COSTIBITE (CoSbS), A NEW MINERAL FROM BROKEN HILL, N.S.W., AUSTRALIA

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ABSTRACT

Costibite from the Consols Mine, Broken Hill, New South Wales is a new mineral having the composition CoSbS, essentially the same as paracostibite from Red Lake, Ontario, Canada, but with a different space group and crystal structure. Costibite is orthorhombic with \( a = 3.603, b = 4.868, c = 5.838 \text{Å}, Z = 2 \), space group \( Pmn2_1 \), calc. \( \rho = 6.89 \text{ g/cc} \). The strongest lines of the X-ray powder pattern are: 4.86(5) (010), 2.90(6) (110), 2.596(10) (111), 2.503(9) (012), 1.908(8) (121), 1.803(4) (200), 1.714(4) (103), 1.616(4) (113), and 1.465(4) (212).

In reflected light the mineral is greyish in color, very similar to paracostibite, it is weakly bireflecting and weakly anisotropic. Its microhardness value is 781 kg/mm\(^2\) with a 15 g load.

INTRODUCTION

Subsequent to discovering the new mineral paracostibite in ore from the Red Lake area, Ontario, we were fortunate to obtain what appeared to be a type willyamite specimen for a reexamination by modern techniques; this led to our discovery of the new mineral costibite. Paracostibite (CoSbS) is orthorhombic with space group \( Pbca \) (Cabri et al., 1970a); willyamite, as redefined (Cabri et al., 1970b), is the portion of the pseudocubic (Co, Ni)SbS series where Co > Ni.

The optical properties of paracostibite and costibite are nearly identical. The composition of these two minerals, as well as those of the hypothetical cobalt end-member of the willyamite solid solution series, are also nearly identical. This created the remarkable situation whereby two, and possibly three polymorphs of CoSbS have been discovered within the space of a few months, where previously none were known.

MATERIALS AND METHOD OF INVESTIGATION

The museum sample examined was obtained from the Smithsonian Institution, Washington, D.C., and bore the U.S. National Museum number R849, labelled “Willyamite, Consols Lode, Broken Hill, N.S.W.” The sample came from the Roebling collection with the following note attached: “from George Smith, chemist at the mine, only specimen found, $10., near ulmannite, W. A. Roebling.” Dr. J. S. White, Jr., who kindly sent us the specimen, feels that this can be regarded as the type specimen from willyamite since it was Smith who had found the “willyamite” described by Pittman (1893); we share this opinion. This specimen will also become the type for costibite, and is preserved at the Smithsonian Institution. A polished section cut from the specimen is preserved at the National Mineral Collection, Ottawa.

The sample was studied by ore microscopy, X-ray diffraction analysis, and electron-

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Fig. 1. Photomicrograph of large ulimanite-willyamite zoned crystal (gray) surrounded by lollingite (white) containing lamellae of costibite (gray). Four of the black areas are holes from which material was removed for X-ray powder diffraction analysis. The gangue mineral (black) surrounding the lollingite is siderite. The large costibite lamella showing a hole, in the upper right portion of the photomicrograph, was subsequently dug out of the single-crystal work.

Probe microanalysis. The X-ray powder data were obtained by the film method using 114.6-diameter Debye-Scherrer powder cameras. Film shrinkage corrections were applied, and the unit-cell parameters were refined by a least-squares computer program. The single-crystal work was done by the precession method.

The composition of costibite was determined using a Materials Analysis Company (MAC) model 400 electron-probe microanalyser. Synthetic CoSbS, NiSb, and FeAs, synthesized from high purity elements, were used as standards. The techniques employed in synthesizing some of these are reported in Cabri et al. (1970a).

The ore microscopy, including reflectivity measurements and microhardness determinations, were performed on samples mounted, polished, and finally buffed as described by Cabri et al. (1970a). The apparatus and techniques used for reflectivity measurements and microhardness indentations are those described by Cabri and Traill (1966) except that a 16.5:1 objective with a numerical aperture of 0.40 was used.

**General Mineralogy**

A section from sample R849 consisted of a zoned crystal of willyamite-ullmannite surrounded by a rim of lollingite. This lollingite contains costibite lamellae (up to 0.2×1.4 mm) that appear to be oriented parallel to the sides of a large willyamite-ullmannite zoned crystal (Fig. 1). Figure
Fig. 2. Photomicrograph of two costibite lamellae (grey) in lollingite (white) near the edge of an ullmannite-willyamite crystal (grey). A vein of pyrargyrite cuts across the costibite. A rim of cobaltite (light grey) can be seen at the boundary between the lollingite and siderite (large black area).

2 shows other costibite lamellae at a greater magnification which permits the sharp contact with lollingite to be seen more clearly. It is noteworthy that, although some of the costibite lamellae are very nearly in contact with willyamite, there is either lollingite or pyrargyrite between them.

**Physical, Optical, and Chemical Properties**

In reflected light the mineral is very similar to paracostibite and willyamite. Like paracostibite, but unlike willyamite, it is weakly bireflecting and weakly anisotropic. It is greyish in color in air and in oil immersion in contrast to the surrounding lollingite. The reflectivity spectrum for two grains, using a calibrated silicon standard, was measured from 440 to 650 nm but was found to be rather featureless. The values at four wavelengths are given in Table 1; those for paracostibite, willyamite and ullmannite are also given, for comparison purposes.

The VHN microhardness gave an average value of 781 kg/mm² (range 695-1009, 12 indentations on four grains) for a 15 g weight, in contrast to 1009 kg/mm² and a narrower range obtained for paracostibite using
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The small differences between these values can be attributed to errors in measurement due to the differences in the surface polish.

The electron back scatter and X-ray images for various elements of a small area in Figure 2 showing a tabular costibite crystal in löllingite is illustrated in Figure 3. The FeKα, CoKα and NiKα images clearly distinguishes cobaltite rimming löllingite, which, in turn, is surrounded by the siderite gangue.

We were able to obtain X-ray diffraction patterns free of any other phases, and one such pattern is listed in Table 2. The X-ray powder pattern for costibite is compared to that of rammelsbergite in Figure 4. The two patterns exhibit some similarity, but close examination shows that there are significant differences. A fragment of costibite was removed for single-crystal work with a precession camera. The space group (Pmn2₁ or Pmma) could not be uniquely determined by the precession method. Dr. E. J. Gabe, of our Division, who is working on the structure of costibite as well as that of synthetic paracostibite, has informed us that the three dimensional Patterson map indicates that the space group for costibite is Pmn2₁. These structures will be reported at a later date. The cell dimensions given in Table 2 are taken from single-crystal diffractometer measurements and agree closely with values calculated from the powder film. On the basis of Z=2, the calculated density is 6.89 g/cc.

<table>
<thead>
<tr>
<th>Wavelength nm</th>
<th>Costibite Consols lode, N.S.W. U.S.N.M. #R 849 Average</th>
<th>Paracostibite Red Lake, Ontario Max.</th>
<th>Willyamite Consols lode, N.S.W. U.S.N.M. #R 849 Max.</th>
<th>Ullmannite Consols lode, N.S.W. R.O.M. #E-1768 Max.</th>
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<tbody>
<tr>
<td>470</td>
<td>44.4</td>
<td>47.8</td>
<td>46.9</td>
<td>47.2</td>
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<tr>
<td>546</td>
<td>45.9</td>
<td>48.1</td>
<td>47.5</td>
<td>47.7</td>
</tr>
<tr>
<td>589</td>
<td>45.5</td>
<td>48.4</td>
<td>47.7</td>
<td>46.7</td>
</tr>
<tr>
<td>650</td>
<td>47.8</td>
<td>48.8</td>
<td>48.0</td>
<td>48.9</td>
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Table 1. Reflectivities, in Percent
Fig. 3. Part of the area of Figure 2 showing electron back-scatter and as element fluorescent X-ray images. This permits all the minerals occurring in this photomicrograph to be distinguished, and the noncontact of costibite and willyamite to be delineated.

The name costibite (KÖ-STĪB-AIT), is for the composition (CoSbS). It has been approved by the Commission on New Minerals and Mineral Names, I.M.A.

**Discussion**

Costibite and paracostibite can both be considered as polymorphs of composition CoSbS, and willyamite, could possibly be yet a third polymorph. The pure CoSbS end-member for willyamite has not yet been found (Cabri et al., 1970b), but there is no theoretical reason why it should not occur. The relationship between these polymorphs, and their thermal stabilities, is of interest because of the clues it provides about the genesis of the ore deposits in which they occur.

Synthetic preparations of CoSbS by “dry fusion” (Cabri et al., 1970a) have only produced paracostibite. Bayliss (1969) reports the production
COSTIBITE

Table 2. X-Ray Powder Diffraction Data for Costibite
Fe-Filtered Co Radiation

<table>
<thead>
<tr>
<th>(a = 3.603 \pm 0.002)</th>
<th>(b = 4.868 \pm 0.002)</th>
<th>(c = 5.838 \pm 0.002)</th>
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<tr>
<td>(I(\text{est.}))</td>
<td>(d(\text{meas.}) \AA)</td>
<td>(hkl)</td>
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<tr>
<td>5</td>
<td>4.864</td>
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<td>4</td>
<td>3.075</td>
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<td>5</td>
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<tr>
<td>2</td>
<td>1.2973</td>
<td>222</td>
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Intensities estimated visually, b signifies broad.

Fig. 4. X-ray powder diffraction patterns of (a) rammslsbergite and (b) costibite. Fe-filtered Co radiation, 57.3-mm Debye-Scherrer camera. The low-angle reflections for costibite cannot be seen in this reproduction. The rammslsbergite is No. 511 from the mine of Siscoe Metals of Ontario, Gowagnda, and has a composition, as determined by electron-probe microanalysis, of Ni 25.0, Co 3.3, Fe 0.0, As 67.0, S 1.7; total 97.0%.
of non-cubic CoSbS at 550°C using a LiCl-KCl flux, but it is not known whether he had costibite or paracostibite. Paracostibite is stable up to 876 ± 5°C and annealing experiments on synthetic material produced no change down to 100°C (Cabri et al., 1970a), which were annealed for three days. These data suggest that costibite is a lower temperature polymorph.

We performed experiments to determine the temperature at which CoSbS reacts with synthetic FeAs$_2$ by grinding mixtures of the two and annealing at various temperatures. The temperature at which the reaction occurs to form (Fe, Co)As$_2$+FeS+Sb was determined to be 445 ± 10°C. This gives an upper temperature limit for the costibite lamellae in löllingite found in the Australian Broken Hill Consols Lode. Longer term experiments, longer than 7 to 17 days, may give a more precise temperature.

The difference between the mineralogy of the A. B. H. Consols lode and the “Thackaringa” sulphide ores has been discussed by Markham and Lawrence (1962) and Lawrence (1967, 1968). Although they suggest that both types of deposits are due to a certain amount of remobilization and redeposition, they imply that the A. B. H. Consols ore must have had a different genesis than the more numerous “Thackaringa”-type deposits in the Broken Hill area. Their arguments are based on the kind of mineralogy and the greater complexity of the Consols ore; they also suggest a similarity between the Consols and St. Andreasburg ores.

The A. B. H. Consols ore contains other mineral pairs that are thought to be dimorphous, such as argentopyrite-sternbergite (AgFe$_2$S$_3$) and pyrostilpnite-pyrargyrite (Ag$_3$SbS$_3$) (Markham and Lawrence, 1962). The apparently non-reversible reaction, pyrostilpnite→pyrargyrite, was given as <197°C (Chang, 1963), and the breakdown of both argentopyrite and sternbergite to form, initially, acanthite, monoclinic pyrrhotite, pyrite, and vapor, (a metastable assemblage) was determined to occur, as low as 152 ± 3°C (Taylor, 1969). Although we were unable to find either argentopyrite or pyrostilpnite in our sample, their presence in other parts of the Consols fissure vein suggests that the ore-forming processes were still in operation below 152°C together with low values for sulfur fugacity (Czamanske, 1969). A more detailed presentation of the chemical identity of argentopyrite and sternbergite is presented by Murdock and Berry (1954), Czamanske and Larson (1969). The presence of the costibite-löllingite mineral pair in our specimen gives an upper temperature limit of 455°C for the crystallization of the assemblage of these minerals. We have no evidence, at present, on the upper stability limit of the zoned willyamite.

It is, of course, very difficult to present a more detailed discussion of
the genesis of the Consols ore on the basis of one sample. The number and
variety of the polymorphic mineral pairs found in this ore warrants a
detailed reexamination of the mineralogy by modern methods. This
would be of help for the eventual elucidation of the phase chemistry
of the ore by laboratory experiments.

Acknowledgments

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