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The Composition of an Actinolite

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A finely fibrous actinolite has been re-analysed, and the occurrence therein of a higher-than-usual water-content has been verified. This new analysis, considered in the light of recently published research, supports the view that extra hydrogen, as hydroxyl, may replace some of the oxygens in the Si_4O_{11} bands. Physical data for the re-analysed actinolite are also reported.

In a paper in a recent issue of this journal Zussman (1955) reported results of a crystal-structure study of a very finely acicular actinolite that had been collected and studied some years ago by the present writer (Hutton, 1940). The chief problem that presented itself in the earlier investigation was the large amount of water evolved above 105° C., and this appeared to lead to poor agreement with the ideal amphibole formula as proposed by Warren (1930). Zussman has now shown that there is an excess of hydrogen but not of oxygen in this particular actinolite, thus accounting for most of the high percentage of water found, and he has presented two possible ways in which such hydrogen may be accommodated in the amphibole structure. Although sufficient evidence is not available to enable him to eliminate either one or other of these alternatives he is slightly in favour of the situation in which the extra hydrogen may, as (OH) ions, replace some of the oxygens in the Si_4O_{11} bands, as occurs in afwillite, rather than that in which SiO_4 groups may be replaced by (OH), as in hydrogrossular, metamict zircon and thorite, and other silicates.

The present writer has long felt that a re-examination of this actinolite was necessary and a recent visit to New Zealand made collection of material from the original locality possible. Unaware that Zussman's investigation was under way, a new chemical analysis was made from material that was especially carefully prepared to eliminate all traces of talc and chlorite, minerals that are intimately associated with the actinolite. Accordingly, and in view of Zussman's paper, the writer would like to place this new analysis on record (Table 1, *B*) since it checks the earlier one quite closely except that a slightly lower percentage of combined water has now been determined, a fact that

Table 1. *Analyses of actinolite**

	A	*B*
SiO_2	50·21	50·47
Al_2O_3	4·55	4·18
TiO_2	1·20	1·11
Fe_2O_3	2·77	2·90
Cr_2O_3	0·10	0·08
MgO	17·85	17·94
FeO	9·03	9·20
MnO	0·19	0·14
Na_2O	0·40	0·57
CaO	9·69	9·44
K_2O	0·23	0·28
H_2O+	4·05	3·55
H_2O-	0·02	0·11
F_2	0·15	0·12
	100·44	100·09
$-O = F_2$	0·06	0·05
	100·38	100·04

Physical properties of actinolite *B*

$\alpha = 1\cdot630 \pm 0\cdot002$, $\gamma = 1\cdot648$; $\gamma - \alpha = 0\cdot018$
$2V = 69°$, $Z{:}c = 19°$

Specific gravity = 3·11 (at 18° C.)

A: Original analysis (Hutton, 1940, p. 15); 55 chains north-east of Bracken Creek–Arrow River junction, Shotover Survey District, New Zealand. Otago University Geology Department No. 2662.
B: New analysis; material from same outcrop as *A*.

* Analysis by C. Osborne Hutton.

G. D. Nicholls (in Zussman, 1955, p. 306) established independently for material from the original specimen that had been deposited in the collections of the Department of Mineralogy and Petrology, Cambridge, England.

Water evolved above 105° C. is 3·55%, but it was found that 0·45% of water was lost between 105 and 200° C., an amount that was almost completely recovered by the fine powder—particle size averaged 10–15 microns—if allowed to remain uncovered at room temperature for several hours. Since the remainder of the water was lost at very much higher temperatures it would seem appropriate to assume that the figure for combined water should be 3·10 rather than 3·55%.

Table 2. *Determination of formula for re-analysed actinolite*

	Weight %	Ionic ratio		Ions			
SiO_2	50·47	0·8403	Si	14·49		16·00	*Z*
Al_2O_3	4·18	0·0820	Al	1·41			
TiO_2	1·11	0·0139	Ti	0·24	0·10 0·14		
Fe_2O_3	2·90	0·0363	Fe^{3+}	0·62		9·98	*Y*
Cr_2O_3	0·08	0·0010	Cr	0·01			
FeO	9·20	0·1280	Fe^{2+}	2·20			
MnO	0·14	0·0019	Mn	0·03			
MgO	17·94	0·4449	Mg	7·67	6·98 0·69		
Na_2O	0·57	0·0183	Na	0·31		4·00	*X*
CaO	9·44	0·1683	Ca	2·90			
K_2O	0·28	0·0059	K	0·10			
H_2O^+	3·10	0·3441	H	5·93	2·04 3·89	2·04	
F_2	0·12	0·0063	F	0·11		4·00	

This leads to the formula:

$$X_4Y_{10}Z_{16}(OH, F)_4(O, OH)_{44}$$

The number of ions of each kind in the unit cell has been calculated from the data in Table 1, *B*, and for this purpose Zussman's cell dimensions and the specific gravity figure determined by the writer for the re-analysed actinolite have been used, namely

$$a_0 = 9{\cdot}89,\ b_0 = 18{\cdot}14,\ c_0 = 5{\cdot}31\ \text{Å},\ \beta = 105°\,48',$$
$$\text{specific gravity} = 3{\cdot}11\ \text{(see Table 2)}\,.$$

Using 1·6603 as the reciprocal of Avogadro's number, a factor of 17·24 was employed to arrive at the numbers of atoms per unit cell from the atomic ratios. The number of oxygens empirically determined is 48·4.

If aluminium and part only of the titanium are grouped with silicon, the *Z*-group ions may be brought to the figure of 16, the value required structurally, and further, the ions of the *X*, *Y* and *Z* groups collectively equal 29·98, a value that is satisfactorily close to 30, and therefore negligibly deficient. *X* and *Y* ions are equal to 13·98, although ions whose radii would usually warrant inclusion in the *Y* group are in excess of 10 (see Zussman, 1955, p. 304). A good balance may be obtained in this instance if we include with calcium a small number of magnesium ions, namely 0·69 out of a total of 7·67, and if we consider the extra hydrogens, as (OH), to replace oxygens in the Si_4O_{11} bands. If it is correct to assume that some *Y*-group ions are associated with calcium when that group is deficient in itself, as suggested by Zussman, then it would seem reasonable to suppose that other ions than magnesium, iron and manganese for instance, might also be capable of inclusion in *X*-group positions, especially since both magnesium and iron appear to exhibit a random distribution.

Therefore, Zussman's first alternative formula seems to have slightly better support than the second in this instance, but it must be remembered that in arriving at the figures employed here, Zussman's cell dimensions obtained for actinolite from a different specimen have been used, although any doubts concerning the similarity of the material studied by Zussman and analysed by the present writer are slight indeed.

I should like to take this opportunity of thanking Dr Zussman for his kindness in communicating to me by letter the details of his research prior to actual publication date; and I wish to acknowledge gratefully the assistance provided by the award of a John Simon Guggenheim Memorial Foundation Fellowship.

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