2·791 w, 2·690 vs, 2·584 w, 2·514 m, 2·316 m, 2·270 vw, 2·154 m, 2·068 vw, 2·013 vw, 1·675 vw, 1·651 w, 1·601 vw, 1·579 w, 1·506 w, 1·427 m, 1·374 w, 1·335 w, 1·306 w, 1·282 m, 1·260 vw, 1·189 w, 1·121 vw, 1·080 vw, 1·068 vw, 1·052 w, 1·043 w, 1·034 w, 1·022 w, 1·011 vw. This pattern is similar to the patterns reported by Kilpady (1964) and Sadashivaiah and Naganna (1964) for 'winchites' from Jothvad and Ponia, India, that have their strongest reflections at 2·68 and 2·70 Å respectively but the Jothvad 'winchite' has, understandably in view of its very different composition, another strong reflection at 3·09 Å that is absent in both the Ponia and Kajlidongri amphiboles.

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