Secondary Zn and Cu minerals from contact deposits of the Oslo region, Norway

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Abstract
A list of 22 Zn/Cu minerals from the oxidised zone of contact deposits in the Oslo region is presented. Brianyoungite, described as a new mineral from Cumbria in 1993, was identified from Glomsrudkollen, Konnerudkollen, and Nyseter (Grua). Cu-poor aurichalcite from Konnerud has a mean Zn:Cu ratio of 4.44:1.00 (range 3.96-5.45:1.00). Zn-rich malachite from Skjerpemyr (Grua) contains up to 17.66 wt.% ZnO, with 50.57 wt.% CuO, corresponding to $(Cu_{1.49}Zn_{0.51})_{\Sigma 2.00}$. Chemical analysis of a white massive mineral from Glomsrudkollen, with a powder pattern deviating in some details from that of hydrozincite, gave a formula close to $Zn_7(CO_3)_3(OH)_8 \cdot H_2O$. A green «curly» mineral from the Sando quarry (Sande, Vestfold) may be identical with a very peculiar «Lockenmineral» described from Schwaz, Tirol. Its X-ray powder data are tabulated, but the material is too scarce for a chemical analysis.

Introduction

The contact-metasomatic ore deposits of the Oslo region and their minerals were described in great detail by Goldschmidt (1911), including the following secondary zinc and copper minerals: aurichalcite, azurite, hemimorphite, malachite, smithsonite, and «Zinkvitriol». The activity of numerous mineral collectors in this area has in recent years brought to light a number of additional weathering minerals. The majority of these has been identified by the X-ray powder method at the Mineralogical-Geological Museum (MGM) in Oslo. Neumann (1985) has summarized the additional findings up to 1983. These include bianchite, brochantite, cuprite, gunningite, hydrozincite, ktenasite, langite, linarite, rosasite, and serpierite.

Table 1 lists all secondary zinc and copper minerals identified so far in the contact deposits (the Hørtekollen helvite deposit, from which hemimorphite and smithsonite have been recorded, is not included). Six additional minerals have been found after publication of Neumann's survey, and these are marked with an asterisk in Table 1. Brief descriptions of these and some of the other minerals follow below, with comments on some still unidentified (and probably new) minerals. More details on some of the minerals can be found in the unpublished «Interne notater» from Mineralogisk-Geologisk Museum. The chances of finding still more minerals of this category seem to be good.

Some selected minerals

Brianyoungite was described as a new mineral from the oxidised zone at Brownley Hill Mine, Nenthead, Cumbria (Livingstone & Champness 1993). The occurrence of this mineral at seven localities in W Germany was reported by Schnorrer (1994a), and six localities in E Germany were reported by Witzke (1994). The new mineral is obviously quite widespread. It was known to us from the Glomsrudkollen and Konnerudkollen mines in 1989 and from Nyseter, Grua in 1990, but the material was not suited for single-crystal work.

Devilline was first identified on a specimen from Glomsrudkollen in 1986 and subsequently from Konnerudkollen. Devilline and serpierite are closely related structurally, and their powder diagrams are almost identical. Positive identification of one or the other requires a good powder pattern, which is often hard to obtain due to the small amounts of material normally available.

Goslarite. Its occurrence has not been verified by X-ray investigation from any Norwegian occurrence. Goldschmidt (1911) has noted efflorescences of «Zinkvitriol» in several zinc deposits of the Oslo region. He did not examine the material closer, but states that it has been identified as zinc sulphate from Nyseter, Grua. Neumann (1985) has quoted the information above under the heading goslarite, $ZnSO_4 \cdot 7H_2O$. It should be noted that the monohydrate gunningite and the hexahydrate bianchite have both been identified from Glomsrudkollen.

Namuwite, which has a characteristic X-ray reflection at 10.6 Å, is probably present together with schulenbergite in a sample from Glomsrudkollen, X-rayed in 1987. However, the X-ray film is weak and the identification of namuwite has not been ascertained.

Posnjakite. The first find of this mineral was made in 1988 from Konnerudkollen. A second locality is Glomsrudkollen.

Rosasite. According to Neumann (1985), rosasite is said to have been recorded from Konnerud. However, the occurrence of this mineral was never confirmed by X-ray investigation. A picture of alleged rosasite from Konnerud appears on the back cover of NAGS-nytt, 7(2), 1980, but similar material from Konnerud has been repeatedly identified as malachite by the X-ray powder method. The first authenticated find of rosasite in the Oslo region was made by H. Folvik from Skjerpemyr, Grua, where the mineral occurs as bluish green globules about 0.5 mm in diameter. Rosasite was finally X-ray identified from Konnerud in 1992.

Schulenbergite was identified on a specimen from Konnerudkollen in 1989. It was subsequently recognized on an older film (recorded in 1987) of a sample from Glomsrudkollen. The film is weak and remained unidentified for some time. It shows an additional reflection at 10.6 Å, possibly due to namuwite.

Wroewolfeite was found in a specimen from Konnerudkollen in 1992, supplied by Øivind Juul Nilsen.

Some mineral varieties

Cu-poor aurichalcite from Konnerud. X-ray powder films of aurichalcite in our files were shown to be of two distinct kinds, most films corresponding to the *PDF* pattern 17-743. Three films were distinguishable by small but distinct differences in line positions and intensities. One of them is of a light green mineral from Konnerud. Macroscopically, the mineral shows a banding of lighter and darker green colour, which was found to be caused by differences in porosity and not by variable Zn:Cu ratios. The mineral was analysed with a Cameca microprobe at 15 kV and 20 nA by scanning smaller or larger areas to avoid problems with porosity and volatility of the mineral. The Zn:Cu ratios for eight analyses were found to be:

4.02:1.00 - 4.96:1.00 - 3.96:1.00 - 4.45:1.00 - 4.03:1.00 - 4.10:1.00 - 5.45:1.00 - 4.51:1.00 [mean 4.44:1.00]

Six analyses tabulated in Dana's System of Mineralogy (Volume II, 1951) have the following Zn:Cu ratios:

2.66:1.00 - 2.69:1.00 - 1.57:1.00 - 1.76:1.00 - 3.17:1.00 - 2.56:1.00

The Konnerud mineral extends the range of Zn/Cu substitution to a considerable degree, being far poorer in Cu than previously reported aurichalcites. Nothing can as yet be said about possible order/disorder relationships of Zn and Cu in this mineral.

Zn-rich malachite from Skjerpemyr, Grua. Some of the X-ray powder films of malachite in our files show small but consistent spacing and intensity differences compared to the majority of films. The composition of malachite is usually close to $Cu_2(CO_3)(OH)_2$ with theoretical weight percentages CuO 71.95, CO_2 19.90, H_2O 8.15, sum 100.00. An abnormally high content of Zn was suspected for material with deviating powder patterns, and a sample from Skjerpemyr was analysed with a Cameca microprobe at 15 kV and 20 nA. Standards were ZnS and Cu metal. Areas were scanned to avoid decomposition of the mineral. The results of eight individual analyses, arranged in order of increasing ZnO, are (in wt. %):

ZnO	8.67	8.85	9.30	10.11	13.95	15.37	16.22	17.66
CuO	60.55	60.47	61.20	59.48	55.57	55.36	55.71	50.57
Sum	69.22	69.32	70.50	69.59	69.52	70.73	71.93	68.23

The analyses are not quite satisfactory, in that the CuO values do not always decrease regularly with the increase in ZnO. Nevertheless, the suspected high Zn content is confirmed. From the analysis with the highest ZnO content the formula $(Cu_{1.49}Zn_{0.51})_{\Sigma 2.00}(CO_3)(OH)_2$ is derived.

In Dana's System of Mineralogy (Vol. II, 1951) it is stated for malachite: «A small amount of Zn substitutes for Cu in analysis 3; but the composition ordinarily does not vary significantly. There is no proof that reported highly zincian material (see rosasite) actually is of this species». It may be concluded that the malachite structure can accommodate up to at least 17-18 wt.% ZnO. Somewhere around 20 wt.% ZnO there seems to be a transition to the related rosasite structure. For rosasite, $(Cu,Zn)_2(CO_3)(OH)_2$, Dana's System states that «Cu and Zn substitute mutually over a small range at least, with Zn:Cu 2:3 in analysis 2 and 1:2 in analysis 4». The corresponding ZnO values are 28.96 and 24.46 wt.%, respectively.

Some probably new minerals

Mineral closely related to hydrozincite.

A survey of the X-ray powder films of hydrozincite in the files of MGM shows that they can be divided into two groups. One group comprises material from three foreign localities (Goodsprings, Nevada, USA; Los Lamentos, Chihuahua, Mexico; Camilia, Spain) and from two Norwegian localities (NE side of Branten, Katterat, Ankenes, Nordland; Minge Zn/Pb mine, Halden, Østfold). The powder patterns of all of these closely match *PDF* 19-1458 (Goodsprings, Nevada). The other group comprises a number of films of material from Konnerudkollen and Glomsrudkollen, including synthetic material made at MGM in 1956 (unfortunately, the book containing the details of synthesis has been lost). Common to the latter group is that the powder films are mostly weak and have broad lines. Some films of Konnerudkollen material may belong to the first group.

Four powder patterns are listed in Table 2. The reference pattern *PDF* 19-1458 can be compared with the nearly identical pattern of the Minge mineral. The pattern of the Glomsrudkollen mineral is rather weak, and the closely matching pattern of the synthetic material is therefore also included in the table. The differences between the patterns of the two groups are admittedly subtle. For patterns of the second group, the intensity of the reflection at line 17 is decidedly weaker, the reflections at lines 16 and 17 are more closely spaced, and a prominent group of three reflections at lines 40-41-42 are somewhat displaced (especially a larger distance between reflections 40 and 41). These differences are in fact better comprehended when comparing the powder films directly.

The Glomsrudkollen mineral may occur as white, porcelain-like coatings up to 2 mm thick. This material was selected for a chemical analysis, which is reported in Table 3. The weight loss below 105°C is 2.73 wt.%; the data given in Table 3 are for dried material. C and H_2O were determined on an untreated sample with a Leco RC-412 CH analyser. Two determinations of H_2O gave 14.3 and 13.8 wt.%, corresponding to a mean of 11.3 wt.% for dried material. Two determinations of C gave 4.35 and 4.45 wt.%, giving a mean of 16.1 wt.% CO_2, corrected to 16.6 wt.% CO_2 for dried material. ZnO, MnO, CaO, SiO_2, and SO_3 were determined by a Uniquant standard-less XRF analysis on dried material. ZnO was also analysed by AAS, giving 70.31 wt.% on dried material and 68.98 wt.% on untreated material, the latter figure corresponding to 70.92 wt.% for dried material. The figure given for ZnO in Table 3 is the mean of the two AAS determinations and 70.5 wt.% ZnO obtained from the XRF analysis.

The resulting chemical formula is very close to $Zn_7(CO_3)_3(OH)_8 \cdot H_2O$, as can be seen from the atomic proportions in Table 3. The formula of hydrozincite is $Zn_5(CO_3)_2(OH)_6$, and although the oxide percentages of the two minerals are rather close, it is remarkable that the Glomsrudkollen mineral gives such a nicely balanced formula with small subscripts. The crystal structure of hydrozincite is not known, and nothing can be said about the possible structural relationships of the two minerals.

«Lockenmineral».

A very peculiar light green mineral from the Sando quarry (Sande, Vestfold), occurring as loose «curls» in a quartz druse from the Drammen granite, was sent to MGM by Per Lid Adamsen in 1992. Small amounts of chalcopyrite are imbedded in the quartz. The curls may reach a length of 1 mm. They give an X-ray powder pattern somewhat resembling, but distinctly different from, that of malachite (see Table 4). The light green colour is quite distinct from the usual grass green colour of malachite. The Sando quarry is situated at the contact between the Drammen granite and Cambro-Silurian sediments, but the copper mineralization is connected with hydrothermal quartz veins, and is not of the true contact-metasomatic type. Fluorite veins are also common in the quarry.

A mineral of similar appearance has been noted from Cu-bearing quartz veins in the Huken basalt quarry (Grorud, Oslo). However, a weak powder pattern (due to paucity of material) is interpreted to be identical with that of malachite. Another occurrence of similar material is the iron mine of Narverud near Konnerud. A powder pattern is essentially of brochantite, and the associated light green curls could not be identified. Neumann (1944, p. 19) described and pictured a similar curly mineral from a sulphide-bearing quartz breccia in Lassedalen near Kongsberg. It was interpreted as a pseudomorph of malachite after native copper.

Pictures of a mineral from Schwaz (Tirol) with amazingly identical appearance to the Sando mineral were recently published by Schnorrer (1994b), who identified it as malachite. It turns out that this mineral has been described in some detail by Meixner & Paar (1975), who introduced the name «Lockenmineral» for it. They noted differences from malachite and rosasite with regard to optical data, chemistry and infra-red spectrum. Unfortunately, they did not publish any X-ray powder data, but refer to a diffractometer recording by Dr. E. Kirchner, who regarded the mineral as a Zn-bearing malachite.

The chemical analysis presented by Meixner & Paar (1975) was performed by Outokumpu Oy (Pori, Finland) on 550 mg of purified material: CuO 61.96, ZnO 4.11, CO_2 21.80, H_2O 10.00, dolomite 2.25, sum 100.12 wt.%. Curiously, they did not calculate a formula from this analysis. The (Cu+Zn):C ratio is close to 5:3, which gives a composition close to $(Cu,Zn)_5(CO_3)_3(OH)_4 \cdot 1.36H_2O$.

The present investigation has not been concluded. It can be stated at this stage that the Sando mineral, based on its unique X-ray powder pattern, is most likely a new species. Material for full chemical characterization is unfortunately not available at the moment. Identity with the Schwaz mineral is highly probable from their very characteristic appearances, but is not yet proven. It is planned to obtain a sample of the Schwaz mineral for X-ray powder work.

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Sammendrag på norsk

Det er gitt en liste med 22 Zn/Cu-mineraler fra oksidasjonssonen i Oslofeltets kontaktforekomster. Brianyoungitt, beskrevet som et nytt mineral fra Cumbria i 1993, er identifisert fra Glomsrudkollen, Konnerudkollen og Nyseter (Grua). Cu-fattig aurichalsitt fra Konnerud har et gjennomsnittlig Zn:Cu-forhold på 4,44:1,00 (variasjonsbredde 3,96-5,45:1,00). Zn-rik malakitt fra Skjerpemyr (Grua) inneholder opp til 17,66 vektprosent ZnO, med 50,57 vektprosent CuO, tilsvarende $(Cu_{1,49}Zn_{0,51})_{\Sigma 2,00}$. *Kjemisk analyse av et hvitt massivt mineral fra Glomsrudkollen, med et røntgendiagram som i enkelte detaljer skiller seg fra hydrosyinkittens, gir en formel nær* $Zn_7(CO_3)_3(OH)_8 \cdot H_2O$. *Et grønt mineral i form av "krøller" eller "spon" fra Sando pukkverk (Sande, Vestfold) er muligens identisk med et særegent "Lockenmineral" beskrevet fra Schwatz, Tirol. Dets røntgenpulverdiagram er oppgitt, men mengden av materiale er ikke tilstrekkelig for kjemisk analyse.*

Table 1.
Secondary Zn and Cu minerals from contact deposits, Oslo region

		1	2	3	4	5	6	7
Aurichalcite	$(Zn,Cu)_5(CO_3)_2(OH)_6$		NX		NX	N		
Azurite	$Cu_3(CO_3)_2(OH)_2$		X		X	B	B	B
Bianchite	$Zn(SO_4)\ \cdot 6H_2O$	NX						
Brianyoungite *	$Zn_3(CO_3,SO_4)(OH)_4$	X	X	X				
Brochantite	$Cu_4(SO_4)(OH)_6$	NX	NX				NX	N
Cuprite	Cu_2O		B			N		N
Devilline *	$CaCu_4(SO_4)_2(OH)_6\ \cdot 3H_2O$	X	X					
Goslarite (?)	$Zn(SO_4)\ \cdot 7H_2O$							
Gunningite	$Zn(SO_4)\ \cdot H_2O$	NX						
Hemimorphite	$Zn_4Si_2O_7(OH)_2\ \cdot H_2O$	B	NX	X?	NX	NX	X	
Hydrozincite	$Zn_5(CO_3)_2(OH)_6$	X**	NX**	B	B	N	B	
Ktenasite	$(Cu,Zn)_5(SO_4)_2(OH)_6\ \cdot 6H_2O$	NX						
Langite	$Cu_4(SO_4)(OH)_6\ \cdot 2H_2O$		NX					N
Linarite	$PbCu(SO_4)(OH)_2$		NX		B	B		
Malachite	$Cu_2(CO_3)(OH)_2$	X	NX	X	X	X	B	X
Namuwite (?) *	$(Zn,Cu)_4(SO_4)(OH)_6\ \cdot 4H_2O$	X						
Posnjakite *	$Cu_4(SO_4)(OH)_6\ \cdot H_2O$	X	X					
Rosasite	$(Cu,Zn)_2(CO_3)(OH)_2$		X		X			
Schulenbergite *	$(Cu,Zn)_7(SO_4,CO_3)_2(OH)_{10}\ \cdot 3H_2O$	X	X					
Serpierite	$Ca(Cu,Zn)_4(SO_4)_2(OH)_6\ \cdot 3H_2O$	NX	X					
Smithsonite	$ZnCO_3$	N	NX	B	NX	NX	X	
Wroewolfeite *	$Cu_4(SO_4)(OH)_6\ \cdot 2H_2O$		X					

1: Glomsrudkollen, 2: Konnerud/Konnerudkollen, 3: Nyseter, Grua, 4: Skjerpemyr, Grua, 5: Lykkens Prøve, Grua, Mutta, Grua, 7: Gjellebekk, Auvi and Buttedal, Lier.
N: Neumann (1985), X: X-ray diffraction laboratory of Mineralogisk-Geologisk Museum, B: personal communicatio from Hans-Jørgen Berg (1995).
* mineral identified since 1983
** mineral closely related to hydrozincite

Table 2.
X-ray powder diffraction data for hydrozincite and -related mineral

No.	*PDF* 19-1458 Goodsprings, Nevada		Film 27686 * Minge, Halden		Film 28499 * Glomsrud-kollen		Film 11993 * Synthetic	
	d (Å)	I/I_0	*d* (Å)	I_{est}	*d* (Å)	I_{est}	*d* (Å)	I_{est}
1.	6.77	100	6.75	vs	6.83	vs	6.73	vs
2.	5.71	5						
3.	5.37	10	5.37	vvw				
4.	3.99	20	4.01	vw b			4.01	vvw
5.	3.81	5						
6.	3.66	40	3.67	w b	3.75	vw	3.70	w b
7.			3.59	vvw				
8.	3.37	5						
9.	3.14	50	3.16	m-s b	3.17	m	3.17	m-s
10.	3.00	10	3.00	vvw				
11.	2.92	20	2.93	vvw			2.96	vw
12.	2.85	30	2.87	w	2.89	w	2.88	m
13.	2.74	10						
14.	2.72	60	2.73	s	2.74	s	2.72	s
15.	2.69	20	2.69	w	2.69	w	2.67	w
16.	2.58	10	2.59	w	2.58	w	2.56	vw
17.	2.480	70	2.486	s	2.496	w	2.496	m
18.	2.394	5						
19.	2.336	10	2.334	vvw	2.331	vvw		
20.	2.301	20	2.311	vw			2.319	vw
21.	2.253	5						
22.	2.213	10	2.210	vw	2.213	vvw	2.193	vvw
23.	2.177	5						
24.	2.086	5	2.090	vvw	2.099	vvw	2.103	vvw b
25.	2.064	10	2.072	vvw				
26.	2.041	5						
27.	2.006	5						
28.	1.944	5	1.958	vvw				
29.	1.915	30	1.913	w b	1.917	vvw	1.921	vvw
30.	1.902	30						
31.	1.842	10						
32.	1.814	10	1.810	vvw				
33.	1.774	20	1.782	vw			1.780	vvw
34.	1.745	5						
35.			1.720	vvw	1.717	vvw	1.708	vvw
36.	1.688	40	1.694	vw b				
37.	1.657	10	1.660	vw b				
38.	1.646	5						
39.	1.609	5						
40.	1.573	20	1.581	m	1.586	w-m	1.586	m
41.	1.559	10	1.559	m	1.556	m	1.558	m
42.	1.547	5	1.548	w	1.546	w-m	1.543	m-w
43.	1.521	5						
44.	1.498	5						
45.	1.466	20	1.468	w				
46.	1.451	5						
47.	1.401	10						
48.	1.368	10	1.365	w b				
49.	1.359	5						
50.	1.345	10	1.345	w b				

* 9 cm Debye-Scherrer camera, Fe radiation, Mn filter, no internal standard

Table 3.
Chemical analysis of hydrozincite-related mineral from Glomsrudkollen

Oxide	Wt.%	At.props.*		1	2
ZnO	70.6	6.80	Zn	71.95	74.12
MnO	0.2	0.02	Mn		
CaO	0.7	0.10	Ca		
SiO_2	0.7	0.09	Si		
SO_3	0.2	0.02	S		
CO_2	16.6	2.96	C	16.67	16.03
H_2O	11.3	9.84	H	11.38	9.85
Sum	100.3			100.00	100.00

Analysts: Alf Olav Larsen, Erik Tveten, and Arne Åsheim (see text for details)
Analytical data are for material dried at 105°C (2.73 wt.% weight loss)
* Based on $\Sigma O = 18$
1: Theoretical composition for $Zn_7(CO_3)_3(OH)_8 \cdot H_2O$
2: Theoretical composition for $Zn_5(CO_3)_2(OH)_6$ (hydrozincite)

Table 4.
X-ray powder data for "Lockenmineral" from Sando quarry

	PDF 41-1390 Malachite synthetic		Film 28965 * Sando quarry, Sande, Vestfold	
	d (Å)	I/I_0	*d* (Å)	I_{est}
1.	7.37	6	7.34	vw
2.	5.97	84	5.93	s
3.	5.04	96	5.01	vs
4.	4.696	15	4.727	vvw
5.	3.690	100	3.686	vvs
6.			3.340	vw
7.			3.161	vw
8.	3.028	15	3.050	w
9.	2.985	20	2.971	w
10.	2.861	73	2.874	s
11.	2.826	18		
12.	2.781	28	2.783	vw
13.			2.718	vw
14.			2.657	vw
15.	2.518	55	2.518	m-s
16.	2.499	9		
17.	2.489	11		
18.	2.480	13		
19.	2.461	12	2.462	m
20.	2.429	8		
21.	2.387	3		
22.			2.361	m
23.	2.347	11		
24.	2.315	17	2.310	m-w
25.	2.289	8		
26.	2.254	5		
27.			2.197	m
28.	2.185	12		
29.	2.159	5		
30.	2.128	20	2.127	m
31.	2.085	5		
32.	2.077	7		
33.	2.066	4		
34.	2.057	6		
35.	2.052	3		
36.			2.039	vvw
37.	2.023	1		
38.			2.010	vw
39.	1.990	9		
40.			1.984	vw
41.	1.970	8		
42.	1.947	13		
43.	1.938	3	1.940	m-w
44.	1.915	4		
45.	1.912	8		
46.	1.899	10	1.900	m-w
47.	1.887	2		
48.	1.855	1		
49.	1.851	1		

50.	1.833	4	1.830	vw
51.	1.821	1		
52.	1.792	8	1.798	w
53.	1.698	4		
54.	1.689	11		
55.	1.678	13	1.676	w
56.	1.672	8		
57.			1.654	w
58.	1.642	4		
59.	1.635	3	1.631	vw
60.	1.619	9		
61.	1.594	6		
62.	1.591	9	1.591	vvw
63.	1.572	8		
64.	1.541	4	1.545	vw
65.	1.531	3		
66.	1.523	3	1.521	vw
67.	1.513	2		
68.	1.510	8		
69.	1.505	8		
70.	1.503	3		
71.	1.498	10	1.497	vw
72.	1.475	12	1.481	w
73.	1.472	13	1.467	vw b
74.	1.465	2		
75.	1.456	2		
76.			1.448	vvw
77.	1.426	1		
78.	1.422	11	1.420	w
79.			1.390	w
80.			1.342	vw
81.			1.309	vvw
82.			1.291	vvw
83.			1.277	vvw

* 9 cm Debye-Scherrer camera, Fe radiation, Mn filter, no internal standard