

# AUSTINITE, A NEW ARSENATE MINERAL, FROM GOLD HILL, UTAH\*

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In September, 1933, a suite of specimens collected from an outcrop of the Western Utah Copper Company's orebody at Gold Hill, Utah, was sent to the mineralogical laboratory of Stanford University by Dr. W. R. Landwehr. The material contained well developed crystals of quartz, adamite,<sup>1</sup> and also some minute colorless crystals which proved to be a new mineral. The name *austinite* was chosen for this new mineral in honor of Professor Austin F. Rogers, and in recognition of his many valuable contributions to the science of mineralogy.

Both gold and copper have been found at Gold Hill and about ten years ago scorodite was mined as a source of arsenic. The fact that this occurrence is normal scorodite was shown by Foshag, Berman, and Doggett.<sup>2</sup> The common minerals and general geology of the district have been discussed by Kemp and Billingsley,<sup>3</sup> and by Butler.<sup>4</sup>

## GENERAL DESCRIPTION OF AUSTINITE

Austinite occurs in distinct, well developed, orthorhombic crystals of bladed or acicular habit, elongated parallel to the *c*-axis. The mineral occurs in the oxidized zone, where it is found developed on the colloform surfaces of limonite or lining small cavities. It is closely associated with adamite, and it appears to be a later mineral, since in many cases groups of crystals of austinite have been found coating and growing on top of the adamite. A very unusual feature of the occurrence of the austinite is the prevalence of scepter crystals of the type shown in Fig. 1. The reason for this peculiar habit is not known to the author. It is difficult to find doubly terminated crystals, but when the scepter

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<sup>1</sup> A description of the adamite will be given in a later paper.

<sup>2</sup> Foshag, W. F., Berman, H., and Doggett, R. A., Scorodite from Gold Hill, Tooele Co., Utah: *Am. Mineral.*, vol. 15, pp. 390-391, 1930.

<sup>3</sup> Kemp, J. F., and Billingsley, P., Notes on Gold Hill and Vicinity, Tooele Co., Western Utah: *Econ. Geol.*, vol. 13, pp. 247-274, 1918.

<sup>4</sup> Butler, B. S., et al, The Ore Deposits of Utah: *U.S.G.S. Prof. Paper 111*, pp. 476-484, 1920.

habit is developed and the "stalk" is very thin, an almost perfectly doubly terminated crystal may be obtained by breaking off the "stalk." The crystals are colorless and have a sub-adamantine luster. The cleavage is good in two directions, parallel to the prism faces  $\{110\}$ . The average length of the crystals is 0.5 mm. and the maximum is about 1 mm. Because of this minuteness it is difficult to obtain good images with the reflection goniometer from some of the smaller faces.

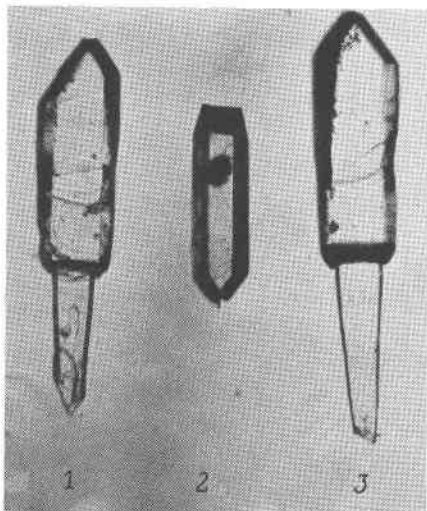


FIG. 1. Crystals of austinite. 1 and 3 are scepter crystals; 2 is doubly terminated, with "stalk" broken off. 1 is a right-handed crystal; 2 and 3 are left-handed. Actual length of 2 is 0.3 mm.

#### GEOMETRICAL CRYSTALLOGRAPHY

Austinite belongs to the rhombic disphenoidal class ( $3A_2$ ) of the orthorhombic system. The most common forms on the crystals are the rhombic prism  $m\{110\}$  and a rhombic disphenoid, either positive  $p\{111\}$ , or negative  $\rho\{1\bar{1}1\}$ . A few of the crystals are modified by  $b\{010\}$  and  $q\{011\}$ . In addition there are faces, on some of the crystals, of very low slope and from their appearance and the easy solubility of the mineral, it seems probable that they are due to solution. If the crystals are doubly terminated and the prism faces equally developed, the crystals resemble those in Fig. 2. The left drawing in Fig. 2 was made by turning over the

right, and connecting pin holes which had been pricked through at the corners of the latter. This is essentially the same method as that given for enantiomorphous crystals by Rogers.<sup>5</sup> The most common habit is that shown by crystals 1 and 3 in Fig. 1, where two of the opposite prism faces are wide and the other two are narrow. This gives the crystal a bladed habit. It is interesting to note that on none of the crystals studied were both right-handed and left-handed disphenoids present. Also, it seems from the crystals studied to date that the right-handed ones are more common

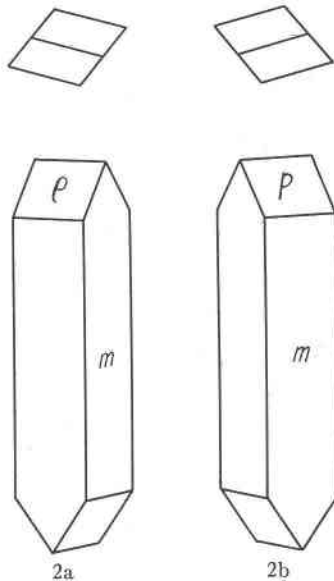


FIG. 2. Left-handed (2a) and right-handed (2b) crystals of austinite with the forms  $m\{110\}$ ,  $p\{111\}$ , and  $\rho\{1\bar{1}1\}$ .

than the left-handed. In Fig. 1, crystal 1 is right-handed while crystals 2 and 3 are left-handed.

Because of the scepter habit of most of the crystals it required examination of a great many of them to obtain material suitable for goniometric work. It was finally found possible to obtain crystals that gave good signals from the prism and the rhombic disphenoid faces. Because of the narrowness of the  $b\{010\}$  faces, weak signals were obtained, but they were fairly good. The  $q\{011\}$

<sup>5</sup> Rogers, A. F., *Introduction to the Study of the Minerals*, 1st ed., p. 153, 1912.

faces were in all cases too small to give definite signals, so positions of maximum reflection had to be chosen, and the results have an accuracy of only about a half of a degree. The angles measured are tabulated below (Table 1).

TABLE 1

Angle	No. of xls.	No. of meas.	Limits	Average angle (weighted)	Calculated angle
$mm'''$ (110 $\wedge$ 1 $\bar{1}$ 0)	12	54	66°27'– 66°45'	* 66°37'	
$pp'$ (111 $\wedge$ 1 $\bar{1}$ 1)	6	30	113 1–113 27	*113 10	
$\rho\rho'$ (1 $\bar{1}$ 1 $\wedge$ 1 $\bar{1}$ 1)	2	10	113 8–113 25	113 12	113°10'
$mb$ (110 $\wedge$ 010)	4	10	56 29– 56 44	56 41	56 41½
$bq$ (010 $\wedge$ 011)	6	12	48 50– 51 26	49 35	50 14
$m\bar{p}$ (110 $\wedge$ 111)	6	11	33 27– 33 31	33 30	33 25
$m''\rho$ (1 $\bar{1}$ 0 $\wedge$ 1 $\bar{1}$ 1)	2	4	33 24– 33 28	33 26	33 25
$m''\bar{p}$ (1 $\bar{1}$ 0 $\wedge$ 111)	1	8	70 32– 70 35	70 34	70 39

The fundamental angles, given with an asterisk in Table 1, lead to the axial ratio:

$$a:b:c = 0.657:1:0.832$$

Although great care was taken in the goniometric measurements, it is believed that because of the small size of the crystals, computation of the axial ratio to the fourth place is not warranted. This is in accord with the suggestion of Hey,<sup>6</sup> who has pointed out the tendency of crystallographers to state their results in a manner indicating unwarranted accuracy.

The angles computed for the unit faces are  $100 \wedge 110 = 33^\circ 18\frac{1}{2}'$ ,  $001 \wedge 101 = 51^\circ 42\frac{1}{2}'$ , and  $001 \wedge 011 = 39^\circ 46'$ .

#### ETCH FIGURES

Crystals of austinite were etched with very dilute HCl (1:6). Etch figures are produced on the rhombic disphenoid in a few seconds, but they are not very distinct. The best etch figures were obtained on the prism faces and this required an immersion in the acid of only three or four minutes for best results. Fig. 3 gives developments of right- and left-handed crystals showing the type of etch figure that is found on each prism face. It would be possible

<sup>6</sup> Hey, M. H., On the Accuracy of Mineralogical Measurements: *Mineral. Mag.*, vol. 23, pp. 495–496, 1934.

to tell whether the prisms were right- or left-handed by using etch figures, even if the crystals were not terminated. The etch figures confirm the lack of symmetry planes and indicate that the crystals must belong to the class with the symmetry  $3A_2$ , that is, the rhombic disphenoidal class. Epsomite, goslarite, morenosite, leucophanite, and edingtonite have this same symmetry and possibly sulphur also belongs in this class. Although the rhombic disphenoidal class includes only a few minerals, it is interesting to note that this class is represented by over 400 artificial substances.

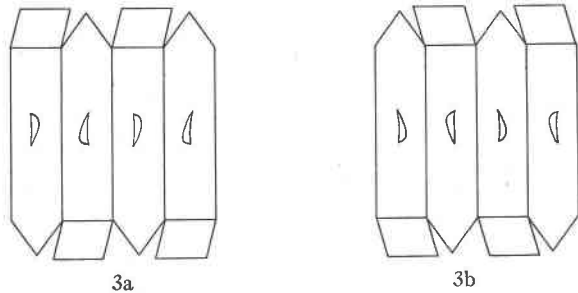


FIG. 3. Etch figures diagrammatically shown on the prism faces of left-handed (3a) and right-handed (3b) crystals of austinite.

#### SPECIFIC GRAVITY

The specific gravity of austinite is about 4.12. This value was determined by the pycnometer method. Since only 0.166 grams of the material was available for the determination, and furthermore since it was impossible to completely free this material from a small amount of impurities, the gravity determination can only be considered an approximate value.

#### OPTICAL PROPERTIES

The values obtained for the three principal indices of refraction using a Wratten orange screen (E 22), made by the Eastman Kodak Co., were:

$$n_{\alpha} = 1.759 \pm 0.003, \quad n_{\beta} = 1.763 \pm 0.003, \quad n_{\gamma} = 1.783 \pm 0.003.$$

The maximum double refraction derived from these indices is,  $n_{\gamma} - n_{\alpha} = 0.024 \pm 0.006$ . The liquids used for the index determinations were made by dissolving sulphur in methylene iodide and although they stood for two months it was considered advisable to check their indices each time when used, since they were found

not to remain absolutely stable. The prism method with the goniometer was used for the index determination of the liquids.

The plane of the optic axes lies parallel to  $a\{100\}$  and  $a=\beta$ ,  $b=\gamma$ ,  $c=\alpha$ . Because of the good prismatic cleavage it was difficult to obtain a random orientation of the cleavage fragments. In order to avoid possible error in the determination of the indices of refraction from this cause, fragments giving desired interference figures were used in the index determinations. Both the crystals and the cleavage fragments are length-fast, or have negative elongation.

The mineral is optically positive, and  $2V$  is approximately  $47^\circ$ . This value for the optic axial angle was obtained by using Mallard's method, the constant  $D$  for the microscope being obtained from a piece of muscovite with carefully determined  $2V$ . The value of  $2V$  for austinite, calculated from the indices of refraction, checks that obtained by Mallard's method within two degrees.

#### CHEMICAL COMPOSITION

A preliminary qualitative examination of the crystals was made by microchemical methods. The value of a microchemical examination, where only a small amount of material is available, was clearly shown in this case. By dissolving just one or two of the crystals it was possible to show that the mineral contained zinc and calcium in abundance and that it was an arsenate. The potassium mercuric thiocyanate test was used for zinc, and calcium was shown to be present by precipitating microchemical gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) with dilute sulphuric acid in the presence of alcohol. The arsenate radical was detected by the  $\text{AgNO}_3$  test, and the presence of arsenic was corroborated by  $\text{H}_2\text{S}$  precipitation. The Penfield closed tube test for water was employed on 0.0435 g. of the mineral and indicated a water content of 3.2 per cent. From these preliminary tests it was concluded that the mineral is a basic calcium zinc arsenate.

Austinite is soluble with ease in cold dilute  $\text{HCl}$ . Due to the ready solubility of the mineral, it proved to be a good subject for study by etch figures.

A complete analysis was made by Dr. R. B. Ellestad of the University of Minnesota Rock Analysis Laboratory on 1.2 grams of carefully selected material. In purifying the material for the analysis, part of the limonite clinging to the grains was dislodged by

means of a needle point, and the rest was taken from the crushed sample by means of a strong electro-magnet. However, in spite of the fact that each minute grain selected for analysis was carefully examined under the microscope, it was impossible to avoid some contamination from quartz and adamite. They are both intimately associated with the austinite and they are difficult to distinguish from it in such small aggregates. The quartz did not seriously interfere in the analysis, since it was insoluble and was just reported as residue. The analysis of the austinite is given in column I.

## ANALYSIS OF AUSTINITE BY R. B. ELLESTAD

	I	II	III	IV	V	VI
CaO	19.2	.342	2×.171	.342	= .342	= 2×.171
ZnO	32.5	.399	2×.199	.399-.057	= .342	= 2×.171
As <sub>2</sub> O <sub>5</sub>	42.7	.186	1×.186	.186-.014	= .172	= 1×.172
P <sub>2</sub> O <sub>5</sub>	0.1					
H <sub>2</sub> O	3.6	.200	1×.200	.200-.014	= .186	= 1×.186
Residue	2.4					
V <sub>2</sub> O <sub>5</sub>	None					
Total	100.5					

Column II represents the molecular ratios, with the small amount of P<sub>2</sub>O<sub>5</sub> added to the As<sub>2</sub>O<sub>5</sub>. From column III it is evident that the analyzed sample closely approaches the composition 2CaO·2ZnO·As<sub>2</sub>O<sub>5</sub>·H<sub>2</sub>O. A microscopic examination of part of the sample, using index liquids, indicated the presence of a small amount of adamite. We, therefore, may assume that the excess of ZnO over CaO shown in the analysis is due to the slight admixture of adamite. If we subtract this excess of ZnO and one-fourth this amount of As<sub>2</sub>O<sub>5</sub> and H<sub>2</sub>O, to correspond to the formula of adamite (4ZnO·As<sub>2</sub>O<sub>5</sub>·H<sub>2</sub>O) as in column IV, we have the figures of column V and their equivalent in column VI. The resultant molecular ratios given in column VI leave little doubt concerning the correctness of the formula 2CaO·2ZnO·As<sub>2</sub>O<sub>5</sub>·H<sub>2</sub>O or CaZn(OH)AsO<sub>4</sub>. The theoretical percentages of the oxides for this formula are: CaO=21.45%, ZnO=31.13, As<sub>2</sub>O<sub>5</sub>=43.97 and H<sub>2</sub>O=3.45.

From the values obtained in column III it might be concluded that austinite is either a double salt or an isomorphous mixture. Zinc and calcium do not seem to be found often replacing each other

in minerals, and the exact 1:1 ratio of the CaO and ZnO, when allowance is made for the contamination of the sample by adamite, indicates that austinite is undoubtedly a double salt.

The mineral austinite is closely related chemically to the members of the olivenite group. However, that it does not belong to the group is shown by its lower symmetry, the different optical orientation and the difference in axial ratios. At present it cannot be placed in any known mineral group. It is the first arsenate of zinc and calcium to be described as a mineral<sup>7</sup> and it is believed to be a basic arsenate with the formula  $\text{CaZn(OH)AsO}_4$ .

#### ACKNOWLEDGMENTS

The author wishes to express his thanks and acknowledge his indebtedness for the many facilities placed at his disposal, as well as for the many valuable suggestions offered by Professor Austin F. Rogers. Thanks are also due to Dr. W. R. Landwehr for the material upon which this study was made.

#### SUMMARY

The following is a tabulation of the properties of austinite.

Chemical formula:  $\text{CaZn(OH)AsO}_4$

Crystal system and class: orthorhombic, rhombic disphenoidal class ( $3A_2$ ).

Habit: prismatic.

Forms:  $m\{110\}$ ,  $p\{111\}$ ,  $\rho\{1\bar{1}1\}$ ,  $b\{010\}$ ,  $q\{011\}$ .

Axial ratio:  $a:b:c=0.657:1:0.832$ .

Cleavage: parallel to  $m\{110\}$ .

Specific Gravity: ca. 4.12

Optical character: positive.

Optical orientation:  $a=\beta$ ,  $b=\gamma$ ,  $c=\alpha$ . Axial plane =  $\{100\}$ .

Optic axial angle:  $2V=ca:47^\circ$ .

Indices of refraction:  $n_\alpha=1.759\pm 0.003$ ,  $n_\beta=1.763\pm 0.003$ ,  $n_\gamma=1.783\pm 0.003$ .

Max. double refraction:  $0.024\pm 0.006$

<sup>7</sup> The name *brickerite* has been given to an arsenate of zinc and calcium from Bolivia, but in the absence of an adequate description the name is a *nomen nudum* and has no standing. The mineral is briefly mentioned by Ahlfeld in *Neues Jahrb. Mineral.*, Abt. A, Beil.-Band, 66, p. 44, 1932, who said that it would be described by its discoverer, Dr. Barrande-Hesse.