A chemical and optical study of a low-grade metamorphic actinolitic amphibole from Coronet Peak, western Otago, New Zealand.

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THIS amphibole is an important constituent of an albite-epidote-actinolite-chlorite-calcite-schist[1] from the summit of Coronet Peak in the Wakatipu district, western Otago. The mineral is somewhat concentrated into folia and porphyroblastic crystals up to 5·0 mm. in length, and is markedly flattened parallel to the orthopinakoid so that sections cut parallel to the schistosity exhibit numerous porphyroblasts, deeply coloured, poorly birefringent, and showing rather poor cleavage lines (fig. 1 A and B; fig. 2 A). In slices cut across the foliation numerous elongated end-sections are to be seen with development of small orthopinakoids (fig. 2 B).

The refractive indices ($\pm 0{\cdot}002$) are α 1·635, β 1·650, γ 1·655; $\gamma-\alpha$ 0·020. The angle $\gamma{:}c = 18°$, and 2V $60° \pm 1°$. Pleochroism follows the scheme α pale yellow, β dirty bluish-green, γ deep bluish-green, with absorption $\gamma > \beta > \alpha$.

It was found that some sections nearly, but not quite, parallel to (100), and especially sections very nearly normal to the acute bisectrix of the optic axes, gave wide extinction-angles, in some cases up to 34°, from the crystallographic axis c; and in order to determine the true angle between γ of the refractive index ellipsoid and the c-axis, a series of extinction-angles in the prism-zone was determined on the universal stage. The curve (fig. 3) shows a rapid rise in the value $\gamma{:}c$ to 22° at only 30° from (100), and then a gentle slope down to 18° on the clinopinakoid.[2] Using the values 2V 60° and $\gamma{:}c$ 18°, theoretical values for the extinction-angles in the prism-zone were calculated stereographically, and the determined values when plotted give a curve corresponding very closely

[1] No. 2718 in the rock section collection, University of Otago.

[2] It is interesting to note that cleavage plates of this amphibole give high extinction-angles, very close to the maximum value obtainable in the prism-zone.

indeed to that experimentally obtained. Stereographically, it is possible to show that sections cut nearly normal to the acute bisectrix of the optic axes exhibit angles as high as 35°.

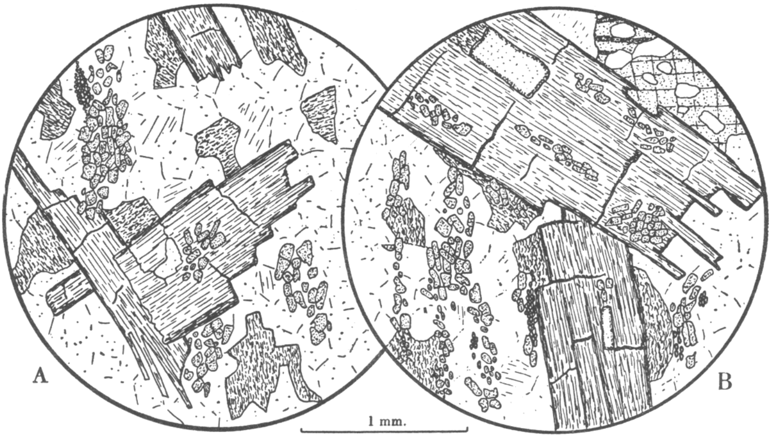

FIG. 1 A and B. Porphyroblastic actinolite in albite-epidote-actinolite-chlorite-calcite-schist (no. 2718); section cut parallel to the plane of schistosity. From Coronet Peak, western Otago, New Zealand.

That the maximum extinction-angle in the prism-zone in amphiboles may be in some other plane than (010) is not a new feature, but has been clearly demonstrated by R. A. Daly,[1] though he stresses the fact that this feature is not believed to be true by many writers. Likewise Rosenbusch and Wülfing[2] show by means of graphs the extinction-angles obtainable in any position in the prism-zone with various values of 2V and $\gamma:c$; from these graphs it is clear that in some cases the maximum extinction-angles in the prism-zone is not always to be found on (010).

The Coronet Peak amphibole was separated in the pure state by the use of the centrifuge and the analysis is given below, together with the structural formula calculated on the basis of 24(O,OH,F) atoms per unit cell. Several points may be noted in the analysis of this amphibole: firstly, the low aluminium figure, most of which replaces silicon in order to make up the ideal Si figure; secondly, magnesia is greater than iron; thirdly, soda is rather high, while K_2O is very low; fourthly, the analysis

[1] R. A. Daly, On the optical characters of the vertical zone of amphiboles and pyroxenes: and on a new method of determining the extinction angles of these minerals by means of cleavage pieces. Proc. Amer. Acad. Arts and Sci., 1899, vol. 34, pp. 311–323; and Bull. Soc. Franç. Min., 1899, vol. 22, pp. 161–174.

[2] H. Rosenbusch and E A. Wülfing, Mikroskopische Physiographie. 1924, vol. 1, part 1, pp. 490–491.

fits the formula of tremolite as worked out by Warren[1] from X-ray data. The alkali group, however, does not exceed 2, therefore as Warren suggested the AA′ position remains vacant.

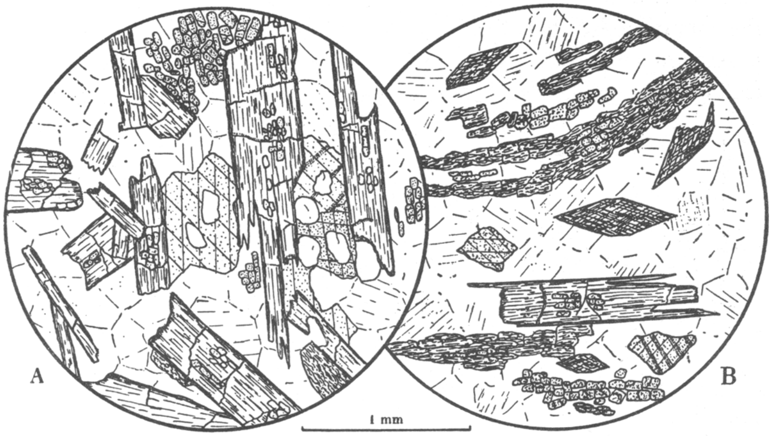

FIG. 2 A. As in fig. 1 A and B.
FIG. 2 B. Section of albite-epidote-actinolite-chlorite-calcite-schist (no. 2718) cut perpendicular to the schistosity, showing end-sections of porphyroblastic actinolite. From Coronet Peak, western Otago, New Zealand.

		Metal atoms.		Metal groups.	Ideal tremolite formula.
SiO_2	52·19	7·474		8·00	8
Al_2O_3	3·93	0·653	0·526		
			0·127		
TiO_2...	0·40	0·043			
Fe_2O_3	4·85	0·516			
FeO...	10·73	1·281		5·09	5
MnO	trace	—			
MgO	14·54	3·123			
CaO...	10·20	1·566			
SrO	nil	—		1·98	2
Na_2O	1·53	0·412			
K_2O	0·03	—			
H_2O+	2·17	2·064		2·06	2
H_2O-	0·02	—			
	100·59				

Formula: $(OH)_2(Na,Ca)_2(Mg,Fe,Ti,Al)_5(Si,Al)_8O_{22}$.

Amphibole from albite-epidote-actinolite-chlorite-calcite-schist (no. 2718), Coronet Peak, western Otago, New Zealand. Analyst, C. O. Hutton.

[1] B. E. Warren, The crystal structure and chemical composition of the monoclinic amphiboles. Zeits. Krist., 1930, vol. 72, pp. 493–517. [M.A. 4–278.]

An interesting but rare feature in this amphibole is the zonary arrangement whereby a nucleus with totally different optical properties passes without perceptible break into the amphibole just described. This nuclear crossite type of amphibole is elongated in the direction of the vibration-direction β and has a transverse optic axial plane. The maximum extinction-angle obtained for $\beta : c = 8° \pm 2°$. Owing to the small size of the nucleus and the zonary arrangement, 2V could not be

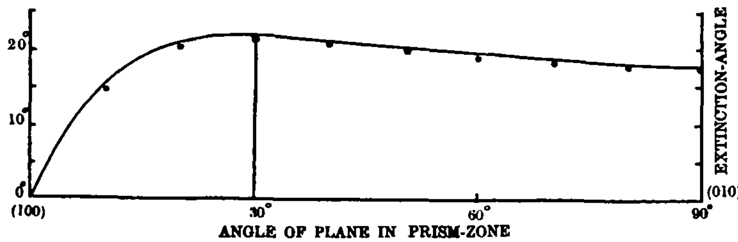

FIG. 3. Curve showing values of the extinction-angles in any plane in the prism zone of a monoclinic crystal when $2V = 60°$, $\gamma : c = 18°$, and $\beta = b$. The continuous line represents values obtained on the universal stage, while the dots are the values obtained stereographically.

measured with any great accuracy, but appears to be approximately $30° \pm 5°$. It should be pointed out that the extinction-angle of 8° is rather greater than that usually given, but Larsen[1] has described two crossites with $\beta : c$ about 7° and 10°. Pleochroism is striking and follows the scheme α pale mauve to colourless, β deep blue, and γ deep mauve; absorption $\beta > \gamma > \alpha$. Dispersion of the bisectrices is strong and the birefringence is low.

This condition of a transverse optic axial plane is realized only in amphiboles such as crossite, laneite, osannite, taramite, fluotaramite (J. Morozewicz[2]), and crocidolite. Murgoci[3] believes that transverse axial planes may be developed in most amphiboles, even in actinolites, but the writer is not clear what Murgoci means in this latter case, for any member of the series from tremolite to ferrotremolite always has the optic axial plane parallel to (010). It should be noted that Murgoci[4]

[1] E. S. Larsen, The microscopic determination of the nonopaque minerals. Bull. U.S. Geol. Surv., 1921, no. 679, p. 64.

[2] J. Morozewicz, Min. Abstr., 1926, vol. 3, pp. 109–110.

[3] G. Murgoci, Contributions to the classification of the amphiboles. Bull. Dept. Geol. Univ. Calif., 1906, vol. 4, no. 15, pp. 359–386.

[4] G. Murgoci, Sur les propriétés des amphiboles bleues. Compt. Rend. Acad. Sci. Paris, 1922, vol. 175, pp. 372–374. [M.A. 2–221.]

classes osannite with those amphiboles having a transverse optic plane, but later in the same year he[1] groups it with riebeckite which has an optic plane parallel to (010).

The optical properties of this rare amphibole situated in the centre of the blue actinolite porphyroblasts are most comparable with those of crossite, an intermediate member of Kunitz's glaucophane-riebeckite series[2] (p. 198). Woyno[3] in a petrological treatment of the Casanna schists finds sodic amphiboles such as glaucophane (pp. 157–159) and crossite (pp. 159–160) important constituents. For crossite he gives the following pleochroism and optical properties: α wine-gold, β blue, γ violet-grey; optic axial plane normal to the symmetry-plane and the angle between β of the refractive index ellipsoid and c is 16° 5′. From New Zealand, Turner[4] (p. 341) describes a closely similar amphibole from a low-grade chlorite-epidote-albite-schist, in which $\beta : c = 28°$. After a consideration of all the properties he comes to the conclusion that the mineral agrees best with crossite.

The writer wishes to thank Professor C. E. Tilley for his criticism and help in connexion with this paper.

[1] G. Murgoci, Sur la classification des amphiboles bleues et de certains hornblendes. Ibid., pp. 426–429. [M.A. 2–221.]

[2] W. Kunitz, Die Isomorphieverhältnisse in der Hornblendegruppe. Neues Jahrb. Min., Abt. A, 1930, Beil.-Bd. 40, pp. 171–250. [M.A. 4–200.]

[3] T. J. Woyno, Petrographische Untersuchung der Casannaschiefer des mittleren Bagnetales (Wallis). Neues Jahrb. Min., 1912, Beil.-Bd. 33, pp. 136–207.

[4] F. J. Turner, Metamorphism of the Te Anau Series in the region north-west of Lake Wakatipu. Trans. Roy. Soc. N.Z., 1935, vol. 65, pp. 329–349.