Damaraite, a new lead oxychloride mineral from the Kombat mine, Namibia (South West Africa)

A. J. Criddle,[1] P. Keller,[2] C. J. Stanley[1] and J. Innes[3]

[1]Department of Mineralogy, The Natural History Museum, Cromwell Rd., London SW7 5BD, U.K.
[2]Institut für Mineralogie und Kristallchemie, Universität Stuttgart, D-700 Stuttgart, Germany
[3]CSIRO Division of Exploration Geoscience, Private Bag, Wembley, Western Australia 6014

Abstract

Damaraite, ideally $3PbO.PbCl_2$, is a new mineral which occurs with jacobsite, hausmannite, hematophanite, native copper, an unnamed Pb–Mo oxychloride, calcite, and baryte, in specimens from the Asis West section of the Kombat mine, Namibia (South West Africa). Damaraite is colourless and transparent with a white streak, and adamantine lustre. It is brittle with an irregular to subconchoidal fracture and a cleavage on (010). The mineral has a low reflectance, a weak bireflectance, barely discernible reflectance pleochroism, from grey to slightly bluish grey in some sections, and is weakly anisotropic. Reflectance data in air and in oil are tabulated. Colour values relative to the CIE illuminant C for the most strongly bireflectant grain are, for R_1 and R_2 respectively:

$$Y\%15.9, 16.9; \lambda_d 475, 472; P_e \%5.3, 8.9$$

It has a VHN_{50} of 148 (range 145–154) with a calculated Mohs hardness of 3. X-ray powder diffraction studies give the following parameters refined from the powder data: orthorhombic; space group *Pma2*, *Pmam* or $P2_1am$; *a* 15.104(1), *b* 6.891(1), *c* 5.806 (1)Å; V is 604.3 (4)Å3 and Z = 3. D_{calc} 7.84 g/cm^3. The strongest six lines of the powder pattern are [*d* in Å (*I*) (*hkl*)]: 2.902 (10) (121,002); 2.766 (10) (510,221); 2.877 (9) (411); 3.164 (6) (401); 3.135 (6) (220); 1.747 (b) (313,721,531). The name is for the Damara sequence which hosts the Kombat deposit.

Keywords: damaraite, new mineral, lead oxychloride, Kombat mine, Namibia.

Introduction and general geology

Damaraite, a new lead oxychloride, was discovered in specimens collected from hematophanite-bearing assemblages in a manganese ore lens on the 1208 metre sill elevation of the W90 (south–east) stope on the 12 level of the Asis West section of the Kombat Mine. The mine is sited on the northern flank of the Otavi Valley, 37 km east of Otavi and 49 km south of Tsumeb, in northern South West Africa/Namibia (lat. 19°45′S long. 17°45′E) and is a medium-rank producer of high-grade Cu–Pb–Ag ores formed by hydrothermal and metasomatic replacement and fracture-fill of dolostones of the Upper Proterozoic Hüttenberg Formation. The geology of the deposits has been described by Innes and Chaplin (1986).

Since 1974, a series of small lenses of manganese and iron ores associated with Cu–Pb–Ag sulphide ores has yielded an extensive suite of rare minerals (reminiscent of some of the assemblages at Långban, Sweden, and Franklin, New Jersey) and the new species johninnesite (Dunn *et al.*, 1986), kombatite (Rouse *et al.*, 1986), ribbeite (Peacor *et al.*, 1987), holdawayite (Peacor *et al.*, 1988) and asisite (Rouse *et al.*, 1988).

The lenses of manganese ore (consisting predominantly of hausmannite), are fine to coarse-grained: their strongly deformed mineral and textural layering mimics the banding of the protore which, it is believed, represents a syngenetic accumulation of bedded manganese oxides, hydrated oxides and siliceous exhalites, originally deposited fumarolically at a sub-aqueous interface between environments of shallow-water carbonate and euxinic sedimentation.

Many of the rare minerals were found in late-stage hydrothermal ptygma-like veins, which are transgressive to the primary layering of the hausmannite ores, and are commonly zoned.

During the week ending 29/6/84, the mill super-

Mineralogical Magazine, December 1990, Vol. 54, pp. 593–598

TABLE 1. Reflectance data for damaraite

	1		2		3		4		1		2		3		4	
nm	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	$^{im}R_1$	$^{im}R_2$	$^{im}R_1$	$^{im}R_2$	$^{im}R_1$	$^{im}R_2$	$^{im}R1$	$^{im}R_2$
400	19.1	20.8	18.9	20.1	19.2	19.9	19.0	19.8	6.31	7.55	6.22	7.27	6.25	6.99	6.03	6.86
420	18.6	23.1	18.5	22.55	18.4	19.0	18.2	18.9	5.97	9.23	5.87	8.97	5.88	6.30	5.58	6.15
440	17.9	21.1	17.9	21.1	17.8	18.3	17.6	18.1	5.58	7.78	5.54	7.76	5.63	5.90	5.30	5.79
460	17.35	19.4	17.3	19.25	17.4	17.7	17.15	17.5	5.26	6.58	5.20	6.51	5.38	5.58	5.01	5.41
470	17.15	18.9	17.1	18.75	17.2	17.5	16.9	17.2	5.11	6.27	5.07	6.18	5.25	5.43	4.89	5.27
480	16.9	18.5	16.9	18.35	17.0	17.3	16.7	17.0	5.00	6.02	4.94	5.92	5.16	5.30	4.77	5.14
500	16.55	17.9	16.55	17.75	16.7	16.9	16.4	16.6	4.80	5.64	4.75	5.56	4.97	5.08	4.58	4.92
520	16.25	17.4	16.25	17.3	16.4	16.55	16.1	16.25	4.65	5.37	4.60	5.31	4.84	4.91	4.42	4.75
540	16.0	17.05	16.0	16.9	16.1	16.25	15.9	16.0	4.51	5.15	4.45	5.08	4.70	4.76	4.29	4.61
546	15.9	17.0	15.9	16.8	16.0	16.2	15.8	15.9	4.48	5.09	4.42	5.03	4.67	4.73	4.24	4.59
560	15.8	16.7	15.8	16.65	15.9	16.0	15.7	15.8	4.40	4.97	4.35	4.93	4.59	4.63	4.19	4.51
580	15.6	16.5	15.6	16.4	15.75	15.8	15.55	15.6	4.33	4.85	4.28	4.80	4.51	4.54	4.11	4.44
589	15.55	16.4	15.55	16.3	15.7	15.8	15.5	15.6	4.28	4.79	4.25	4.74	4.48	4.50	4.09	4.40
600	15.5	16.3	15.5	16.25	15.6	15.7	15.45	15.5	4.25	4.75	4.22	4.71	4.44	4.46	4.08	4.39
620	15.4	16.15	15.4	16.1	15.5	15.6	15.4	15.4	4.20	4.66	4.18	4.63	4.41	4.41	4.03	4.34
640	15.25	16.0	15.3	15.95	15.4	15.5	15.3	15.35	4.17	4.60	4.14	4.57	4.36	4.35	3.98	4.30
650	15.25	16.0	15.3	15.9	15.4	15.4	15.25	15.3	4.15	4.57	4.12	4.55	4.34	4.35	3.96	4.27
660	15.15	15.9	15.2	15.85	15.35	15.4	15.25	15.3	4.13	4.54	4.11	4.53	4.32	4.30	3.94	4.26
680	15.1	15.75	15.15	15.75	15.25	15.3	15.15	15.2	4.09	4.50	4.07	4.47	4.28	4.27	3.89	4.21
700	15.0	15.65	15.1	15.65	15.2	15.15	15.1	15.1	4.07	4.45	4.03	4.43	4.25	4.22	3.88	4.20
Colour values relative to CIE Illuminant C																
x	.300	.293	.300	.294	.300	.299	.301	.299	.291	.278	.291	.279	.293	.290	.291	.291
y	.304	.294	.304	.294	.305	.303	.305	.303	.293	.272	.293	.272	.296	.293	.293	.292
Y%	15.9	16.9	15.9	16.8	16.0	16.15	15.8	15.9	4.47	5.09	4.42	5.04	4.65	4.70	4.26	4.59
d	475	472	474	471	475	475	474	473	474	470	473	469	475	474	474	473
Pe%	5.3	8.9	5.2	8.8	4.8	5.6	4.8	5.5	9.8	17.1	9.7	17.0	8.6	10.1	9.6	9.9

intendent at the Kombat Mine noted a dense reddish-brown mineral in the sulphide concentrate during the froth flotation process: when this was separated it was identified as hematophanite. A subsequent search underground resulted in the discovery of hematophanite *in situ* as a constituent of banded hausmannite–baryte–jacobsite–hematite ores in the W90 stope. Here, the hematophanite formed layers (up to 17 mm in thickness) of densely packed aggregates of micaceous flakes (themselves up to 4 mm wide), associated with native copper. The layers were conformable with the gross mineralogical layering of the manganese ore lens and have been tectonically deformed, resulting in the hematophanite flakes developing a curvi-lamellar habit. The hematophanite layers/lenses were concentrated within the thicker layers of jacobsite and hematite rather than within the hausmannite layers.

Over the ensuing two months, further samples of hematophanite-bearing ores with various mineral associations (e.g. defernite–crednerite–jacobsite–hausmannite–baryte–calcite–native–copper–vesuvianite–hematophanite; jacobsite–hematophanite–baryte–hematite–native-copper–asisite–molybdophyllite–chlorite and hematophanite–andradite–vesuvianite–baryte) were recovered both from the layered hausmannite ores and from a meshwork of ptygma-like veins of baryte–calcite–jacobsite–hematite. The type specimen of damaraite (mine sample number MINA 02 0884) is from the late-stage vein paragenesis. The W90 stope is also the type locality for the recently described species kombatite and asisite (see earlier).

Damaraite is named for the Damara sequence which forms the host rocks to the Kombat–Asis deposit. The mineral and name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association. Type specimens are preserved at the British Museum (Natural History) in polished section E.1218 (BM 1988, 255) and BM 1988, 256–257; also at the Institut für Mineralogie und Kristallchemie, Universität Stuttgart.

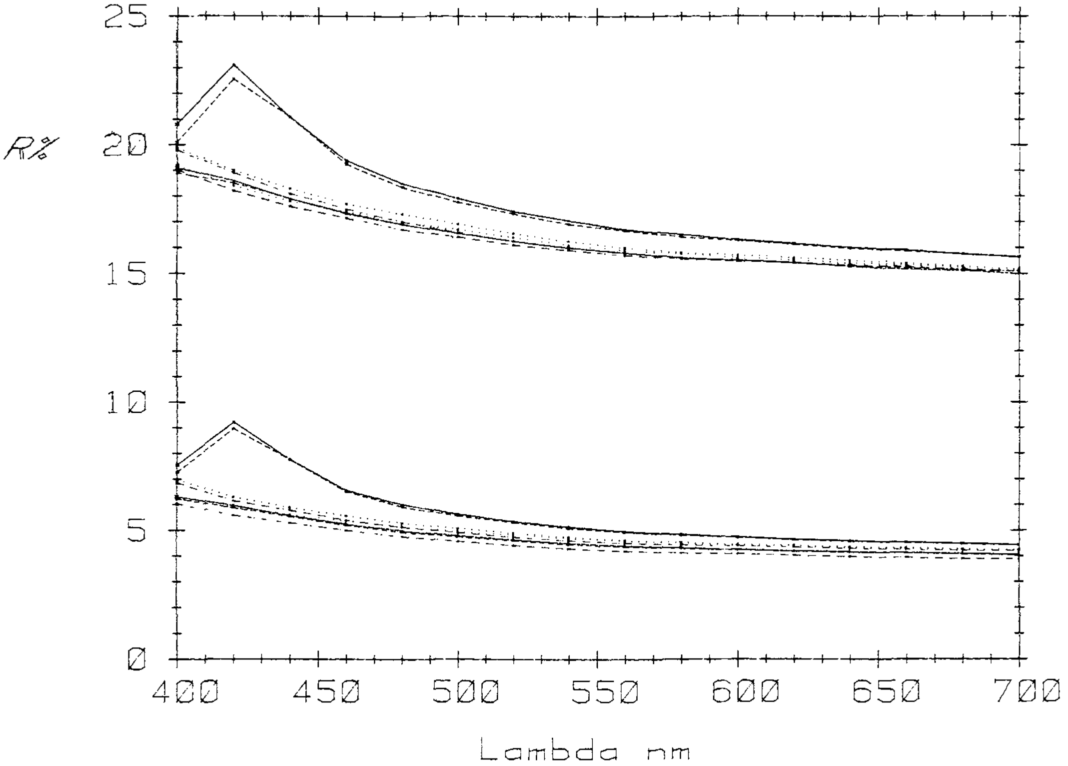

FIG. 1. R and ^{im}R spectra for grains of damaraite. Data from Table 1.

Table 2. Electron microprobe analyses of damaraite

	Pb	Cl	O	Total
1	86.87	7.13	5.10	99.10
2	86.91	7.20	5.08	99.19
3	87.32	7.37	5.08	99.77
4	87.07	7.45	5.04	99.56
5	87.04	7.29	5.08	99.41
6	87.5	7.5	5.1	100.00
7	87.55	5.16	5.59	98.30

Cambridge Instruments Microscan IX at 20kV with mendipite standard. Radiations measured Pb Mα ClK . [oxygen by stoichiometry]

1-4. different grains of damaraite (specimen KOAA)
5. Average of 1-4.
6. Ideal 3PbO.PbCl$_2$.
7. Average of six analyses of damaraite from specimen KOAE.

Physical properties

Damaraite is colourless with a white streak (determined from the powder extracted for an X-ray mount), and it has an adamantine lustre. It is transparent but its relatively high refractive index (see below) means that optical characterization is more readily performed in reflected light.

Polished sections were prepared according to the method of Criddle *et al.* (1983) finishing at the 1/4 μum diamond stage. Damaraite occurs as subhedral grains (<200 × 150 μm) in interstices in calcite and is associated with jacobsite, hausmannite, hematophanite, native copper, a red unnamed Pb–Mo oxychloride, and baryte. Damaraite has a VHN$_{50}$ of 145–154 (mean 148) kg/mm^2, equivalent to a Mohs hardness of about 3. The indentations are fractured at their corners suggesting it is brittle with an irregular to subconchoidal fracture. The mineral has a good cleavage on (010) and possibly a parting. Due to lack of material, the density could not be measured and the calculated density is given below.

In reflected light, damaraite appears grey with white to colourless internal reflections. It is weakly bireflectant and very slightly pleochroic from barely detectable bluish grey to grey. It is weakly anisotropic but, being transparent, there are no perceptible rotation tints.

Table 3. Indexed X-ray powder diffraction pattern of damaraite, FeKα radiation, Mn filter, camera diameter 114.6mm.
Intensity I/Io is estimated.

$d_{meas.}$	I/I_o	$d_{calc.}$	hkl
7.55	2	7.552	200
6.90	3	6.891	010
6.28	2	6.269	110
4.61	2	4.603	201
4.27	1	4.260	111
4.06	2	4.065	310
3.824	5	3.828	211
3.773	1	3.776	400
3.446	1	3.445	020
3.327	4	3.330	311
3.164	6	3.165	401
3.135	6	3.135	220
2.964	2	2.963	021
2.902	10	2.908, 2.903	121, 002
2.877	9	2.876	411
2.842	3	2.843	320
2.766	10	2.767, 2.758	510, 221
2.553	1	2.554	321
2.497	1	2.498	511
2.370	2	2.364	610
2.303	1	2.301	402
2.271	2	2.271, 2.271	520, 130
2.196	3	2.198, 2.196	230, 122
2.130	2	2.130	222
2.093	5	2.090	330
2.063	2	2.059	710
2.030	2	2.033, 2.031	620, 323
2.003	2	2.003	512
1.967	1	1.966	331
1.917	1	1.0918, 1.914	621, 422
1.888	3	1.888	800
1.834	1	1.833	612
1.822	2	1.821	810
1.796	1	1.795	801
1.791	1	1.789, 1.789	522, 132
1.747	6	1.474, 1,744, 1.744	313, 721, 531
1.724	1	1.723, 1.722	040, 403
1.696	2	1.697, 1.696	630, 332
1.684	1	1.687, 1.680, 1.680	023, 240, 712
1.670	2	1.671	413
1.643	5	1.642	141
1.631	5	1.631, 1.630	910, 340
1.587	1	1.586	513
1.573	2	1.573	730
1.543	1	1.543, 1.541	812, 423
1.518	2	1.518	731
1.451	2	1.452, 1.451, 1.449	233, 004, 541

Reflectance measurements in air and in oil were made using the procedure outlined in Criddle *et al.* (1983), and the data are summarized in Table 1, with the spectra shown in Fig. 1. It can be seen that the mineral is practically uniaxial with a constant R_1. At 590nm, damaraite is 'uniaxial' positive with refractive indices of n_1 2.29 and n_2 2.34. There is a strong absorption peak at 410–420nm for R_2 and the refractive indices peak between 420 and 430nm, with n_2 2.76.

Chemistry

Four electron probe microanalyses were obtained on one specimen (with the working name KOAA) using an analysed mendipite (BM 1923, 709) as standard. the data are summarized in Table. 2. The empirical formula based on $O \pm Cl = 5$ is $Pb_{4.02}O_{\cdot 3.03}Cl_{1.97}$ which leads to a simplified formula $Pb_4O_3Cl_2$. Because of the paucity of material it was not possible to determine

O directly, nor any possible H_2O content. Given that six analyses of damaraite from another specimen, KOAE, gave a low total and low chlorine content (Table 2,7), it is conceivable that OH may substitute, in part, for Cl. An unsuccessful attempt to confirm this was made with an FTIR microscope at the University College of London.

X-ray crystallography

The indexed powder diffraction data are given in Table 3. They were obtained using a 114.6mm Debye-Scherrer camera and Fe-Kα radiation, filtered with Mn. No standards were used. The intensities were estimated visually.

A small fragment of a crystal, showing (010) cleavage faces, was examined using Weissenberg and precession techniques. The systematic extinctions observed from the single crystal patterns were (1) $h0l$ where h was odd, and (2) $h00$, where h was odd. Thus the space group may be $Pma2$, $Pmam$ or $P2_1am$. The unit cell parameters obtained from the single crystal study were used to index the X-ray powder pattern and were then refined with the indexed data. The results are: a 15.104(1), b 6.891(1) and c 5.806(1) Å. The calculated formula unit for the cell is surprisingly Z = 3. For this reason, the X-ray data were rechecked to eliminate the possibility of mistakes, for instance, diagonal rotation axes or missing layers of the reciprocal lattice. There is a trigonal/hexagonal pseudosymmetry, but the deviation is very strong (c 5.968 instead of 5.806 Å). Furthermore, trigonal/hexagonal pseudosymmetry is not permitted by the extinction rules, even if the wrong rotation axis was chosen. These data give a calculated density of 7.84 g/cm^3.

Discussion

There is no similarity between the X-ray data for damaraite and for the two synthetic compounds of $3PbO.PbCl_2$ published in the literature (and for which optical data were not supplied).

1. A quenched compound, possibly a high-temperature modification, tetragonal, with a 3.927, c 13.003 Å, V 200.5 Å^3, and Z = 1 (Aurivillius, 1982).
2. An orthorhombic modification with a 5.58, b 5.62 and c 13.6 Å, V 426.5 Å^3, Z = 2 (Gmelins Handbuch, 1969).

Of the naturally occurring oxychlorides, blixite, $Pb_2Cl(O,OH)_{2-x}$ with x about 0.32, orthorhombic, a 5.832, b 5.694 and c 25.47Å, V 845.8Å, Z = 8 (Gabrielson *et al.*, 1958), has a distinctly different powder pattern from damaraite, as has mendipite, $Pb_3O_2Cl_2$., space group $Pnma$, a 11.87. b 5.806 and c 9.51Å, V 655.4Å^3, Z = 4 (Perrault *et al.*, 1971). However, if slightly more than 1% H_2O is added to the formula of damaraite, the ideal formula, based on 12 Pb atoms, becomes $Pb_{12}O_8Cl_6(OH)_2$ and consequently damaraite would be a dimorph of mendipite. On the other hand, the chlorides and oxychlorides of lead are usually densely packed structures with large ions (Wells, 1984; Aurivillius, 1982 and 1983) and, therefore, randomly distributed vacant sites in the structure may occur (cf. blixite). Taking such vacancies into account, the possible formula of damaraite for Z = 4 would be $Pb_3O_2Cl_{2-x}$ with x about 0.5. Until more material becomes available, suitable for structure determination and IR analysis, these uncertainties must remain unresolved.

Acknowledgements

The authors are indebted to the management of the Tsumeb Corporation Limited and Mr R. C. Chaplin, formerly geological superintendent, for facilitating the recovery of mineral samples from the Kombat mine.

References

Aurivillius, B. (1982) On the crystal structure of a number of non-stoichiometric mixed lead oxide halides composed of PbO-like blocks and single halogen layers. *Chemica Scripta* **19**, 97–107.

—— (1983) On the crystal structure of some non-stoichiometric mixed lead oxide halides and their relation to the minerals lorettoite and sundiusite. Ibid. **22**, 5–11.

Criddle, A. J., Stanley, C. J., Chisholm, J. E. and Fejer E. E. (1983) Henryite, a new copper-silver telluride from Bisbee, Arizona. *Bull. Mineral.* **106**, 511–17.

Dunn, P. J., Peacor, D. R., Su, S.-C., Nelen, J., and von Knorring, O. (1986) Johninnesite, a new sodium manganese arsenosilicate from the Kombat Mine, Namibia. *Mineral. Mag.* **50**, 667–70.

Gabrielson, O., Partwel, A., and Wickman, F. E., (1958) Blixite, a new lead oxyhalide mineral from Langban. *Arkiv Mineral. Geol.* **2**, 411–15.

Gmelins Handbuch (1969) Blei, Teil C, Lieferung 1, 335. Verlag Chemie, Weinheim.

Innes, J. and Chaplin, R. C. (1986) Ore bodies of the Kombat Mine, South West Africa/Namibia, pp. 1789–1805. In *Mineral Deposits of southern Africa.* (Anhaeusser, C. R. and Maske, S., eds.) Vol.2, pp. 1021–2335. Geol. Soc. South Africa.

Peacor, D. R., Dunn, P. J., Su, S.-C. and Innes, J. (1987) Ribbeite, a polymorph of alleghanyite and member of the leucophoenicite group from the Kombat mine, Namibia. *Am. Mineral.* **72**, 213–6.

—— Essene, E. J., Rouse, R. C., Dunn, P. J., Nelen, J. A., Grice, J. D., Innes, J., and von Knorring, O. (1988) Holdawayite, a new manganese hydroxylcarbonate from the Kombat mine, Namibia. Ibid. **73**, 632–6.

Perrault, G., Vincent, H. and Renaud, M. (1971) Étude cristallographique de deux oxychlorures de plomb synthetiques $Pb_3O_2Cl_2$ et Pb_2OCl_2. *Bull. Soc. fr. Mineral. Crist.* **94**, 108–12.

Rouse, R. C., Dunn P. J., and Innes, J. (1986) Kombatite, the vanadium analogue of sahlinite, from the Kombat Mine, South West Africa. *Neues Jahrb. Mineral., Mh.*, 519–22.

—— Peacor, D. R., Dunn, P. J., Criddle, A. J., Stanley, C. J. and Innes, J. (1988) Asisite, a silicon-bearing lead oxychloride from the Kombat mine, South West Africa (Namibia). *Am. Mineral.* **73**, 643–50.

Wells, A. F. (1984) *Structural inorganic chemistry*. Clarendon Press, Oxford.

[*Manuscript received 16 th March 1990*]