co-exists with no sulphide other than pentlandite. It is sparsely distributed, never exceeding 0.25 per cent in amount. It is thought to have formed as a result of reaction between sulphur and nickel in the silicates of the peridotite. This problem, together with the implications that this and other data obtained in this study of nickel deposits of the Porcupine have on the genesis of the deposits are the subject of a forthcoming paper.

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X-RAY CRYSTALLOGRAPHY OF AURICHALCITE AND HYDROZINCITE

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Although both aurichalcite, $(Zn,Cu)_5(CO_3)_2(OH)_6$, and hydrozincite, $Zn_5(CO_3)_2(OH)_6$, contain zinc as the dominant cation and are otherwise chemically similar, they do not form a solid solution series. The range of copper substitution in aurichalcite is rather limited, and the composition does not closely approach that of a theoretically possible zinc end-member. On the other hand, hydrozincite, which is crystallographically and mineralogically distinct from aurichalcite, does not contain significant amounts of copper (Palache *et al.*, 1951, p. 247).

Aurichalcite, $(Zn,Cu)_5(CO_3)_2(OH)_6$

Frondel & Wolfe (Palache *et al.*, 1951, p. 250) tentatively assigned to aurichalcite from Magdalena, New Mexico, an orthorhombic *A*-centered cell with $a = 6.40$, $b = 27.78$, $c = 5.25$ kX. Shimazaki (1957), on the basis of *c*-axis Weissenberg photographs of material also from Magdalena, New Mexico, reported cell dimensions of $a = 6.45$, $b = 13.60$, $c = 5.27$ Å, space group *Pmma*. However, all lines of the powder pattern cannot be satisfactorily indexed with this cell and space group.

In the present study, Weissenberg and precession examination of

aurichalcites from Magdalena, New Mexico, Hayden, Arizona, and Mapimi, Durango, Mexico has confirmed the A-centered cell established by Frondel & Wolfe. However, in order to facilitate comparison and emphasize the similarity to hydrozincite, a and b have been interchanged. The newly determined cell dimensions are:

$$a = 27.2 \pm 0.1 \text{ Å}$$
$$b = 6.41 \pm 0.02 \qquad V = 921 \text{ Å}^3$$
$$c = 5.29 \pm 0.03 \qquad \text{Space group } B22_12$$

X-ray powder data for aurichalcite from Mapimi, Mexico are given in Table 1. The cell dimensions given in Table 1, and a Zn:Cu ratio of

TABLE 1. X-RAY POWDER DATA FOR AURICHALCITE FROM MAPIMI, DURANGO, MEXICO

Nickel-filtered copper radiation; 114 mm. camera. Indexing based on $a = 27.1$, $b = 6.40$, $c = 5.29$ Å, space group $B22_12$

I	d_{meas}	d_{calc}	hkl	I	d_{meas}	d_{calc}	hkl
10	6.78 Å	6.80 Å	400	2	2.42	2.41	911
						2.41	212
½	5.77	5.79	210	1	2.33	2.33	820
½	5.17	5.19	101	1	2.29	2.28	602
½	4.64	4.65	410	2	2.23	2.24	721
						2.23	11.0.1
½	4.52	4.52	600	2	2.145	2.150	612
½	4.02	4.03	111	½	2.111	2.109	11.1.1
						2.107	230
1	3.77	3.79	501	½	2.092	2.085	802
7	3.68	3.69	610	½	2.038	2.039	022
						2.035	430
½	3.38	3.39	800	½	2.019	2.016	222
3	3.25	3.26	511	½	1.977	1.973	131
2	3.19	3.20	020	1	1.951	1.952	422
2	3.11	3.12	701	1	1.929	1.929	630
½	2.99	2.99	810	½	1.887	1.893	10.0.2
4	2.89	2.89	420	½	1.856	several possibilities	
3	2.81	2.81	711	4	1.827	1.831	11.2.1
4	2.72	2.72	121	½	1.764	1.762	731
		2.71	10.0.0				
8	2.61	2.62	321	½	1.750	1.747	822
		2.62	901				
		2.61	620	½	1.713	1.710	15.0.1
		2.60	202				
1	2.50	2.50	10.1.0	1	1.694	1.694	16.0.0
						1.697	113
2	2.47	2.46	402				

I	d_{meas}	I	d_{meas}	I	d_{meas}	I	d_{meas}
½	1.675 Å	1	1.560 Å	½	1.434 Å	½	1.345 Å
4	1.656	1	1.544	1	1.421	½	1.335
½	1.635	½	1.525	½	1.405	½	1.317
½	1.619	1	1.510	1	1.381	½	1.306
2	1.601	1	1.488	½	1.368		

2.4:1 determined by x-ray spectrography, yield a calculated specific gravity of 3.94 assuming $Z = 4$. The measured value, obtained by suspension in Clerici solution, is 3.96 ± 0.03.

Examination of fine lath-like aurichalcite crystals from Mapimi with the optical goniometer indicates that the prominent {100} form is associated with {$hk0$} and {$h0l$} which, on the basis of the measured angles, are presumably {410} and {501} respectively. Minute {hkl} or {$0kl$} faces are also present but are much too small to be clearly observed. The {100} zone of many crystals has fine, closely-spaced, parallel striations parallel to the trace of (001); in some crystals these are combined with striations parallel to the trace of (010), yielding an extremely fine grid pattern which corresponds to very good (010) and (100) cleavages. The reported perfect (100) cleavage could not be verified.

Hydrozincite, $Zn_5(CO_3)_2(OH)_6$

Ramsdell's (1947) examination of hydrozincite crystals from Goodsprings, Nevada by the Weissenberg method established that the mineral is monoclinic, with $a = 13.452$, $b = 6.307$, $c = 5.355$ kX, $\beta = 95°30'$, space group $C2/m$, Cm, or $C2$. Ghose's (1964) structure determination has shown the space group to be $C2/m$.
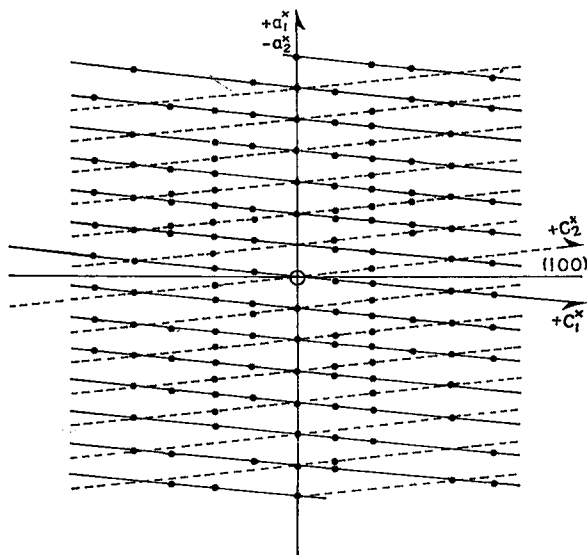

FIG. 1. Dot copy of zero level b-axis precession photograph of hydrozincite from Goodsprings, Nevada. Main crystal is no. 1 (full lines); twin crystal is no. 2 (dashed lines).

TABLE 2. X-RAY POWDER DATA FOR HYDROZINCITE FROM GOODSPRINGS, NEVADA

Nickel-filtered copper radiation; 114 mm. camera. Indexing based on $a = 13.58$Å, $b = 6.28$, $c = 5.41$, $\beta = 95° 35'$, space group $C2/m$

I	d_{meas}	d_{calc}	hkl	I	d_{meas}	d_{calc}	hkl
10	6.77 Å	6.76 Å	200	$\frac{1}{2}$	2.394 Å	2.396 Å	112
$\frac{1}{2}$	5.71	5.70	110	1	2.336	2.336	$\bar{5}$11
1	5.37	5.38	001	2	2.301	2.300	420
2	3.99	3.99	$\bar{1}$11	$\frac{1}{2}$	2.253	2.253	600
$\frac{1}{2}$	3.81	3.83	111	1	2.213	2.213	$\bar{4}$02
4	3.66	3.66	310	$\frac{1}{2}$	2.177	2.182	511
$\frac{1}{2}$	3.37	3.38	400	$\frac{1}{2}$	2.086	2.091	312
5	3.14	3.15	$\bar{3}$11	1	2.064	2.066	421
		3.14	020	$\frac{1}{2}$	2.041	2.044	022
1	3.00	3.00	401	$\frac{1}{2}$	2.006	2.010	601
2	2.92	2.92	311	$\frac{1}{2}$	1.944	1.941	$\bar{1}$31
3	2.85	2.85	220		1.915	1.917	222
1	2.74	2.74	401	3		1.912	$\bar{5}$12
6	2.72	2.71	021		1.902	1.898	330
2	2.69	2.69	002	1	1.842	1.846	710
1	2.58	2.59	$\bar{2}$02				
7	2.480	2.483	510				
		2.476	221				

I	d_{meas}	I	d_{meas}	I	d_{meas}	I	d_{meas}
1	1.814 Å	$\frac{1}{2}$	1.646 Å	$\frac{1}{2}$	1.521 Å	1	1.368 Å
2	1.774	$\frac{1}{2}$	1.609	$\frac{1}{2}$	1.498	$\frac{1}{2}$	1.359
$\frac{1}{2}$	1.745	2	1.573	2	1.466	1	1.345
4	1.688	1	1.559	$\frac{1}{2}$	1.451		
1	1.657	$\frac{1}{2}$	1.547	1	1.401		

The present study of hydrozincite crystals from Goodsprings, Nevada by Weissenberg and precession methods has confirmed the unit cell dimensions and space group established by Ramsdell. However, all four crystals studied yielded single crystal photographs with several spots additional to those required by the diffraction symmetry. These spots, which also appear on the Weissenberg films made available to us by Ghose, are particularly evident on b-axis precession photographs where they occur on most rows of spots where l is not 0, 4, 8, etc. When trying to index the photographs, these anomalous spots introduce extra extinctions in the $h00$ type of reflections and lead to (1) replacement of the recognized C-centering by a pronounced pseudo B-centering, (2) doubling of the a-axis to 27Å, as in aurichalcite.

The anomalous spots can be explained as due to the twinning about (100) of the normal, C-centered hydrozincite cell (figure 1). The twinning brings out the "dimensional specialization" (Buerger, 1960, p. 54) of the hydrozincite cell: $lc^* \sin (\beta^* - 90°) = l(a^*/4)$, so that with $l = 4$, 8, etc., twinning on (100) brings about a perfect registry of spots from the twinned crystal onto the main crystal.

Because of the prominent blade-like habit of hydrozincite and the fact that the XZ optic plane almost coincides with the thin (100) plane ("blade plane") of the crystals, it is not possible to observe the twinning under the petrographic microscope. However, the twinning interpretation is though to be well supported by (1) the variation in intensities of the reflections from the two individuals from specimen to specimen, (2) the excellent specialization of the lattice as explained above, (3) the fact that the relative intensity of corresponding reflections from the main lattice and twin lattice is constant for any one crystal, and (4) the fact that *all* the anomalous spots can be related to the C-centered lattice by reflection across (100).

Dimensions of the C-centered cell and indexed powder data are given in Table 2. Clerici suspension of the Goodsprings crystals gave a specific gravity of 4.00 ± 0.03, in good agreement with the calculated value of 3.97 based on $Z = 2$.

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