Gyrolite and reyerite from 'S Airde Beinn, northern Mull

J. R. CANN, M.A., Ph.D.

Department of Mineralogy and Petrology, Cambridge

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Summary. Reyerite is found in close association with gyrolite in the metamorphic aureole of the volcanic plug of 'S Airde Beinn, northern Mull, and has apparently been formed by metamorphism of the gyrolite. The gyrolite, with a composition close to $Ca_{16}Si_{24}O_{60}(OH)_8.14H_2O$, closely approaches trigonal symmetry with a 9.76 ± 0.02 Å and c $3 \times 22.26 \pm 0.1$ Å; biaxial with a small 2V and α 1.537, β 1.547, γ 1.549. The reyerite is trigonal with a 9.76 ± 0.02 Å, c 19.10 ± 0.04 Å and space group $P\bar{3}$; ω 1.568 and ϵ 1.563, and the unit cell contains about 14 atoms of Ca, 24 of Si (with some substitution by $4(OH)^-$), and $14H_2O$ as $(OH)^-$ and H_2O.

GYROLITE and reyerite have been found closely associated in plateau basalts near the volcanic plug that forms the hill of 'S Airde Beinn, 3 miles west of Tobermory, Isle of Mull, Scotland.

The gyrolite fills amygdales in the basalts just outside the aureole of the plug at the north end of the hill, and is seen as radiating aggregates of colourless plates of high birefringence associated with analcime, thomsonite, and natrolite. The reyerite is found a few yards away just within the metamorphic aureole of the plug. It forms coarse pale-green radiating aggregates of plates of low birefringence filling amygdales and associated with the same zeolites as the gyrolite. The field relations indicate that it has been formed by mild metamorphism of the gyrolite, and it seems probable that this is also the origin of the reyerite of the type locality, at Niakornak in Greenland, where it is found in amygdales in blocks in a tuff pipe (Cornu, 1906; Bøggild, 1908). This origin is compatible with the experimental work of Roy and Harker (1962), although Meyer and Jaunarajs (1961) consider that such a relationship is not possible. At higher grades of metamorphism, wollastonite has replaced the reyerite; xonolite, which the experimental work shows to be formed intermediate between reyerite and wollastonite, was not found.

Gyrolite. The gyrolite is optically negative with a small 2V: refractive indices are α (normal to the perfect cleavage) 1.537, β 1.547, γ 1.549

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and the density is 2·40. Laue photographs indicate that the symmetry closely approaches trigonal (Laue group $\bar{3}m$) but there were distinct divergences from this in relative intensities of related spots. Oscillation photographs with the trigonal a-axis as oscillation axis showed a repeat of 9·76±0·02 Å, and the closeness of spots along the layer lines indicated a considerable spacing along the trigonal c-axis. However, oscillation photographs with the trigonal c-axis as oscillation axis were difficult to interpret; spots showed considerable streaking both in directions of constant ξ and constant θ, a typical spot having a dark nucleus somewhat elongate along constant θ, with fainter extensions along lines of constant ξ. Such effects indicate considerable disorder in the direction of the trigonal c-axis. Using the intense centres of the spots only, it was possible to interpret the photographs in terms of a 67 Å c-axis repeat, but it is possible that the same effects might be given by a mixed layer structure. A diffractometer trace, with the inevitable preferred orientation induced by a perfect basal cleavage, showed strong peaks corresponding to basal spacing of 22·26±0·04 Å, suggesting that the structure is made up of layers of this thickness (as has also been observed by other workers, Mackay and Taylor, 1952, and Strunz and Micheelson, 1958), and if this evidence is combined with that from the oscillation photographs, it suggests strongly that the unit cell is made up of three such layers of relatively low symmetry stacked to give a trigonal structure. However, the undoubted presence of frequent stacking mistakes, responsible for the streaking of the spots, the departures from trigonal Laue symmetry and the biaxial nature of the mineral, make it difficult to sustain this interpretation in detail. It is noteworthy, however, that the gyrolite studied by Mackay and Taylor (1952) had a six-layer unit cell and was hexagonal, so that there is a strong possibility that stacking polytypes may be found in gyrolite in close analogy to those of the micas.

The chemical analysis and unit-cell contents (calculated for a single 22·26 Å layer from the measured density) of the gyrolite from 'S Airde Beinn are given in table I. In the single-layer unit cell, after taking sufficient Al to make (Si+Al) equal to 24, the sum of the remaining cations is close to 16 and water is close to 18 molecules, and this distribution corresponds closely with that of other natural gyrolites (Mackay and Taylor, 1952; Christie, 1925). The dehydration work of Mackay and Taylor (1952) suggests that approximately one quarter of the water is present as (OH)$^-$, so that the ideal formula for gyrolite must be close to $Ca_{16} \cdot Si_{24}O_{60}(OH)_8 \cdot 14\ H_2O$.

Alkalis do not play a significant part in the composition of the gyro-lite from 'S Airde Beinn, and Na is more abundant than K, suggesting substitution in the Ca sites rather than the existence of a separate alkalis site.

Reyerite. The reyerite from 'S Airde Beinn is uniaxial negative with a perfect basal cleavage. Refractive indices measured were ω 1·568, ϵ 1·563 and density 2·57$\pm$0·01. X-ray photographs show none of the

TABLE I. Chemical composition and empirical unit-cell contents of gyrolite (1, 1a) and reyerite (2, 2a) from 'S Airde Beinn, Mull

	1	2		1a		2a	
SiO_2	50·60	51·35	Si	22·04	} 24	20·63	} 22·52
Al_2O_3	5·54	4·00	Al	2·84 {1·96 / 0·88		1·89	
Fe_2O_3	0·41	0·41	Fe	0·14		0·13	
MgO	1·98	1·31	Mg	1·28	} 16·38	0·78	} 15·32
CaO	28·54	30·92	Ca	13·32		13·31	
Na_2O	0·67	0·42	Na	0·57		0·33	
K_2O	0·35	1·32	K	0·19		0·68	
H_2O+	7·74	6·80	O	63·53		58·89	
H_2O-	4·60	3·60	H_2O+	11·24		9·11	
CO_2	nil	nil	H_2O-	6·68		4·82	
SO_3	nil	nil					
	100·43	100·10	$\sum$ (O,OH)	81·45		72·82	

disorder of the gyrolite; the Laue group is $\bar{3}$, and as there are no systematic absences the space group is either $P3$ or $P\bar{3}$. Intensity statistics on $(h0\bar{h}l)$ reflections carried out by Dr. E. J. McIver strongly suggest the presence of a centre of symmetry, so that the space group is probably $P\bar{3}$. The unit-cell dimensions are a 9·76 + 0·02 Å, c 19·10 + 0·02 Å. a was determined from oscillation photographs and c was initially determined approximately also from oscillation photographs, but was refined by measuring the spacing between 0005 and 0006 reflections on a dif-fractometer trace. The data agree well with those of Chalmers *et al.* (1964) for reyerite from the type locality at Niakornak in Greenland.

Columns 2 and 2a of table I give the chemical analysis and the unit cell contents calculated from the measured density for the reyerite. The composition agrees well with that of the reyerite from the type locality (Chalmers *et al.*, 1964; Bøggild, 1908) except that the water content is much higher. As it was feared that the water content of the separated material might have been increased by absorption during separation, another determination was made on large hand-picked fragments of pure

reyerite, but this agreed closely with the original determination, so that the high content of water must be real.

The unit-cell contents show a deficiency of about $1\cdot5$ atoms of $(Si + Al)$ from the expected 24 (there are six general positions in $P\bar{3}$ so that the Si content would be expected to be a multiple of six). If the analysis is recalculated to 24 $(Si + Al)$ the calculated density is found to be impossibly greater than that measured, and it is probable that there is a substitution of 4 $(OH)^-$ for SiO_4^{4-} in a similar manner to that postulated for the Greenland reyerite (Chalmers et al., 1964), though to a far greater extent.

The distribution of alkalis and alumina is rather different from that of the Greenland reyerite. In the reyerite from 'S Airde Beinn $(Na + K)$ is nearly equal to 1, and Na is much less than Al (for the Greenland reyerite, $K \approx 1$ and $Na \approx Al$). In this case, then, the alkali site postulated by Chalmers et al. (1964) seems to be filled by $(Na + K)$, and the substitution of Al perhaps compensated by substitution of $(OH)^-$ for $O^=$. In general, though, the unit-cell contents show a great resemblance to those of the Greenland reyerite, and the similarity is reinforced by the similarity of the infra-red absorption spectra (Chalmers et al., 1964 compare results obtained from the 'S Airde Beinn reyerite with those for the Greenland material).

It is perhaps interesting to note in passing that this is the second recorded natural occurrence of reyerite, if the separate identity of truscottite postulated by Chalmers et al. (1964) is upheld.

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