

3. It has been established, by spectroscopic methods, that in vesbine lead is replaced, to a very small extent, by metals of the rare earths, among which have been certainly recognized La, Ce, Nd, Y, and Er, and Dy doubtfully. This is the first time that the rare earth elements have been detected in Vesuvian lavas. The same may be said of tungsten, which was also noted spectroscopically; it probably replaces molybdenum. There are doubtful spectroscopic indications of the presence of columbium and of tantalum, neither of which have heretofore been noted at Vesuvius. Arsenic, also found by us as the orthoarsenate in vesbine, is new for the Vesuvian fumaroles.

4. It is shown that vesbine is not an autoneumatolytic product, but that it was formed at a period after the solidification of the lava, through the agency of water.

NOTES ON THE TRICLINIC PYROXENES

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The standard treatises on mineralogy all refer rhodonite, bustamite, fowlerite and babingtonite to the triclinic pyroxenes, but show no agreement at all regarding the other members of the group. Dana¹ includes hiortdahlite in the group, but it is excluded by others because it is not a metasilicate; Hintze² includes jadeite as a triclinic pyroxene, but other authors agree that it is monoclinic; Groth³ adds schizolite and margarosanite to the triclinic pyroxenes, but their crystallographic angles and constants differ decidedly from those of any pyroxenes. Washington and Merwin⁴ add sobralite, pyroxmangite and vogtite to this triclinic group of minerals, but suggest that the group should not be regarded as pyroxenes.

Every mineralogist understands that mineral formulas are practically always simplified too much to represent accurately the real composition. Such simplification is highly desirable so long as no elements which are necessary to the mineral are excluded from the formula. For example, it is proper to consider that ZnS is the formula of sphalerite since the iron, usually present, is entirely unnecessary and merely proxies for part of the zinc. Similarly, it

¹ *System of Mineralogy*, 1892, p. 344.

² *Handbuch der Mineralogie*, II, 1897, p. 960.

³ *Mineralogische Tabellen*, 1921, p. 88 and 108.

⁴ *Am. Mineral.*, VIII, 1923, p. 215.

is correct to state that NaAlSiO_4 is the formula of nephelite since other constituents (including excess SiO_2) are quite unnecessary to the mineral.

With these facts in mind what formulas should be assigned to rhodonite and babingtonite? According to all authorities the formula of rhodonite is MnSiO_3 ; according to Miers⁵ that of babingtonite is FeSiO_3 . Analyses show that MnSiO_3 forms about 85 molecular percent of rhodonite and FeSiO_3 forms only about 15–20 percent of babingtonite. Since FeSiO_3 forms such a small portion of babingtonite it is not surprising that other writers do not agree with Miers in the view that the simplified formula of babingtonite is FeSiO_3 ; but the case is interesting as illustrating to what lengths this process of simplification of formulas is sometimes carried in our text books. It is the prevailing view that the formula of babingtonite must be more complicated than FeSiO_3 , but there is no agreement concerning it. Rammelsberg⁶ regarded it as composed of $(\text{Ca, Fe, Mn})\text{SiO}_3$ and $\text{Fe}_2(\text{SiO}_3)_3$. Doelter⁷ explained it as composed of $\text{Ca}(\text{Fe, Mn})\text{Si}_2\text{O}_6$, $\text{CaFe}_2\text{Si}_4\text{O}_{12}$ and CaSiO_3 . Silvia Hillebrand⁸ regarded it as a mixture of $\text{Ca}_2\text{Si}_3\text{O}_8$ and $\text{CaFe}_2\text{Si}_2\text{O}_8$. More recently Washington and Merwin⁹ have concluded that it is a mixture of $\text{Ca}(\text{Fe, Mn})\text{Si}_2\text{O}_6$, $\text{FeFe}_2\text{Si}_4\text{O}_{12}$, CaSiO_3 , and $\text{H}_2\text{CaSi}_2\text{O}_6$. It seems possible that the correct explanation of the composition of babingtonite is still undiscovered.

In regard to rhodonite, the simplification involved in considering that it is MnSiO_3 is no greater than that involved in deriving many mineral formulas. However, the fact that the simplification is not greater than in many other cases does not prove that it is permissible in this case. That depends upon whether the constituents omitted from the formula are necessary or unnecessary to the mineral. In other words, it depends upon whether the mineral rhodonite is essentially the same as, or essentially different from, pure crystallized MnSiO_3 . Kallenberg¹⁰ has investigated this matter with the following results:

1. Natural rhodonite is negative and biaxial of large optic angle.

⁵ *Mineralogy*, London, 1902, p. 424.

⁶ *Handbuch der Mineralchemie*, II, 1875, p. 404.

⁷ *Tsch. Min. Pet. Mitt.*, II, 1880, p. 198.

⁸ *Tsch. Min. Pet. Mitt.*, XX XII, 1914, p. 264.

⁹ *Am. Mineral.*, VIII, 1923, p. 215.

¹⁰ *Centr. Mineral.*, 1914, p. 388.

2. Natural rhodonite, when fused and recrystallized, is negative and biaxial of large optic angle.

3. Artificial MnSiO_3 crystals are positive and biaxial of small optic angle.

4. Crystallization of artificial MnSiO_3 at lower temperatures with fluxes does not change the optic sign.

5. The addition to MnSiO_3 of small percentages of FeSiO_3 (similar to the tenor of FeSiO_3 in some natural rhodonites) does not change the optic sign to negative, but this result is obtained by adding 30-40 per cent of FeSiO_3 .

6. The addition to MnSiO_3 of MgSiO_3 does not change the sign.

7. The addition to MnSiO_3 of 5 percent (or more) of CaSiO_3 changes the substance to negative and biaxial.

Kallenberg supposed that MnSiO_3 and CaSiO_3 form an isomorphous or isodimorphous series, but his evidence on this point is not conclusive; in fact, his fusing point curve may well pertain to a pair of substances miscible as liquids, but showing little or no solubility as crystals; and one or more intermediate compounds are quite possible, especially if they are unstable at their melting points.

The writer would therefore reinterpret the evidence supplied by Kallenberg to mean that:

1. Natural rhodonite is essentially different from pure MnSiO_3 . This difference is not due to inversion, nor is it due to admixed FeSiO_3 or MgSiO_3 .

2. Natural rhodonite is essentially the same as MnSiO_3 with some CaSiO_3 . Therefore Ca can not correctly be omitted from the formula of rhodonite.

A brief study of the analyses of rhodonite shows that calcium is always present and does not vary very radically in tenor. The best analyses may be represented fairly well by writing the formula as $\text{CaMn}_3(\text{SiO}_3)_6$. It seems clear from the analyses of rhodonite (excluding bustamite which is probably a separate species and not a variety) that more Ca than is expressed by this formula is not possible in this mineral; this conclusion is supported by the observation of Hallimond¹¹ that slags containing more than about 8% CaO crystallize to vogtite and not to rhodonite.

If rhodonite is a mineral whose formula expresses a definite ratio between Ca and Mn then what is to be said regarding other ratios? Are any other ratios known among minerals?

¹¹ *Mineral. Mag.*, XVIII, 1919, p. 368.

It seems possible that pyroxmangite¹² represents the essentially calcium free¹³ substance, though it contains much iron. Ford and Bradley very properly emphasized the fact that pyroxmangite is not the same as, nor a variety of, rhodonite in their original description of the mineral. It is positive and biaxial of rather small optic angle.

Sobralite¹⁴ is complex in composition; it has been assigned the formula: $\text{CaMgFe}_2\text{Mn}_4(\text{SiO}_3)_8$. Since some analyses of rhodonite suggest that considerable $\text{MnMn}_5(\text{SiO}_3)_6$ is miscible in crystal solution in $\text{CaMn}_5(\text{SiO}_3)_6$ it might be supposed that sobralite represents such an isomorphous member of a rhodonite system, but, since sobralite differs optically and also in its X-ray pattern¹⁵ from rhodonite, such a conclusion is not warranted.

Fowlerite¹⁶ has about the same tenor of Ca as rhodonite and may be regarded as $\text{Ca}(\text{Mn, Fe, Zn})_5(\text{SiO}_3)_6$. The optic sign of fowlerite is different from that of rhodonite, but this may well be due to variation through 90° with increase of zinc, since the dispersion is also different.

Bustamite¹⁷ has much more Ca than rhodonite and seems to be essentially $\text{CaMnSi}_2\text{O}_6$. The best analyses show little evidence of the existence of a gradation between rhodonite and bustamite. In crystallography, also, bustamite seems to differ distinctly from rhodonite.

Vogtite¹⁸ is a substance found in slags which is similar to bustamite in optic orientation but seems to differ both from bustamite and rhodonite in composition since the formula is $\text{Ca}(\text{Fe, Mn, Mg})_2\text{Si}_3\text{O}_9$. Hallimond¹⁸ in the original description showed that vogtite differs in essential characters from rhodonite, and it seems probable that it is also essentially different both in composition and properties (notably the cleavages) from bustamite.

In summary, there is a group of triclinic minerals usually (but incorrectly?) referred to the pyroxene group whose formulas and mutual relationships are still uncertain. This group consists of

¹² W. E. Ford and W. M. Bradley: *Am. Jour. Sci.*, CLXXXVI, 1913, p. 169.

¹³ This assumes that the CaO actually found (1.88%) is negligible because it is not essential.

¹⁴ J. Palmgren: *Bull. Geol. Inst. Univ. Upsala*, XIV, 1917, p. 109 and J. M. Sobral: *Bull. Geol. Inst. Univ. Upsala*, XVIII, 1922, p. 47.

¹⁵ Wyckoff, Merwin and Washington: *Am. Jour. Sci.* CCX, 1925, p. 383.

¹⁶ E. S. Larsen and E. V. Shannon: *Am. Mineral.* VII, 1922, p. 95 and 149.

¹⁷ E. S. Larsen and E. V. Shannon: *Am. Mineral.* VII, 1922, p. 95.

¹⁸ A. F. Hallimond: *Mineral. Mag.* XVIII, 1919, p. 368.

metasilicates of manganese¹⁹ and calcium in which the ratio between manganese and calcium seems to vary from 1 : 0 to 1 : 1. However, these minerals differ too much optically and crystallographically²⁰ to belong to an isomorphous series in the narrow sense of that term. The chief types thus far known are the following:

MINERAL	FORMULA	RATIO OF Ca TO Mn(+Fe+Mg)
Pyroxmangite	(Fe, Mn)SiO ₃	1 to ∞ or 0 to 1
Sobralite	CaMgFe ₂ Mn ₄ (SiO ₃) ₅	1 to 7
Rhodonite	CaMn ₃ (SiO ₃) ₆	1 to 5
Fowlerite	Ca(Mn, Fe, Zn) ₅ (SiO ₃) ₆	1 to 5
Vogtite	Ca(Mn, Fe, Mg) ₂ (SiO ₃) ₃	1 to 2
Bustamite	CaMn(SiO ₃) ₂	1 to 1

Babingtonite probably belongs to this group, but its formula is still under discussion.

THE MINERALS OF VESUVIUS¹

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The minerals that occur about Vesuvius, which now number more than one hundred and fifty species, may be arranged genetically into four groups:

I. Minerals that are found in the ejected limestone blocks of Monte Somma.²

II. Pneumatolytic minerals formed in cavities of leucotephrites and conglomeratic blocks ejected by Monte Somma and Vesuvius, or coating the walls of ancient lavas.

¹⁹ With or without iron and magnesium.

²⁰ As proved especially by their X-ray patterns: see *Am. Jour. Sci.*, **CCX**, 1925, p. 383.

¹ In the preparation of this paper, I have consulted and taken considerable data from the following important works on Vesuvian minerals:

A. Scacchi. *Catalogo dei minerali vesuviani con notizie della loro composizione e giacimento Napoli, 1887.*

ibid. *Catalogo dei minerali e delle rocce vesuviane. (Atti della R. Accademia delle scienze fisiche e matematiche di Napoli, Vol. I, 4 Series) Napoli, 1889.*

A. Lacroix. *Etude minéralogique des produits silicates de l'éruption du Vésuve (avril 1906). (Nouvelles archives du Muséum, 4 series. Vol. IX) Paris, 1907.*

ibid. *Les minéraux des fumerolles de l'éruption du Vésuve en avril 1906. (Bulletin de la Société française de minéralogie), Paris 1908.*

F. Zambonini. *Mineralogia vesuviana. (Atti della R. Accademia delle scienze fisiche e matematiche di Napoli, Vol. XIV Ser es 2, no. 7) Napoli, 1912.*

F. Zambonini. *Appendice alla Mineralogia vesuviana (Atti Reale Accad. delle scienze di Napoli, Vol. XV series 2, no. 12) Napoli, 1912.*

Notices of new vesuvian minerals are reported in the publication: *Annali dell'Osservatorio vesuviano* (terza serie a cura del comitato vulcanologico di Napoli) of which the first vol. (1924) has been issued.

² Monte Somma is the name of an ancient crater wall which forms a semicircular cliff to the north and east of the modern cone. In views of Naples it is seen as a ridge to the left of the present cone.