THE

AMERICAN JOURNAL OF SCIENCE.

FOURTH SERIES

VOL. L—[WHOLE NUMBER, CC].

NEW HAVEN, CONNECTICUT.

1920.

ART. XVI.—*Some Minerals of the Melanterite and Chalcanthite Groups with optical data on the hydrous sulphates of manganese and cobalt;*[1] by ESPER S. LARSEN and M. L. GLENN.

Zinc-copper Melanterite and other members of the Melanterite Group.

Introduction.—During the summer of 1916 one of the authors (E. S. L.) found a secondary mineral in considerable amount in the dumps of the Good Hope and Vulcan mines at Vulcan, Gunnison county, Colorado. The mines are on a great body of sulphides made up chiefly of pyrite with some chalcopyrite and sphalerite. The proportion of the constituents, especially the sphalerite, varies greatly in different bands of the ore. Thin seams of quartz carrying gold and tellurium are present on the walls of the sulphide body. The dumps carry thousands of tons of this sulphide, in part massive, in part friable and sandy in texture. Many of the interstices between the fragments on the dumps are filled with a green, columnar mineral which on study in the laboratory proved to be a new member of the melanterite group, which carries about equal amounts of copper and zinc and a little iron; the name zinc-copper melanterite is proposed for the mineral.

In adopting a name for this mineral as well as in adopting the names for the chalcanthite-like dehydration products of the members of the melanterite group, the authors at first planned to follow the suggestion of Washington[2] and to designate the various members of the groups by prefixes to the group names, melanterate and chalcanthate. However, as there were so many objections from all the mineralogists who were consulted and as it seemed probable the names would not be accepted and confusion would result, the plan was adopted of using the usual group name with the principal metals present prefixed to it. Accordingly, the melanterites are minerals with the general composition $RO.SO_3 . 7H_2O$; they are monoclinic and their properties are related to those of the common mineral melanterite. Zinc-copper melanterite is a melanterite in which R is chiefly Zn and Cu with Zn predomi-

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[1] Published with permission of the Director of the U. S. Geol. Survey.

[2] Washington, Henry, S.; A suggestion for mineral nomenclature, this Journal, vol. 33, pp. 137-151, 1912.

nating molecularly. Copper-zinc melanterite would have Cu predominating molecularly. To be precise, for zinc melanterite the molecular ratio ZnO to CuO should be greater than 3 to 1, for zinc-copper melanterite that ratio should be between 3 to 1 and 1 to 1, for copper-zinc melanterite between 1 to 1 and 1 to 3, and for copper melanterite the ratio should be less than 1 to 3. Similarly the chalcanthites are minerals with the general composition $RO.SO_3.5H_2O$, they are triclinic and their properties are related to those of the common mineral chalcanthite. In both groups the various members are similar in all their physical properties, notably in their optical properties.

If the unsystematic procedure of giving each species a distinct name without regard to its relations to other minerals had been followed out in the present paper six new mineral names would be required for six relatively unimportant minerals and it is probable that in both groups there are many more members. If independent names are given to all the members of both groups very few mineralogists would find it worth the effort to remember the significance of the various names, but if Washington's suggestion, or some modification of it, is carried out for the groups every mineralogist should know the composition and group relations of any member from its name. It is sincerely to be hoped that mineralogists will soon adopt a systematic nomenclature.

Physical properties.—Zinc-copper melanterite is pale greenish-blue (calamine blue 43d of Ridgways[3] color standards). It has a vitreous luster, a hardness of about 2, and a specific gravity as determined by matching in a heavy solution of 2.02. It fuses readily with intumescence at about 1 to a white froth which on high heating turns black; on rapid heating it decrepitates violently. It colors the flame green. It loses water in a dry room as will be shown in a succeeding paragraph. It is readily soluble in water.

Under the microscope it is seen to consist of very pale blue-green rods not sensibly pleochroic and nearly a millimeter across and several millimeters long. The indices of refraction were measured by matching in oils and immediately measuring the indices of refraction of the oils, and the following values should not be in error more than 0.001; $\alpha = 1.479$, $\beta = 1.483$, $\gamma = 1.488$. The mineral

[3] Ridgeway, Robert. Color Standards and Nomenclature, 1912.

is optically positive, 2 V is near 90°, and the dispersion of the optic axis is slight. The fibers are imperfect and measurements of extinction angles gave inconsistent results. Several sections nearly normal to X and perhaps lying on a cleavage face gave extinction angles, Y to the elongation, of about 34°. The mineral is probably monoclinic and Y to the elongation is large.

The principal optical properties of zinc-copper melanterite, goslarite, pisanite, and bieberite are given in Table I for comparison. In optical properties zinc-copper melanterite is very similar to pisanite, but it has a somewhat lower birefringence; it has a different color and a somewhat lower birefringence than melanterite and bieberite. Goslarite is distinctly different from the others and obviously belongs to a different group. The monoclinic form corresponding in composition to goslarite has not been described.

TABLE I. *Optical properties of members of the melanterite group and of goslarite.*

	Zinc-copper melanterite	Pisanite[a]	Melanterite	Bieberite[a]	Goslarite
Crystal System	Mon.?	Mon.	Mon.	Mon.	Orth.
Color	pale greenish blue	pale blue	pale green	Carmine	colorless
Opt. character	+	+	+	—	—
2V	near 90°	very large	86	near 90°	46
Dispersion	$\rho > v$ perc ?	$\rho > v$ perc?	$\rho > v$ perc.	slight	$\rho < v$ slight
α	1·479	1·472	1·471	1.477	1 457
β	1·483	1·479	1·478	1·483	1·480
γ	1·488	1·487	1.486	1·489	1·484
γ-α	·009	·015	·015	·012	·020

[a] Unpublished data on artificial mineral by E. S. Larsen.

Chemical analysis.—The zinc-copper melanterite selected for analysis showed under the microscope a little admixed chlorite and sulphides and about 1 or 2 per cent of zinc-copper chalcanthite. The result of an analysis of the water soluble portion of this sample by M. L. Glenn is shown in Table II. The formula derived from this analysis is $(Zn,Cu,Fe)O.SO_3 . 7H_2O$ in which Zn : Cu : Fe : : 100 : 98 : 19. The analysis fits the formula very well except for the water and it is probable, as will be shown later, that the mineral had partly dehydrated to zinc-copper chalcanthite between the time it was examined microscopically and the time it was analyzed.

TABLE II. *Analysis and molecular ratios of zinc-copper melanterite from the dump of the Good Hope Mine, Vulcan, near Gunnison, Colo., by M. L. Glenn.*

CuO	12.37	156	1 × .98
ZnO	12.89	158	
FeO	2.14	30	
SO_3	28.78	360	1 × 1.02
H_2O	42.61	2365	7 × .96
Insol.	1.11		
	99.90		

The Chalcanthite Group.

Zinc-copper melanterite loses water rapidly in dry air and alters to a fine, homogeneous aggregate of a mineral that has optical properties very near those of chalcanthite, and it must be the zinc-copper equivalent of chalcanthite. A small amount of the fine powder left from the analysis of the zinc-copper melanterite and kept in a room two months during the winter was completely altered. The sample contained 35.0 per cent H_2O while the compound with $5H_2O$ should theoretically contain 36.1 per cent H_2O. The resulting product is a pale blue, finely crystalline aggregate which is apparently homogeneous and which has the optical properties given in column 1 of Table III. In column 2 the properties of chalcanthite are given for comparison; in column 3 the properties of an iron-copper chalcanthite derived from the dehydration of artificial pisanite; in column 4 the properties of the siderotil derived from the dehydration of melanterite; in column 5 those of artificial cobalt chalcanthite; and in column 6 those of artificial manganese chalcanthite.

TABLE III. *Optical properties of members of the chalcanthite group.*

	Zinc-copper chalcanthite	Chalcanthite	Iron-copper chalcanthite[a]	Siderotil[a]	Cobalt chalcanthite[a]	Mangan chalcant
Color	pale blue	Berlin blue	pale green	white	rose pink	pale pi
Opt. character	—	—	—	—	—	—
2V	mod.	56°	mod.	rather large	med.	med. la
Dispersion		slight	$\rho > v$ slight	$\rho > v$ weak	not stg.	
α	1·513	1·516	1·517	1·526	1·530	1·495
β	1·533	1·539	1·536	1·536	1·548	1·508
γ	1·540	1·546	1·543	1·542	1·550	1·514
γ-α	·027	·030	·026	·016	·020	·019

[a] Unpublished manuscript by E. S. Larsen.

The probable error of the indices of refraction should be less than ± 0.003; zinc-copper chalcanthite, iron-copper chalcanthite, and chalcanthite are very similar optically, but differ slightly in color; the other members of the chalcanthite group can be readily distinguished by their color and optical properties.

Boothite dehydrates to chalcanthite as a specimen so labeled, kindly furnished the author by Colonel Roebling, had the optical properties of chalcanthite. Pisanite dehydrates readily as four specimens so labeled proved on microscopic examination to have changed to iron-copper chalcanthite; artificial pisanite alters rather rapidly to pentahydrate. Melanterite, either natural or artificial, is commonly coated with a white powder of siderotil and the fine powder will dehydrate after standing for some months to the pentahydrate; siderotil is nearly as common a mineral under surface conditions as melanterite and has been found in a number of specimens sent in to the author (E.S.L) from the field. Two museum specimens labelled bieberite proved on optical study to have changed to cobalt chalcanthite. A specimen labelled mallardite had apparently altered to an uncertain lower hydrate.

On standing for a few days at about 45° zinc-copper chalcanthite loses water and alters to a white powder made up of an aggregate of minute fibers with the following indices of refraction:

$\alpha = 1.60 \pm 0.01$, parallel to the fibers. $\gamma = 1.656 \pm 0.01$

The hydrous Sulphates of Cobalt.

Artificial "cobalt sulphate" from the stock bottle in the chemical laboratory of the U. S. Geological Survey is made up of blue, vitreous crystals that are uniaxal—, and very faintly pleochroic in pale pink with $\omega = 1.495 \pm 0.003$, $\epsilon = 1.460 \pm 0.003$. This form also crystallized from a solution of $CoSO_4$ at 45°. A water determination on material from the stock bottle gave 40.7 per cent. and the material is no doubt $CoSO_4.6H_2O$, which should have 41.1 per cent water and is said to crystallize from a water solution at from 40 to 50° C.

It dehydrates rather rapidly on exposure to air to a finely crystalline, pale rose pink (Ridgways 71 f) powder which has the following optical properties and is the pentahydrate: Opt.—, 2V medium, dispersion not strong, faintly pleochroic.

$\alpha = 1.531 \pm 0.003$. Eosine-pink (1 d)
$\beta = 1.549 \pm 0.003$.
$\gamma = 1.552 \pm 0.003$. Pale rose-pink (71 f)

A mineral specimen labelled bieberite (cobalt melanterite) Bieber, Hesse, kindly furnished the authors by Col. Roebling of Trenton, New Jersey, is a very finely crystalline, rose red coating; and has the following optical properties: pale rose in section, opt. —, 2V medium,

$\alpha = 1.523 \pm 0.003$. $\beta = 1.542 \pm 0.005$. $\gamma = 1.547 \pm 0.005$.

It is probably the pentahydrate, cobalt chalcanthite, and was derived from the dehydration of bieberite.

In a desiccator over H_2SO_4 the $CoSO_4 . 6H_2O$ alters in a few days to a mixture made up of about 80 per cent of a pale rose-pink, porous pentahydrate and 20 per cent of small red crystal aggregates of the monohydrate. The monohydrate is in drusy crystals on the surface and in the pores of the pentahydrate. The optical properties of the pentahydrate are: Opt.—, 2V medium, dispersion not strong, faintly pleochroic.

$\alpha = 1.529 \pm 0.003$, eosine-pink (1 d)
$\beta = 1.546 \pm 0.003$.
$\gamma = 1.548 \pm 0.003$, pale rose-pink (71 f)

A gram of the pale rose-pink material was hand picked for water determination and gave 33.3 H_2O. The microscope showed that the analyzed powder contained approximately 10 per cent of the monohydrate. This would give 35.9 per cent H_2O for the pure material. The pentahydrate should contain 36.7 per cent H_2O and the rose pink material is probably the pentahydrate.

The monohydrate crystals formed with the pentahydrate have the following optical properties: Opt.—, 2V near 90. Inclined extinction.

$\alpha = 1.603$. $\beta = 1.639$. $\gamma = 1.683$.

A water determination gave 11.0 per cent H_2O and shows that the crystals are the monohydrate, which should contain 10.4 per cent H_2O.

A solution of $CoSO_4$ either slightly acidified with H_2SO_4) or not and evaporated to dryness on a steam bath gave an amaranth pink (Ridgways 69 d) powder made up of very minute crystalline spherulites and fibers with the following optical properties: $\alpha = 1.600 \pm 0.005$, $\gamma = 1.645 \pm 0.1$, elongation negative. The monohydrate is said to form under these conditions and a water determination on the material gave 12.2 per cent and indicates the monohydrate which theoretically contains 10.4 per cent H_2O. Material precipitated by slowly pouring a concentrated solution of $CoSO_4$ into concentrated H_2SO_4 was no doubt the same though it was not entirely homogeneous and γ appeared to be a little lower. This is probably also the monohydrate although the tetrahydrate is said to form when the solution is poured into H_2SO_4.

The optical properties of the monohydrate formed with the pentahydrate in a desiccator are sufficiently different from the properties of the monohydrate crystallized on a water bath, although the latter is too finely crystalline for accurate measurements to justify the conclusion that there are two forms of that hydrate.

$CoSO_4$ crystallized from a solution at 23°C in a desiccator under reduced pressure was in aggregates of carmine colored (Ridgway 1-i), tabular crystals with the following optical properties: Opt.—, 2V near 90°, dispersion slight.

$$\alpha = 1.477 \pm 0.003. \quad \beta = 1.483 \pm 0.003. \quad \gamma = 1.489 \pm 0.003.$$

The heptahydrate is said to be formed under these conditions; a water determination on this material gave 44.8 per cent and the theoretical water content of the heptahydrate is also 44.8 per cent. The optical properties are similar to those of the members of the melanterite group and the material is artificial bieberite.

The hydrous Sulphates of Manganese.

Artificial "manganese sulphate" from the stock bottle of the U. S. Geological Survey is made up of two forms: pale pink, glassy crystals which are largely altered to nearly white aggregates of minute crystals. The glassy crystals have the following optical properties: Opt.—, 2V moderately large.

$$\alpha = 1.511 \pm 0.003. \quad \beta = 1.519 \pm 0.003. \quad \gamma = 1.521 \pm 0.003.$$

A determination of the water in this material gave 31.5 and indicates the tetrahydrate which theoretically contains 32.3 per cent H_2O. This form was crystallized from solution at 45° and was formed from the alteration of the pentahydrate.

The nearly white alteration product in the stock bottle is optically +, 2V is near 90°.

$$\alpha = 1.562 \pm 0.003. \quad \beta = 1.595 \pm 0.003. \quad \gamma = 1.632 \pm 0.003.$$

A water determination on this material gave 10.85 per cent and indicates the monohydrates which theoretically contains 10.66 per cent H_2O.

$MnSO_4$ crystallized from solution in a desiccator under reduced pressure at 23° C was in well formed tabular crystals that gave inclined extinction when on the flat face or on edge and are no doubt triclinic. Y is nearly normal to the laths and crystals lying on the flat face give an extinction of Z′, length 15° ± 1°. They are optically—, 2V is rather large, and the dispersion is slight.

$\alpha = 1.495 \pm 0.003$. $\beta = 1.508 \pm 0.003$. $\gamma = 1.514 \pm 0.003$.

Carefully selected crystals wiped dry on filter paper were analyzed and gave 38.1 per cent H_2O, while the theoretical value for $MnSO_4 . 5H_2O$ is 37.4.

It alters slowly on standing to a form that is opt. —, 2V moderate.

$\alpha = 1.513 \pm 0.003$. $\beta = 1.520 \pm 0.003$. $\gamma = 1.522 \pm 0.003$.

This is probably the same as the glassy form of the original sample.

Crystals formed at 45° C and drained from the solution are imperfect laths. Lying on the flat face they appear to give parallel extinction with X nearly normal to the flat face and Z parallel to the length; turned on edge they give extinction Z elongation 5°. They are probably monoclinic, tabular parallel to (100), and elongated along c. $Y = b$ and $Z \wedge c = 5°$. They are optically—, 2V is rather large.

$\alpha = 1.509 \pm 0.003$. $\beta = 1.518 \pm 0.003$. $\gamma = 1.522 \pm 0.003$.

This is probably the tetrahydrate and is like the form of the original sample.

A solution evaporated on a water bath gave a very pale pink powder made up of aggregates of minute fibers with the following optical properties: Opt. — (?), 2V large, probably monoclinic with $Z = b$, Y to elongation varies with color of light and gives abnormal interference colors.

$\alpha = 1.560 \pm 0.003$. $\beta = 1.592 — 0.005$. $\gamma = 1.627 \pm 0.005$

A water determination of this gave 11.2 per cent and shows that it is the monohydrate which should contain theoretically 10.75 per cent. This is the same as the alteration product in the original sample.

Natural szmikite ($MnSO_4 . H_2O$) from Felsöbanya, Hungary[1] is a nearly white chalky aggregate of very minute fibers or plates, probably monoclinic with Z = b.

$$\alpha = 1.57 \pm 0.01. \quad \gamma = 1.62 \pm 0.01.$$

The optical properties of the hydrous sulphates of cobalt and manganese are tabulated in Table IV.

TABLE IV. *Optical properties of the hydrous sulphates of cobalt and manganese.*

	MnSO$_4$ 1H$_2$O[4]	[1]CoSO$_4$ 1H$_2$O[4]	[2]CoSO$_4$ 1H$_2$O[4]	MnSO$_4$ 4H$_2$O[4]	MnSO$_4$ 5H$_2$O[4]	CoSO$_4$ 5H$_2$O[4]	CoSO$_4$ 6H$_2$O[4]	CoSO$_4$ 7H$_2$O
tem	Monocl (?)			Monocl (?)	Tricl.	Tricl.	Uniax.	Monocl.
bit		Fibers Crusts	Crystals	Tab.				Tab.
char.	+	?	+	—	—	—	—	—
2V	near 90	?	near 90	mod. lge.	rather lge.	med.	0	near 90
α	1·562	1·600	1·603	1·508	1·495	1·530	1·460	1·477
β	1·595		1·639	1·518	1·508	1·548	1·495	1·488
γ	1·632	1·645	1·683	1·522	1·514	1·550		1·489

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[1] Formed when CoSO$_4$ solution is evaporated to dryness on a water bath.

[2] Formed in small amount when CoSO$_4$.6H$_2$O is allowed to dehydrate in a desiccator at room temperature.

[4] Unpublished manuscript by E. S. Larsen.