

## Danielsite: A new sulfide mineral from Western Australia

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### ABSTRACT

Danielsite, a new supergene sulfide mineral, occurs with other supergene minerals derived from a pocket of primary sulfides in a quartz vein near Coppin Pool, Western Australia. Microprobe analyses gave Ag 36.5, Cu 33.9, Hg 12.3, and S 16.1%, total 98.8%. This corresponds to the formula  $(\text{Cu},\text{Ag})_{14}\text{HgS}_8$ , with Cu:Ag approximately 1.6. Danielsite is gray and weakly bireflecting in reflected light, and moderately anisotropic in shades of gray between crossed Nicols. Maximum and minimum reflectivity values (in %) are 34 and 32 at 470 nm, 31 and 30 at 546 nm, 30 and 28 at 589 nm, and 29 and 27 at 650 nm. Microhardness is  $\text{VHN}_{10} = 38$ . Strongest lines in the powder-diffraction pattern are 2.831(3), 2.622(10), 2.392(5), 1.959(6) and 1.875(6) Å. Danielsite has a composition similar to that of balkanite,  $\text{Cu}_9\text{Ag}_3\text{HgS}_8$ , but its X-ray diffraction pattern, hardness, and anisotropism are quite dissimilar. The mineral is named after John L. Daniels who collected the specimens in which the mineral was found.

### INTRODUCTION

A pocket of unusual supergene minerals in the north-western region of Western Australia was recently described by Nickel (1985). The occurrence is 41 km ESE of the Community of Mount Tom Price, at lat 118°8'E, long 22°53'S, about 1 km due west of a locality known as Coppin Pool.

The supergene assemblage is in a gossanous pod in an otherwise barren white quartz vein and is evidently the weathering product of a sulfide assemblage originally consisting largely of galena and chalcopyrite. Remnants of primary galena contained inclusions of argentian tetrahedrite, breithauptite, chalcopyrite, and amalgam; inclusions of pyrrotite, galena, and chalcopyrite were found in the quartz. These inclusions, and the remnants of galena, represent the only remaining evidence for the composition of the primary sulfide assemblage.

The supergene minerals in this occurrence include anglesite, cerussite, phosgenite, pyromorphite, vanadinite, mottamite, covellite, chalcocite, cuprite, tenorite, malachite, rosasite, stromeyerite, and cinnabar, plus a number of apparently new minerals, brief descriptions of which have been published by Nickel (1985). One of the new minerals is the subject of this paper. It was named danielsite in honor of the geologist Dr. John L. Daniels of Geoscan Pty. Ltd., who collected the material in which the new mineral was found. Both mineral and name have been approved by the IMA Commission on New Minerals and Mineral Names. The holotype specimen has been deposited with the W.A. State Mineral Collection at the Government Chemical Laboratories in Perth, and a cotype specimen is at the Museum of Victoria in Melbourne. No additional specimens exist for distribution.

### OCCURRENCE

Danielsite generally occurs in anglesite as ragged, polycrystalline masses, generally intergrown with covellite, stromeyerite, and/or chalcocite, and as small inclusions in anglesite. Individual grains in the polycrystalline masses are small, attaining about 20  $\mu\text{m}$  in maximum diameter. Paragenetic evidence for the origin of the mineral is very scarce, and no instances of the replacement of primary sulfides have been observed. The only evidence that might have a bearing on its origin is its occurrence, with stromeyerite, in a triangular patch (Figs. 1 and 2), possibly a relict of galena. This occurrence suggests that danielsite, at least in this instance, may have participated in the polymorphic replacement of galena.

### PHYSICAL AND OPTICAL PROPERTIES

Danielsite has not been observed in hand specimen because of its fine grain size and intergrowth with other minerals, and therefore its macroscopic appearance cannot be described. In polished section, it is gray in color, with weak bireflectance. The reflectivity of danielsite was measured against the Zeiss WTiC reflectivity standard, at the four standard wavelengths recommended by the IMA Commission on Ore Minerals. Maximum and minimum percentage reflectivities at these wavelengths are 470 nm—34, 32; 546 nm—31, 30; 589 nm—30, 28; and 650 nm—29, 27. Between crossed Nicols, it is moderately anisotropic in shades of gray. It is very similar in appearance to stromeyerite, with which it is sometimes associated, the chief difference being in the anisotropism of the two minerals: stromeyerite is more strongly anisotropic, with colors going from yellow to brown.

Danielsite is brittle and quite soft, with a  $\text{VHN}_{10}$  hard-

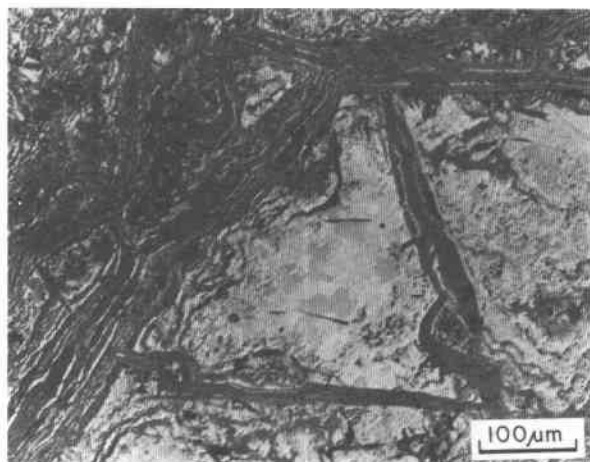


Fig. 1. Photomicrograph of polished section showing a triangular area composed of an intergrowth of danielsite, stromeyerite and chalcocite (shades of light gray). The lamellae bounding the triangular area consist mainly of anglesite. From Nickel (1985); reprinted by permission of the Geological Society of Australia.



Fig. 2. Scanning-electron micrograph (back-scattered-electron image) of the same area as Fig. 1, but with the contrast between minerals greatly increased. Danielsite (light gray) and stromeyerite (slightly darker) occupy the center of the triangular area and are surrounded by chalcocite (black). The anglesite is white.

ness of 38 (equivalent to a Mohs' hardness of 2–2½). No cleavage was discernible, but because of the small size of the crystallites, the possibility of cleavage cannot be excluded. The density could not be measured, but it can be expected to be in the neighborhood of 6 g/cm<sup>3</sup>, by analogy with balkanite and stromeyerite.

### COMPOSITION

Danielsite was analyzed in polished section by electron microprobe, using crystal spectrometers and the following standards: galena (S), cinnabar (Hg), and metals (Ag and Cu). The results, shown in Table 1, calculated on the basis of 23 atoms, by analogy with the composition of balkanite, give a composition corresponding to Cu<sub>8.54</sub>Ag<sub>5.43</sub>Hg<sub>0.98</sub>S<sub>8.05</sub>, or ideally, (Cu,Ag)<sub>14</sub>HgS<sub>8</sub>. No elements other than Cu, Ag, Hg, and S were detected.

### X-RAY DIFFRACTION

No crystals of suitable size for single-crystal X-ray work could be isolated. In fact, it was difficult to find areas sufficiently large to enable material to be gouged out for a powder-diffraction pattern. However, a Debye-Scherrer pattern was obtained from a small amount of powder scraped from an area of relatively pure danielsite in a

TABLE 1. Results of microprobe analysis of danielsite

	Weight percent				Atomic proportions	
	1	2	3	Avg.		
Cu	34.5	34.6	32.5	33.9	8.54	} 13.97
Ag	36.8	35.8	37.1	36.5	5.43	
Hg	12.2	12.4	12.2	12.3	0.98	
S	16.2	16.3	15.8	16.1	8.05	
Total	99.7	99.1	97.6	98.8	23.00	

polished section. Measurements of this pattern are given in Table 2. The pattern contains a few weak lines that can be attributed to anglesite, but otherwise the pattern does not correspond with that of any known mineral, in particular with that of balkanite or stromeyerite, the two minerals closest in composition to danielsite.

Attempts were made to index the diffraction pattern in the hope of determining the unit cell of danielsite. The majority of the lines could be indexed on a triclinic unit cell, but the agreement between measured and calculated *d* values was too poor to maintain confidence in the indexing, and therefore the values obtained are not cited here. In any case, triclinic sulfides are virtually nonexistent, and such a unit cell is therefore unlikely for danielsite. The main reason for the failure to adequately index the powder pattern is the broadness of many of the diffraction peaks.

TABLE 2. X-ray powder-diffraction data for danielsite

<i>l</i>	<i>d</i>	<i>l</i>	<i>d</i>
2	4.44	<1	2.222
1	4.11 (A)	1	2.080 (A)
2	3.648	1	2.034
<1	3.493	1	1.991
<1	3.401	6	1.959
1	3.314 (A)	6	1.875
<1	3.198 (A)	2	1.692
2B	3.018 (A)	1	1.642
<1	2.885	<1	1.588
3	2.831	<1	1.512
10	2.622	<1	1.425
1	2.564	1B	1.279
1	2.475	1	1.259
5	2.392		

Note: Cu<sub>Kα</sub> radiation, 1.54178 Å, 57.3-mm Debye-Scherrer camera. (A): possible interference with strongest lines of anglesite pattern.

Attempts were also made to synthesize danielsite in the hope that crystals suitable for single-crystal X-ray work could be produced, but these efforts were unsuccessful. Much as I dislike publishing unindexed X-ray diffraction patterns, in this case there does not appear to be an alternative.

### DISCUSSION

The empirical formula for danielsite,  $\text{Cu}_{8.54}\text{Ag}_{5.43}\text{Hg}_{0.98}\text{S}_{8.05}$ , is quite similar to the chemical formula of balkanite,  $\text{Cu}_9\text{Ag}_5\text{HgS}_8$  (Atanassov and Kirov, 1973), with Ag being somewhat higher, and Cu somewhat lower, in danielsite. The reflectivities of the two minerals are also quite similar, but there the similarity ends. The X-ray diffraction patterns of the two minerals are quite different, and balkanite is substantially harder, and more strongly anisotropic than danielsite. Furthermore, balkanite appears to be a primary mineral, formed as the result of hydrothermal activity, whereas danielsite is clearly of supergene origin.

If the empirical formula is written as  $\text{Cu}_{1.11}\text{Ag}_{0.71}\text{Hg}_{0.13}\text{S}_{1.05}$ , the similarity with stromeyerite,  $\text{CuAgS}$ , becomes evident. Here again, however, there are equally

substantial differences in X-ray diffraction pattern and anisotropism. Another, perhaps essential, difference is the Hg content of danielsite. Since it was not possible to synthesize danielsite, it is uncertain whether Hg is essential for the structural stability of the mineral. If not, then a possible general formula for the mineral might be  $(\text{Cu,Ag})_2\text{S}$ . However, in his exploration of the Cu-Ag-S system, Skinner (1966) did not report any evidence for the existence of such a compound. On balance, therefore, it appears that the ideal formula for danielsite should be  $(\text{Cu,Ag})_{14}\text{HgS}_8$ , with Cu:Ag approximately 1.6.

### REFERENCES

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