On the nature of Berthierite.

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SIX analyses of berthierite from various localities are quoted by Dana [1] and show a varying composition. The analyses correspond approximately to the formulae $FeS.Sb_2S_3$, $3FeS.2Sb_2S_3$, and $3FeS.4Sb_2S_3$. It is considered by Dana that the variation is probably due to the impurity of the analysed material and that the composition of berthierite is probably $FeS.Sb_2S_3$. This view is supported by the examination and analysis of a specimen of berthierite from Nullamanna, 18 miles north of Inverell, New South Wales.

The specimen was kindly lent by Mr. G. W. Card, Curator of the Mining Museum, Sydney, for comparison with certain minerals under investigation, and measured approximately $1 \times 1 \times 0.7$ cm. It was sliced and one portion was polished for examination under the reflecting microscope while the other portion was used for the chemical analysis. In the hand-specimen a columnar structure is seen and the colour is dark steel-grey, except for tarnish colours. Like stibnite, it is soft and takes a good polish when polished on a soft flannel or felt.

The polished section proves on examination to be fairly pure except for a certain amount of intergrown stibnite, from which berthierite is not readily distinguished without etching. The colour of the berthierite is bright white and may show a faint tinge of pink in comparison with stibnite. Like stibnite, the colour is slightly variable according to the orientation of the crystals; and in a homogeneous aggregate, some grains possess a shade distinctly more grey or greyish-pink than others, and sufficient to partly reveal the structure of the aggregates. When the reflected light is wholly polarized these changes are stronger and general. This may be observed in a crystal by rotating the stage, and the phenomenon is analogous either to that of general absorption in transmitted light in such minerals as calcite, or to pleochroism.

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[1] Dana, System of Mineralogy, 6th edit., 1892, p. 115.

Like stibnite, berthierite shows a marked effect in polarized light with crossed nicols. The section, being parallel to the columnar structure, shows a number of long prismatic crystals, lying with their long axes parallel. In places the prisms are fractured and bent, and some are twinned. The colours are similar to those of stibnite, from which it can be distinguished in this section by the absence of the complex internal structure of stibnite. The structure of the berthierite visible between crossed nicols is shown in fig. 1, where the intergrown stibnite has been darkened by etching prior to photographing.

Berthierite is readily distinguished from stibnite by its behaviour on etching with HNO_3 or with KOH. With HNO_3 of standard strength (1 to 1) stibnite is readily blackened, while berthierite is only faintly affected. A tarnish slowly develops on the Nullamanna berthierite, but at a very much slower rate than on stibnite. A slight tarnish also develops on berthierite upon etching with KCN (20 % solution), and in these two respects the Nullamanna berthierite differs from that recorded by Murdoch[1] and Davy and Farnham,[2] which is negative to all etching reagents except KOH and NaOH.

With a concentrated solution of KOH both minerals are rapidly attacked, but stibnite is immediately covered with a yellow coating, while the berthierite is merely darkened. Berthierite is also darkened by NaOH, while stibnite remains unaffected.

The etching process thus enables a strong contrast to be developed between the berthierite and the stibnite (fig. 2). This photograph represents the same field of view as fig. 1, which, prior to photographing, was etched with KOH and partly re-polished. The internal structure of the prism of stibnite in the photograph is not uniform, but, when polished, is revealed in polarized light as an aggregate of interlocking individuals, some of which show twinning. The differing orientation of these crystals is the cause of varying depths of etching. The more lightly etched surfaces have been cleaned during re-polishing after etching, so producing a speckled appearance on the stibnite in the photograph. The difference between the two minerals is finally demonstrated when a microchemical test for iron is carried out on excavated particles of berthierite and a copious development of Prussian blue is observed microscopically upon addition of a grain of potassium ferrocyanide to the test solution.

[1] J. Murdoch, Microscopical determination of the opaque minerals, 1916, p. 103.

[2] W. M. Davy and C. M. Farnham, Microscopic examination of the ore minerals, 1920, p. 117.

In order to estimate the relative proportions of berthierite and stibnite, the etching process with KOH was used and the yellow precipitate allowed to remain on the stibnite. The amount of the yellow coated mineral was then determined by the Rosiwal micrometric method in the same way as employed in rock sections in transmitted light, and it was found that the amount of stibnite was approximately 16 % of the surface area of the

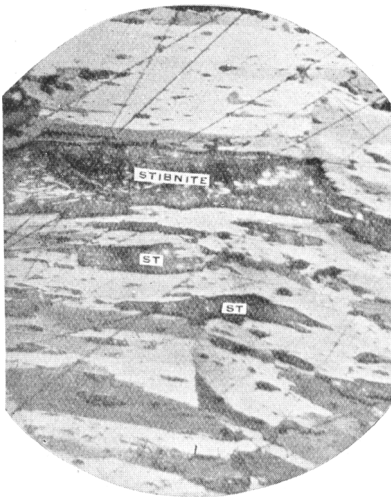<div align="center">FIG. 1.   FIG. 2.</div>

FIG. 1. Polished section of berthierite and stibnite (st), showing parallel arrangement of prisms of berthierite visible between crossed nicols, from Nulla-manna, New South Wales. The section has been etched with KOH and sufficiently re-polished to remove all tarnish from the berthierite, so that, in ordinary light, the stibnite (st) appears dark in comparison with the berthierite. Mag. 50 diams.

FIG. 2. Polished section of berthierite and stibnite (st), Nullamanna, New South Wales. It represents the same field of view as fig. 1 photographed in ordinary light. Mag. 50 diams.

polished section. Allowing for the relative densities of stibnite and berthierite, this is increased to approximately 18 % by weight.

Chemical Analysis.—The specimen was analysed by W. A. Grieg in the Mines Department laboratory, New South Wales, and the result is given in column I. The atomic ratios derived from this analysis are given in columns II and III, while column IV is an analysis of berthierite from Bräunsdorf, Saxony, quoted by Dana.

	I.	II.	III.	IV.
Sb	58·63	0·480	8	59·30
Fe	10·08	0·180	3	10·16
S	28·71	0·897	15	30·53
Insol. matter	1·44			—
Water	1·14			—
	100·00			99·99

The similarity with the Bräunsdorf specimen is evident on these figures, and it can be inferred that the Bräunsdorf specimen, like the Nullamanna specimen, was contaminated with stibnite. Moreover, the extent of the contamination is practically the same, because both analyses correspond approximately to the formula $3FeS, 4Sb_2S_3$.

The actual composition of the berthierite can be estimated by making allowance for the 18 % of stibnite which has been determined microscopically. In the compound $3FeS . 4Sb_2S_3$ there is 83·6 % Sb_2S_3 and 16·4 % FeS. Removing 18 % Sb_2S_3, there remains 65·6 % Sb_2S_3 and 16·4 % FeS, which, expressed in percentages, is 80 % Sb_2S_3 and 20 % FeS. The calculated amounts of Sb_2S_3 and FeS in the compound $FeS . Sb_2S_3$ are 79·2 % Sb_2S_3 and 20·8 % FeS. Considering the approximate nature of the Rosiwal determination, these figures seem sufficiently close to indicate that the formula of berthierite is $FeS . Sb_2S_3$.

The association of berthierite with the same amount of stibnite in two such widely separated localities as Bräunsdorf and Nullamanna appears to indicate that an iron sulph-antimonite $3FeS . 4Sb_2S_3$ formerly existed during an early stage of the formation of the mineral vein, and that during the later stages this compound dissociated into berthierite and stibnite. In any case it would appear as if the development of the berthierite occurred in the presence of excess antimony sulphide.