

expense incident thereto. Through the kindness of E. W. Todd of the Department of Mineralogy, University of Toronto, the writer was able to obtain for examination some of the ore from this mine. It is very fine-grained, with the three main constituents, sphalerite, pyrrhotite, and galena so intimately mixed as to require too fine crushing to accomplish a clean-cut separation.

A similar mixture of minerals obtains at the Sullivan Mine in the same district, but the individual mineral grains are larger in this ore making it more amenable to treatment.

From these few examples it would appear that a preliminary microscopic examination of any ore would be extremely useful in determining the kind of milling to be undertaken, that it is possible to examine all classes of fragmental material, down to that passing through a 300-mesh screen, and finally that without such microscopic investigation the mill-man is handicapped in the majority of cases.

AUGITE OF THE ALBAN HILLS, ITALY

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In a continuation of our study of volcanic augites, we have recently examined an augite from the Alban Hills, using material sent to us by Professor F. Millosevich, of the University of Rome, to whom we would express our sincere thanks. The material studied by us was used also by Drs. L. H. Adams and E. D. Williamson, of the Geophysical Laboratory, in their investigation of the compressibility of minerals and rocks.¹

The augite of the Alban Hills has not been much studied, although it is one of the most abundant and most prominent minerals of the district, and has been known for about one hundred and fifty years. An analysis by Klaproth, made in 1810, gives a remarkably close approximation to its chemical composition. The latest general description (chiefly crystallographic) is that of Zambonini,² who gives a full bibliography to 1899. Later papers on Alban augite have been published by Viola and Kraus,³ and by Parravano.⁴

¹ L. D. Adams and E. D. Williamson, *Jour. Franklin Inst.*, **195**, 482, 1923.

² F. Zambonini, *Zeits. Kryst.*, **33**, 39, 1900.

³ Viola and Kraus, *Zeits. Kryst.*, **33**, 36, 1900.

⁴ Parravano, *Rend. Accad. Lincei*, **21**, 469, 1912.

There seems to be considerable variation in the characters and the composition of Alban augite. According to Zambonini there is a black and a light green variety, the former being much the more abundant. Viola recognizes another, stated to be intermediate between aegirite and aegirite-augite, which he calls fedorowite. Von Rath⁵ describes very briefly a green augite, occurring in ejected blocks in peperino (tuff), which has a habit markedly different from the crystals described by us.

From among the several specimens kindly sent us by Professor Millosevich, all of which are of the black variety, we selected for study a batch of loose crystals from the Fosso del Tavolato, on the Via Appia Nuova, a few kilometers southeast of Rome. Crystals of the same general habit and characters occur in the solid tuffs, near Ariccia and at many other localities, and the loose crystals studied by us have presumably the same origin.

TABLE I. ANALYSES OF AUGITE, ALBAN HILLS

	1	2	3	4	5	6	7
SiO ₂	48.11	48.86	52.36	44.53	53.81	48	49.69
TiO ₂	1.19	0.37	n. d.	0.69	0.44	n. d.	0.14
Al ₂ O ₃	5.45	5.23	2.42	10.29	10.82	5	3.31
Fe ₂ O ₃	4.42	1.71	2.24	2.95	2.13	12	6.30
Cr ₂ O ₃	0.06	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.
FeO	3.74	10.02	1.94	9.14	1.27	n. d.	0.71
MnO	0.09	0.23	n. d.	0.04	n. d.	1	1.13
MgO	12.03	8.35	14.53	5.78	7.54	8.75	14.57
CaO	24.50	24.34	24.57	25.22	22.46	24	20.26
Na ₂ O	0.46	n. d.	2.05	n. d.	0.86	n. d.	2.15
K ₂ O	none	n. d.	none	n. d.	n. d.	n. d.	0.68
H ₂ O+	0.09	n. d.	n. d.	0.04	0.34	n. d.	1.22
	<u>100.14</u>	<u>99.12</u>	<u>100.11</u>	<u>98.66</u>	<u>99.78</u>	<u>98.75</u>	<u>100.16</u>
D	3.373	3.441				3.40	3.26

1. Augite (black), Fosso Tavolato. Washington analyst.
2. Augite (bottle green), Frascati. Zambonini analyst. *Zeits. Kryst.*, **33**, 54, 1900.
3. Augite (light green), Alban Hills. Viola and Kraus, *Zeits. Kryst.*, **33**, 37, 1900. Mean of two.
4. Augite (black), Fosso Tavolato. N. Parravano, analyst. *Rend. Accad. Lincei*, **21**, 469, 1912. Sum given as 99.77.
5. Augite (dark green), Castelnuovo del Porto. N. Parravano, *op. cit.* Includes 0.07 H₂O-.
6. Augite (black), Frascati. Klaproth analyst. *Beitr.*, **5**, 166, 1810. Cited in Hintze, *Handb. Min.*, II, 1040 note 1, 1897.
7. Augite, (brown), Fiano, Phlegrean Fields. Zambonini analyst. *Mem. carta, Geol. Ital.*, **7**, (2), 94, 1919.

⁵ Von Rath, *Zeits. Deut. Geol. Ges.*, 543, 1866.

The augite crystals, from 1 to 2 centimeters in greatest dimension (vertical), are mostly rather rough, with dull faces; they are quite free from scoria. They all show the most common planes, $a(100)$, $b(010)$, $m(110)$, and $s(\bar{1}11)$, and their general habit is that usual with such volcanic augites. L. H. Adams determined the *density* as 3.373 at 29°.

On fresh fracture surfaces the color is a lustrous black. Sections 3 mm. thick are dull greenish yellow, between 25''k and 25'''i of Ridgway; the washed powder, 0.1 to 0.01 mm. grains, is between 25''k and 25'''k.

Microscopic examination shows that the material is slightly zoned, but on the whole fairly uniform, and that it is very free from inclusions. The refractive indices show extreme variations of about ± 0.004 from the following values, estimated from measurements; $\alpha = 1.703$, $\beta = 1.710$, $\gamma = 1.727$ (H. E. M.).

An analysis was carried out on carefully selected material and gave the results shown in column 1 above.

It is of interest to note the presence of a small amount of chromium and the entire absence of potash in our analysis. Viola and Kraus state that potash was not detectable spectroscopically in the augite which they analyzed.

The analysis of our material from the Alban Hills resembles, in general, analyses of other volcanic augite which we have published, such as those of Vesuvius and Etna,⁶ Haleakala,⁷ and Kilimanjaro.⁸ These are all much alike in their content of silica, titania, magnesia, soda, and potash; and show somewhat variable but not widely diverse amounts of alumina and the iron oxides. Lime, however, is notably higher in the Alban Hills augite, 24.5 per cent as against about 21.5 in the others. The relatively high lime is remarkable, inasmuch as the above augites with less lime occur either in considerably more calcic lavas (Haleakala), or in those which contain about the same percentage of lime as the Alban rocks (Etna), as well as, in some with less (Vesuvius). This is a matter, however, which must be postponed to a future general discussion of the composition and occurrence of volcanic augite. The entire absence of potash is remarkable in view of the fact that

⁶ Washington and Merwin, *Am. Jour. Sci.*, 1, 22 and 29, 1921.

⁷ Washington and Merwin, *Am. Jour. Sci.*, 3, 119, 1922.

⁸ Washington and Merwin, *Am. Mineralogist*, 7, 123, 1922.

the lavas of the Alban Volcano are highly potassic, being uniformly either albanite,⁹ (leucitite) or melilite albanite.

Zambonini's analysis resembles ours closely in silica, alumina, and lime, the differences in the minor constituents being insignificant, while he neglected to determine the alkalies. But his iron oxides differ widely from ours, their total amount being higher, and ferrous oxide dominating greatly over ferric; and his magnesia is decidedly lower than in ours. Although he calls his analyzed augite "black," he states that it is bottle green in small pieces, while ours is black in small fragments a few millimeters thick, except on the thin edges.

The analysis by Viola and Kraus is unsatisfactory, their value for soda being almost certainly too high. The high silica, magnesia, and lime, and the low iron oxides are in harmony with the light green color; but there is not enough ferric oxide to satisfy the two per cent of soda in forming acmite, even if all the iron oxide be reckoned as ferric. This will be referred to later. It would seem that they used the old Berzelius method of decomposition for alkalies, and separated the magnesia from the alkalies by mercuric oxide, the soda being weighed as sulphate. This method tends to yield too high figures for the alkalies.

The analyses by Parravano also are very unsatisfactory. Both of them show an inordinate amount of alumina and a correspondingly low figure for magnesia, so that we may assume that some of the magnesia has been weighed with the alumina, which is one of the most frequent analytical errors. That this is so is indicated on calculations of the molecular composition. Analysis No. 4 yields more than 20 per cent of the wollastonite molecule, while with No. 5 we obtain 22.5 per cent of wollastonite and also about 14 per cent of excess silica.

It is of interest to turn to the analysis by Klaproth, made more than one hundred years ago. Its close similarity to the analysis by Zambonini is striking testimony to Klaproth's skill as an analyst. The two augites may not have been identical, although they came from the same locality, but they surely cannot have differed very widely. It is to be remembered that in Klaproth's day there was no good method for the separate determination (in silicates) of ferrous and ferric oxides. If all of Zambonini's iron

⁹H. S. Washington, *Am. Jour. Sci.*, 50, 47, 1920; *Rend. Accad. Lincei*, 29, 435, 1920.

oxides are calculated as ferric we obtain a total of 12.84 per cent, which is not far from the 12 per cent found by Klaproth.

We have added an analysis by Zambonini of an "acmite augite" from the tuffs of the Phlegrean Fields, near Naples. Pleochroism is not mentioned. This is low in silica and lime, and high in magnesia and soda.

We may now calculate the composition of these augites in terms of their constituent molecules, assuming that soda enters acmite, the alumina and the ferric oxide in excess of that used for acmite are present in solid solution and not in the Tschermak molecule,¹⁰ and that TiO_2 replaces SiO_2 .

TABLE 2. MOLECULAR COMPOSITION OF ALBAN AUGITES.

	1	2	3	4	5
Diopside ($CaMgSi_2O_6$)	65.02	45.14	78.41	31.32	40.82
Hedenbergite ($CaFeSi_2O_6$)	13.15	35.21	none	31.49	4.47
Wollastonite ($CaSiO_3$)	9.63	9.63	8.82	20.65	22.50
Acmite ($NaFeSi_2O_6$)	3.23	(3.23)	15.25	6.47
$Al_2O_3 + Fe_2O_3$	9.41	6.44	2.42	13.24	10.82
Excess SiO_2	<u>none</u>	<u>none</u>	<u>none</u>	<u>1.89</u>	<u>14.22</u>
	100.44	100.65	104.90	98.59	99.30

The molecular amount of SiO_2 needed for the composition of No. 1 is .819, while the analysis shows $SiO_2 + TiO_2 = .817$. Zambonini did not determine the soda in his augite, but when the composition is calculated on the assumption that no acmite is present there is an excess of silica which, oddly enough, is exactly that needed for the amount of acmite shown in our analysis, No. 1. We have, therefore, assumed that about 0.46 per cent of soda is present in Zambonini's augite. The molecular composition as thus calculated differs from Zambonini's in that he considers the aluminous and ferric Tschermak molecules to be present, and does not allow for acmite; on making these modifications his calculated composition agrees with our calculation from his data.

Our augite, from Fosso del Tavolato, is eminently rich in diopside, $MgSiO_3$, with little hedenbergite and with some wollastonite. Zambonini's, on the other hand, is rich in hedenbergite, but has the same amount of wollastonite as ours. Both contain a small amount of acmite. The presence of the wollastonite

¹⁰ It is to be remembered that the amount of silica needed to satisfy $(Mg,Fe)O$ is the same, whether $(Al,Fe)_2O_3$ is assumed to be present in the Tschermak molecule (e.g. $MgO.Al_2O_3$, SiO_2) or is in solid solution in $MgO.SiO_2$.

molecule is somewhat remarkable, inasmuch as none of the other augites studied by us show this but, on the contrary, an excess of the hypersthene molecule $(Mg,Fe)SiO_3$. The differences in density between our and Zambonini's Alban augite are in accord with the chemical differences, and the differences in color would also seem to be in harmony, although we know too little of the optical characters of Zambonini's mineral to permit of proper comparison.

Even though Viola and Kraus' analysis is not satisfactory, yet its main features are sufficiently clear to permit us to believe that their light green augite is essentially diopside, with some wollastonite and with a little acmite, less than is indicated by their soda determination but sufficient to render the augite pleochroic. Zambonini did not make a complete analysis of his light green augite because of the paucity of material, but he determined the iron oxides with the result Fe_2O_3 5.58 and FeO 0.60 per cent, while in another crystal of like color he obtained 4.37 per cent of FeO. These results indicate that, although there is considerable variation in its composition, his light green augite is probably closely similar to that of Viola and Kraus.

A word must be said as to Viola and Kraus calling their Alban Hills augite "fedorowite." This name was applied originally by Viola¹¹ to a monoclinic pyroxene, occurring in the Hernican District south of Rome, "intermediate between aegirite and aegirite-augite, with 9-13 percent of alkali [soda] and about 24 per cent of FeO." Its extinction angle is given at $65^\circ-75^\circ$. It is evident that, quite apart from the inadvisability of bestowing a new name on a merely intermediate variety of a mineral group which is already more than sufficiently baptized, the augite from the Alban Hills described by Viola and Kraus does not accord chemically with the definition of the original "fedorowite" from the Hernican District, and it corresponds optically only in being pleochroic and (in the fragments selected) roughly in extinction angle. We may therefore reject the name "fedorowite" as applied (at least) to the Alban light green pyroxene, and consider it as a slightly acmitic diopside.

Although, as we have seen, they are both unsatisfactory, yet Parravano's analyses indicate that a hedenbergitic augite occurs

¹¹ C. Viola, *Neues Jahrb.*, 1, 121, 1899. No analysis of the Hernican augite was given.

at Fosso Tavolato (No. 4) and that an acmitic diopside, much like that of Viola and Kraus, occurs elsewhere at the Alban Volcano (No. 5).

It seems to be clear that there is a very considerable variety in the characters of the augites at the Alban Volcano, which is the more remarkable in view of the fact that this volcano, of all those along the Bolsena-Vesuvius line, shows the greatest uniformity among its lavas.

AN ALLEGED OCCURRENCE OF THE $\alpha\text{CaO.SiO}_2\text{-3CaO.2SiO}_2$ EUTECTIC

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In March, 1923, a brownish mass, 5x3x2 cm., was sent to the writer for identification, which upon optical investigation proved to be a mixture of the compounds $\alpha\text{CaO.SiO}_2$ (pseudowollastonite), and 3CaO.2SiO_2 . A thoro study of the material was made, followed by a visit to the supposed locality, near Spartanburg, S. C.

The mass showed the following properties: color, ivory-yellow to brown; luster, vitreous to greasy; translucent; hardness, about 5.5; specific gravity, 2.86. One surface showed distinct, but very brittle crystalline plates. The mass gelatinizes in HCl.

A thin section revealed the mass to be a eutectic mixture, and an analysis by Dr. J. Edward Whitfield established its identity with the binary eutectic obtained by Rankin and Wright¹ at 1455°C. in their investigation of the system $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ at the Geophysical Laboratory. An analysis of the Spartanburg material as well as the binary eutectic are given below for comparison.

	A	B
SiO ₂	44.34	45.5
Al ₂ O ₃	2.28	—
Fe ₂ O ₃	0.40	—
CaO	52.05	54.5
MgO	0.56	—
	99.63	100.0

A. Analysis of Spartanburg material, by Dr. Whitfield.

B. Binary eutectic, $\alpha\text{CaO.SiO}_2\text{-3CaO.2SiO}_2$.

¹ *Am. J. Sci.*, 39, 1-79, 1915.