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

By C. Osborne Hutton, M.Sc., Ph.D., F.G.S.
Shirtcliffe Fellow of the University of New Zealand.
Department of Mineralogy and Petrology, University of Cambridge.
[Read June 9, 1938.]

This amphibole is an important constituent of an albite-epidote-actinolite-chlorite-calcite-schist 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 (+0.002) are $\alpha$ 1.635, $\beta$ 1.650, $\gamma$ 1.655; $\gamma - \alpha$ 0.020. The angle $\gamma : c = 18^\circ$, and $2V 60^\circ \pm 1^\circ$. Pleochroism follows the scheme $\alpha$ pale yellow, $\beta$ dirty bluish-green, $\gamma$ 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 $c$ 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. Using the values $2V 60^\circ$ and $\gamma : c 18^\circ$, 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 $35^\circ$.

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, though he stresses the fact that this feature is not believed to be true by many writers. Likewise Rosenbusch and Wülfing 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

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.

---

**Table:**

<table>
<thead>
<tr>
<th></th>
<th>Metal atoms</th>
<th>Metal groups</th>
<th>Ideal tremolite formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO(_2)</td>
<td>52.19</td>
<td>7.474</td>
<td>8-00 8</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>3.93</td>
<td>0.653 0.526</td>
<td>5-09 5</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>0.40</td>
<td>0.043</td>
<td></td>
</tr>
<tr>
<td>Fe(_2)O(_3)</td>
<td>4.85</td>
<td>0.516</td>
<td></td>
</tr>
<tr>
<td>FeO</td>
<td>10.73</td>
<td>1.281</td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td>trace</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>14.54</td>
<td>3.123</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>10.20</td>
<td>1.566</td>
<td></td>
</tr>
<tr>
<td>SrO</td>
<td>nil</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Na(_2)O</td>
<td>1.53</td>
<td>0.412</td>
<td>1.98 2</td>
</tr>
<tr>
<td>K(_2)O</td>
<td>0.03</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>H(<em>2)O(</em>+)</td>
<td>2.17</td>
<td>2.064</td>
<td>2.06 2</td>
</tr>
<tr>
<td>H(<em>2)O(</em>-)</td>
<td>0.02</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

100.59

**Formula:** \((\text{OH})_2(\text{Na}_2\text{Ca})_2(\text{Mg,Fe,Ti,Al})_4(\text{Si,Al})_8\text{O}_{22}\).


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 $\beta$ and has a transverse optic axial plane. The maximum extinction-angle obtained for $\beta:c = \theta^\circ \pm 2^\circ$. Owing to the small size of the nucleus and the zonary arrangement, $2V$ could not be measured with any great accuracy, but appears to be approximately $30^\circ \pm 5^\circ$. It should be pointed out that the extinction-angle of $8^\circ$ is rather greater than that usually given, but Larsen has described two crossites with $\beta:c$ about $7^\circ$ and $10^\circ$. Pleochroism is striking and follows the scheme $a$ pale mauve to colourless, $\beta$ deep blue, and $\gamma$ deep mauve; absorption $\beta > \gamma > a$. 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), and crocidolite. Murgoci 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

---

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: a wine-gold, \(\beta\) blue, \(\gamma\) violet-grey; optic axial plane normal to the symmetry-plane and the angle between \(\beta\) 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 \(\beta : c = 28^\circ\). 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.]

