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*An axinite-epidote-tourmaline vein cutting amphibolite,  
western Connemara, Eire*

A quartz-axinite-epidote-plagioclase-tourmaline vein has been found cutting amphibolite of the Ballyconneely mass to the north of Roundstone, in west Co. Galway. The veins are usually 2 to 3 cm wide, and are near, and possibly related to, a large quartz porphyry dyke. The dyke has been intruded along a fault plane, and the veins are parallel to a series of shears in the amphibolite. The intrusion of the dykes was a late phase of the main Galway Granite intrusion (see Leggo, Compston, and Leake, 1966, pp. 93-94). The country rock is a recrystallized, medium-grained, plagioclase-hornblende schist. Some quartz is present in most samples, and retrograde metamorphism has left the assemblage plagioclase-hornblende-quartz-chlorite-epidote. Veins containing much epidote material are common throughout the area, and evidence the local redistribution of material that occurred during the metamorphisms.

The axinite is a manganese-poor variety, pale clove-brown in thin section. The tourmaline and epidote are both iron-rich, and are blue-green and green respectively in thin section. The plagioclase that remains in the veins is extensively altered to a sericite-saussurite aggregate, and its composition cannot be determined by optical means. The quartz is of several generations, some appearing to be extremely late. The petrographic evidence indicates that the following mineral changes have occurred:

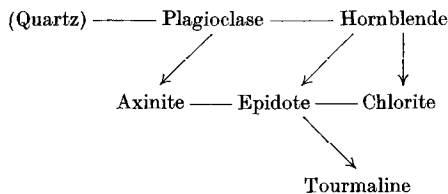


TABLE I. Analyses and optical data for hornblende (1), epidote (2), tourmaline (3), axinite (4), and altered plagioclase from Roundstone, Co. Galway, Eire

<i>Sample</i>	1	2	3	4	5
SiO <sub>2</sub>	44.18	36.25	34.43	43.32	48
Al <sub>2</sub> O <sub>3</sub>	11.51	21.77	33.49	18.71	22
TiO <sub>2</sub>	0.66	0.05	0.16	0.09	—
Fe <sub>2</sub> O <sub>3</sub>	4.30	13.69	0.24	1.38	} 9 (8.4)
FeO	13.00	1.81	12.20	6.92	
MgO	11.84	0.27	1.75	1.93	0.5
CaO	10.16	24.19	0.69	19.01	14
Na <sub>2</sub> O	1.15	0.02	2.41	0.22	3 (2.7)
K <sub>2</sub> O	0.15	0.01	0.28	0.08	0.5 (0.8)
MnO	0.28	0.54	0.32	1.26	—
P <sub>2</sub> O <sub>5</sub>	0.03	0.01	0.02	0.00	—
H <sub>2</sub> O+	2.33	1.53	3.26	1.53	1
B <sub>2</sub> O <sub>3</sub>	ND	ND	10.46	6.11	—
Total	99.59	100.14	99.71	'99.56'	98
<i>Cell contents</i>					
Si	6.4966	2.9467	5.8366	7.9351	
Al	1.9944	2.0852	6.6897	4.1338	
Ti	0.0730	0.0031	0.0204	0.0127	
Fe <sup>3+</sup>	0.4756	0.8370	0.0306	0.1946	
Fe <sup>2+</sup>	1.5982	0.1230	1.7290	1.0848	
Mg	2.5934	0.0327	0.4419	0.5391	
Ca	1.6000	2.1059	0.1253	3.8174	
Na	0.3277	0.0032	0.7918	0.0799	
K	0.0281	0.0010	0.0605	0.0191	
Mn	0.0349	0.0372	0.0459	0.2000	
P	0.0037	0.0007	0.0029	0.0000	
OH	2.2844	0.8292	3.6847	1.9127	
B	—	—	3.0585	1.9761	
<i>No of</i>					
<i>(O,OH) atoms</i>					
<i>as basis</i>	24	13	31	32	
$\alpha$	—	1.736	1.634( $\epsilon$ )	1.672	} all
$\gamma$	1.670	1.787	1.666( $\omega$ )	1.686	
$2V_{\gamma}$	66°	—	—	73°	} all
$\gamma$ : [001]	19°	—	—	—	

As in the axinite-bearing veins of the Norwegian Caledonides (Carstens, 1965, p. 401), calcite is absent. The optical properties of the hornblende in the veins are identical to those of the normal amphibolite mineral. It is probable that the plagioclase is also similar, e.g. An 30–40.

Table I gives analyses of the minerals in the veins, together with their optical properties and cell contents. The methods of Riley (1958) were used for all determinations, save for boron. This latter was determined spectrophotometrically using the absorption of crystal violet at 584  $m\mu$ .

The hornblende is from a nearby outcrop of amphibolite, but the rest are from the veins. All are corrected for impurities (never greater than 5 %), determined by grain-counting some of the analysed powder.

To follow the observed mineral changes in terms of the chemistry, it was necessary to estimate the mineral proportions in the veins. This was done by counting on a 1-mm grid interval a total of 1500 points in

TABLE II. Mode of the veins cutting amphibolite, western Connemara, and estimates of migration of the elements

<i>Element transfers</i>					<i>Mineral composition of the veins</i>
	<i>A</i>	<i>B</i>	<i>C</i>	Overall	
SiO <sub>2</sub>	-1	-3	-0.1	-4.1	Quartz 18 %
Al <sub>2</sub> O <sub>3</sub>	-0.5	+3.5	+1.4	+4.4	Plagioclase 10 %
TiO <sub>2</sub>	0	-0.1	0	-0.1	Axinite 45 %
Fe (total)	0	+0.3	-0.3	0	Epidote* 22 %
MgO	+0.3	-4	+0.2	-3.5	Tourmaline 1 %
CaO	+1	+5	-2.3	+3.7	Hornblende 4 %
Na <sub>2</sub> O	-0.7	-0.3	+0.3	-0.7	
MnO	0	+0.1	0	+0.1	
B <sub>2</sub> O <sub>3</sub>	+1.1	0	+1	+2.1	

*A* — change plagioclase to axinite.

*B* — change hornblende to epidote.

*C* — change epidote to tourmaline.

\* The figure for epidote includes some chlorite (about 40 % of the 22 %).

10 different thin sections of rock. The results, whilst not accurate, are probably representative, and are given in Table II. The composition of the altered plagioclase also had to be determined, and estimates of the amounts of alteration products were used to calculate a rough composition. The figures for sodium, potassium, and iron were then checked in the laboratory, and proved surprisingly accurate (figures in parentheses in table I are the actual determinations).

Using these derived figures and the analyses, a semi-quantitative estimate of the changes involved in the transformation of unit rock volumes can be made. The figures for the migration of elements in the various mineral changes are given in table II, together with the total change. Over-all, silica, magnesium, and sodium were released into the rock, and boron, calcium, and aluminium taken up. If a closer approximation to the rock composition is made, by the substitution of chlorite for about 40 % of the epidote, the figures for silica, aluminium, calcium, and magnesium are reduced to about one-third of their given values. It is probable that all of the adjusted figures are within the error of the calculations, with the exception of boron. Some silica may have been

released into the rock, accounting for the late quartz, and some of the alteration of the plagioclase may date from this time.

The localization of the boron metasomatism argues a non-ionic method of introduction, since the rock on either side of the vein is identical to that originally occupying the position of the introduced material. A boron-bearing hydrothermal solution, limited to the easy passages afforded by the shear zones, explains the occurrence better. The ultimate origin of the hydrothermal solution was probably the Galway Granite.

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### *Etching of baryte*

THIS communication reports some microtopographical observations on the etching of natural and synthetic baryte crystals; as far as the authors are aware, little has been reported on the dissolution phenomena of these crystals.

Natural baryte crystals were cleaved along (001) and examined under a Vickers projection microscope after depositing silver over them by the thermal evaporation technique. They were then etched in cold conc.  $H_2SO_4$  for a few minutes. Figs. 1 ( $\times 170$ ) and 2 ( $\times 360$ ) represent a photomicrograph and a light-profile picture (Tolansky, 1952) respectively of a lightly etched cleaved surface. The etching has developed three sets of parallel lines over the whole surface, representing the intersection of  $d\{102\}$ ,  $m\{110\}$ , and  $O\{011\}$  with the cleavage plane (fig. 1); similarly oriented etch pits appear in all the three sets. At a higher magnification (fig. 2) it is seen that these alternately raised and depressed lines are crossed by more widely spaced bands at which the elevation changes abruptly; no regularity in these changes of elevation, or in the depths of the lines themselves, could be found. This is revealed by a histogram (not shown) constructed from measurements. A close