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ANNUAL REPORT FOR JUNE 30, 1954 TO APRIL 1, 1955

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By
P. K. Hamilton

May 1955

Columbia University
New York, New York

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Paul F. Kerr, Director

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PROGRESS REPORT ON THE MINERALS FROM THE DELTA DEPOSIT, EMERY COUNTY, UTAH

By

P. K. Hamilton

INTRODUCTION

A mineralogical study of a suite of specimens from the Delta deposit which is located along the Muddy River at the southern bend of the San Rafael Swell, Emery County, Utah is in progress. This material was submitted by Mr. W. Scott Keys as part of a comprehensive investigation which he is making of the deposit. Gruner and Gardiner (1952) note the presence of becquerelite, carnotite, metazeunerite, phosphuranylite plus probably uranophane and muscovite. In this report optical and x-ray diffraction data are given for carnotite, a "zippeite-like" mineral and antlerite from the Delta deposit together with a brief history of antlerite. As more data are accumulated, it is hoped to derive a better understanding of the mineral relationships at this interesting deposit.

CARNOTITE

Carnotite occurs on the outside of log 124 as a soft greenish yellow powdery coating which is non-fluorescent. Indices of refraction for this material range between a lower limit of 1.785 ± .003 and an upper limit which is over 1.94.

An x-ray diffraction pattern of this material is compared (Table 1) with similar material from Naturita, Colorado (Vaes and Kerr, 1949); the Happy Jack mine, White Canyon, Utah; Goodsprings, Nevada as well as with the strong lines as given by Weeks and Thompson (1954).

"ZIPPEITE-LIKE" MINERAL

Several secondary uranium minerals of interest occur at this locality. Among these is the dark orange yellow material which occurs in veinlets associated with log 113. Its bright green fluorescence distinguishes it from the associated minerals and it is identified as being similar to the "zippeite-like" mineral described by Weeks and Thompson (1954). This material which they formerly (1953) called betazippeite,

Table 1

CARNOTITE

Delta Deposit cu rad ni fil		Naturita, Colorado cu rad ni fil		Goodsprings, Nevada* cu rad ni fil		Weeks & Thompson cu rad	
dÅ	I	dÅ	I	dÅ	I	dÅ	I
		(a)					
6.45	10	6.425	10	6.45	10	6.5	s
5.063	2	5.063	3	5.077	1		
4.228	6			4.218	2		
3.531	7	3.493	6	3.510	3	3.51	w
3.224	3	3.208	3	3.241	2		
3.118	9	3.092	8	3.108	3	3.1	m
		2.998	3				
		2.822	1				
2.704	1	2.742	2	2.716	1/2		
2.576(b)	2	2.552	3	2.554	1		
2.453(b)	1	2.452	2	2.473	1		
		2.356	1/2				
		2.267	1				
2.154	3	2.146	3				
2.027	1	2.081	2				
1.985	1	2.016	2	1.993	2		
1.939	2	1.934	3	1.937	1		
		1.901	2				
		1.864	1				
		1.816	1				
		1.756	1				
1.673	1	1.670	2				
		1.599	2				
		1.500	2				

(a) The 11.142 space reported by Vaes and Kerr (1949) is found to be a spurious diffraction effect.
(b) broad
*pattern measured by Paul B. Barton, Department of Geology, Columbia University

now appears to vary so much that they (1954) indicate that there may be polymorphous forms of the same mineral, or different hydration states, or perhaps even more than one mineral. They assign the formula $(UO_2)_2(SO_4)(OH)_2 \cdot 4H_2O$, but it would appear that further investigation will be necessary in order to classify this material properly. The qualitative test for SO_4 is positive in the Delta material. The mineral is associated in the veins with a soft, colorless material with a vitreous luster which appears to be gypsum.

Optically, this material appears as fine aggregates or as plates and is pleochroic from yellow green to pale yellow green. The indices of refraction are similar to those given by Weeks and Thompson (1954) for the Oyler mine "zippeite-like" mineral, from the Henry Mountains district.

Delta Deposit	Oyler Mine
X 1.637 ± .003 pale yellow green	X 1.630 pale yellow
Y 1.684 ± .003 yellow green	Y 1.689 yellow
Z 1.730 ± .003 yellow green	Z 1.739 darker yellow

The x-ray diffraction data are given in Table 2. The interplanar spacings for the Delta deposit material are compared with those of similar material from the Happy Jack mine and with the strong lines of the Oyler mine material as given by Weeks and Thompson (1954).

ANTLERITE

Bands of light green powder which cut sandy shale and are associated with the iron oxides, limonite and hematite, are identified as antlerite ($3CuO.SO_3.2H_2O$). This mineral is also present as a darker green crystalline and more compact form which coats sandstone, and is associated with gypsum, malachite and an unidentified impurity. The occurance is of interest as an additional locality for antlerite and its preservation is attributed to the arid climate.

History

Hillebrand (1889) proposed the name antlerite for the soft green hydrous copper sulphate found at the Antler mine, Mohave County, Arizona. Audieth and Martens (1925) established that this mineral ($3CuO.SO_3.2H_2O$) rather than brochantite ($4CuO.SO_3.3H_2O$) is the principal and almost the only copper mineral in the main oxidized ore body at Chuquicamata, Chile. Nevertheless, as Jarrell (1944) points out, despite the fact that independent investigators have established the ore as antlerite, the mineral is often mistaken for brochantite. Palache

Table 2

"ZIPPEITE-LIKE MINERAL"

Delta Deposit Emery Co., Utah cu rad ni fil		Happy Jack Mine San Juan Co., Utah cu rad ni fil		Oyler Mine Henry Mountains District cu rad	
dÅ	I	dÅ	I	dÅ	I
7.3	10	7.3	10	7.31	s
5.611	1/2	5.604	1/2		
4.721	1/2	4.680	1/2		
4.251	1	4.257	1		
4.114	5	4.110	2		
4.005	1	3.983	1		
3.663	7	3.646	5	3.66	m
3.500	8	3.495	8	3.49	m
3.209	1/2	3.336	1/2		
3.159	9	3.156	9	3.15	m
		3.046	1/2		
2.861	5	2.855	5		
2.670	4(b)	2.657	3		
2.527	6	2.523	4		
2.435	1	2.428	1/2		
2.250	3	2.232	4		
2.207	3	2.206	4		
2.118	7	2.115	6		
2.000	4	1.995	3		
1.958	1(b)	1.949	1/2		
1.894	1(b)	1.886	1/2(b)		
		1.850	1/2(b)		
1.830	1/2	1.823	1/2(b)		
1.784	1/2	1.789	1/2		
1.749	6				
1.701	6				
1.619	1				
1.578	2				
1.426	1(db)				
1.400	1(db)				
1.349	1/2				
1.330	1/2				
1.310	1/2				
1.265	1/2(b)				

(b) broad
(db) doublet

(1939) determined that brochantite is monoclinic rather than orthorhombic as formerly held, and that antlerite is orthorhombic. Although these two minerals occur in such form that they are indistinguishable by inspection alone, the difference in crystallinity gives rise to characteristic x-ray diffraction patterns.

Origin

As Jarrell (1944) indicates, there are a number of considerations which prevent the direct application of laboratory results to interpretation of paragenesis, since the oxidizing solutions of ore deposits are more complex than those present in a simple closed laboratory system. However, experimental evidence obtained by Posnjak and Tunell (1929) correlates with many of the features of field occurrence at Chuquicamata. These two investigators find that in the system $CuO-SO_3-H_2O$ at a given pressure and temperature, the stability range of the different copper sulphates depends largely on the concentrations of the sulphate radical.

Thus, with increasing SO_3 or proximity to the ore body or source, the following sequence of mineralization develops:

	CuO	SO_3	H_2O
Melaconite CuO	100.0	———	———
Brochantite $4CuO.SO_3.3H_2O$	70.3	17.7	12.0
Antlerite $3CuO-SO_3-2H_2O$	67.2	22.5	10.3
Chalcanthite $CuO.SO_3.5H_2O$	31.8	32.1	36.1

Field evidence at Chuquicamata shows that antlerite may form directly from chalcocite, or if pyrite is not too abundant, it may form with chalcanthite in the wall rock adjacent to the oxidizing sulphide ore. Farther away from the oxidizing sulphides, antlerite becomes unstable and brochantite is deposited. Thus, the few specimens of brochantite from this locality have come from the fringes of the ore body. If present in the central area, brochantite would occur presumably high above the top of the sulphides. The country rock may be an important influence in depleting SO_3 by base replacement. Thus, a few meters from the oxidizing sulphides, the SO_3 concentration may become so reduced that chalcanthite becomes unstable and antlerite is deposited.

Tunell and Posnjak's (1931) investigation of the four component system $CuO-Fe_2O_3-SO_3-H_2O$ shows that when there is an appreciable concentration of iron in solution, that is when Fe_2O_3 is present in quantities greater than 0.01%, iron sulphates rather than copper sulphates precipitate. Copper is held in solution until the iron content falls to a trace at which point the copper salts begin to form.

Thus, since iron present in the oxidizing solutions prevents the precipitation of copper minerals in place, the oxidation of chalcocite and pyrite ore leaves only iron minerals in place, whereas chalcanthite and sometimes antlerite are deposited nearby. Bandy (1938) points out that antlerite is the end product in the copper enrichment at Chuquicamata where, after forming, it is removed and carried downward in iron sulphate solutions with the precipitation of iron oxide either as a hydrate mineral or as hematite. This is known locally as "maroon oxide" which during the oxidation process, changes eventually to a brown limonite which is stable.

Jarrell (1944) indicates that Lindgren's 1917 theory still appears to be the most logical. According to this theory the oxidized ore body at Chuquicamata formed by the oxidation in place under arid conditions of a relatively rich chalcocite-covellite ore body. This, in turn, was followed by prolonged supergene enrichment. The depression of the water level with the change from a semi-humid to a very arid climate, and the exposure of the chalcocite-covellite body above the water level was responsible for the formation of antlerite. Several areas of unaltered sulphides are present. These appear to have been protected by an impervious casing which prevented supergene enrichment and later oxidation.

The formation of antlerite at the Chilean deposits, and of brochantite at almost every other basic copper sulphate deposit except at the Antler mine in Arizona, is explained by Bandy (1938) as being due to the presence of abundant soluble sulphates with an excess of available acid. The extremely arid conditions also favor the formation of sulphates, chlorides, and oxides from concentrated solutions and from solutions which maintain a uniform composition over a long period of time. In most other deposits much of the sulphur is not fixed in the oxidized portion of the deposit, but is carried downward to the water table. Thus copper sulphate which does precipitate above the water table tends to be antlerite and forms when the sulphate concentration is high.

DELTA DEPOSIT

Although the paragenesis at the Delta deposit is still a subject for study, the presence of antlerite seems to confirm preceding copper sulphide mineralization followed by the development of antlerite under acid conditions. The preservation of the mineral is due largely to the arid climate. It would be of interest to examine the sulphide mineralization of the area in order to determine what relation it may have to the antlerite. In addition, the possible role of carbonate in the sediments as a reducing agent for SO_3 solutions which may cause antlerite to be precipitated rather than chalcanthite, should be investigated. The presence or absence of hydrous iron sulphates would be

of interest since copper sulphates tend not to precipitate in the presence of iron sulphates.

The material from the Delta deposit occurs in bright green bands which cut through a sandy shale. It is associated with bands of what appear to be iron oxides - - - limonite and hematite. An x-ray diffraction pattern of the tan limonitic (?) material shows only quartz lines. It would be of interest to determine whether this material is actually amorphous and whether it contains residual copper. The latter would indicate a previous association with copper bearing solutions.

Qualitative chemical analysis of the Delta deposit antlerite shows the presence of copper, sulphate, water and chlorine. There is no indication of any significant amount of vanadium, nickel, arsenic or nitrate in close association with the mineral. The presence of chlorine is unexplained except that as Jarrell (1944) indicates, this element is common in the ground water of arid regions.

Microscopically, the material exhibits high birefringence and a somewhat lath-like structure. It is pleochroic from dark green to pale yellow-green and the optical properties have been determined as follows:

Delta Deposit	Palache (1939)
X 1.730 $\pm$ .003 pale yellow green	X 1.726 yellow green
Y 1.743 $\pm$ .003 light green	Y 1.738 blue green
Z 1.784 $\pm$ .003 dark green	Z 1.789 green
Biaxial (+)	Biaxial (+)

The x-ray diffraction data for antlerite are given in Table 3. Measurements were made on the debye-scherrer powder pattern obtained with copper radiation and nickel filter. The intensities have been estimated visually. This is compared with antlerite from Chuquicamata, Chile, measured under the same conditions. For comparison, data for synthetic antlerite as determined by Posnjak and Tunell (1929) as well as for natural antlerite by Waldo (1935) are included. Agreement of previous data with the Delta material and these recent Chuquicamata measurements is only fair. However, the differences are probably due to the use of shorter wave length molybdenum radiation in the earlier work which yielded fewer lines, whereas longer wave length copper radiation is used in the current study.

Table 3

ANTLERITE

X-ray Diffraction Data

Posnjak and Tunell (1929)		Waldo (1935)		Chuquicamata (1954)		Delta Deposit (1954)	
dÅ	I	dÅ	I	dÅ	I	dÅ	I
mo rad.	no fil.	mo rad.	no fil.	cu rad.	ni fil.	cu rad.	ni fil.
--	--	--	--	6.88	30	6.88	30
5.83	50	--	--	6.04	50	6.02	70
5.35	40	--	--	5.434	40	5.450	50
4.80	70	--	--	4.857	100	4.870	100
--	--	--	--	4.516	10	4.548	10
--	--	--	--	4.148	20	4.138	20
--	--	3.85	100	3.783	30	3.807	30
3.58	70	--	--	3.609	90	3.617	90
--	--	--	--	3.417	60	3.430	40
3.37	10	--	--	3.336	20	3.349	30
3.31	10	3.17	60	3.101	40	3.102	50
3.07	20	--	--	--	--	--	--
2.99	30	2.90	20	3.010	50	3.010	60
2.73	20	2.80	20	2.765	10	2.766	10
2.67	40	2.66	80	2.684	80	2.692	80
2.55	90	--	--	2.572	100	2.572	90
2.48	10	2.51	100	2.509	50	2.509	30
2.42	20	2.45	80	2.437	40	2.437	20
2.37	10	2.37	40	--	--	--	--
2.31	10	--	--	2.315	30	2.318	10
2.25	10	2.18	60	2.262	40	2.268	20
2.12	100	2.13	60	2.132	90	2.135	90
2.06	10	2.07	20	2.069	20	2.067	5
2.01	10	2.00	20	2.040	30	2.036	10
--	--	--	--	2.003	20	2.017	5
1.94	10	1.949	20	1.945	30	1.945	20
--	--	--	--	1.897	5	--	--
1.83	10	--	--	1.834	20	1.834	30
1.81	10	1.810	60	1.815	30	1.817	30
--	--	1.733	80	--	--	--	--
--	--	1.701	20	1.707	5	1.708	5
--	--	1.668	20	1.691	10	1.692	5
1.63	50	1.628	40	1.638	60	1.638	40
--	--	1.591	40	1.619	10	1.618	5
1.56	10	1.558	60	1.568	40	1.569	20
1.55	10	1.532	60	1.550	40	1.556	20
1.50	70	1.500	60	1.513	30	1.515	20
--	--	--	--	1.499	10	1.504	10

Posnjak and Tunell (1929)		Waldo (1935)		Chuquicamata(1954)		Delta Deposit (1954)	
dÅ	I	dÅ	I	dÅ	I	dÅ	I
mo rad.	no fil.	mo rad.	no fil.	cu rad.	ni fil.	cu rad.	ni fil.
1.48	10	1.454	20	1.480	40	1.487	30
1.44	20	1.425	20	1.439	30	1.444	10
1.39	20	1.400	20	1.392	10	1.394	20
---	--	1.337	20	1.361	5	--	--
1.31	20	1.311	20	--	--	1.320	20
1.28	30	1.260	20	--	--	1.282	10
1.24	10						

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