BERYLLIUM IN MINERALS AND IGNEOUS ROCKS

HENRY S. WASHINGTON, *Geophysical Laboratory.*

In a recent paper C. Palache and L. H. Bauer[1] record the discovery of the presence of beryllium in vesuvianite from Franklin, New Jersey. This observation is of great interest, not only because it suggests possibly a new source of supply for beryllium, as was pointed out by the authors, but it also simplifies the chemical formula of vesuvianite, which has been more or less uncertain. In addition, this discovery indicates the importance of determining beryllium in various silicate minerals in which it has not been previously looked for or its presence suspected. In the ordinary course of silicate analysis beryllia (BeO) is precipitated with and weighed as alumina (Al_2O_3), unless it is separated from this constituent, which demands a somewhat complicated procedure. Indeed, the authors say: "It seems highly probable that beryllium is generally present in this mineral [vesuvianite] but has not been recognized, being determined as alumina."

In this connection attention may be called to the fact that the norm of certain rocks, nephelite syenites for the most part, show an excess of alumina ("normative corundum") over that needed for the feldspars and nephelite, which can not be accounted for by the minerals present in the rock.

Several examples of this are: the nephelite syenite of Wausau, Wisconsin;[2] the nephelite aplite of the Los Islands;[3] and the nephelite syenite of Almunge, Sweden.[4] None of these rocks contain biotite or any other mineral that would serve to explain the excess of alumina, "C" being given in each case.[5]

Other rocks that show an excess of alumina contain biotite or muscovite, but, according to the descriptions, the amount of mica is insufficient to account for the normative excess of alumina. Examples of such rocks are: the nephelite syenite of East Cape, Siberia;[6] the nephelite syenite of Vizagapatam, India;[7] and that of Assynt, Scotland.[8]

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[1] Palache and Bauer, *Am. Mineral.*, **15**, 30, 1930.

[2] Weidman, *Jour. Geol.*, **12**, 552, 1904. (C=1.53).

[3] Lacroix, *Nouv. Arch. Mus.*, **3**, 105, 1911. (C=1.84).

[4] Quensel, *Bull. Geol. Inst. Upsala*, **12**, 185, 1914. (C=5.30).

[5] The norms of these rocks are to be found in *U. S. Geol. Survey, Prof. Paper* **99.**

[6] Washington, *Am. Jour. Sci.*, **13**, 176, 1902. (C=2.96).

[7] T. L. Walker, *Rec. Geol. Survey India*, **36**, 21, 1908. (4.08).

[8] Shand, *Trans. Edinburgh Geol. Soc.*, **9**, 399, 1910. (C=3.88).

In some, or most, of these cases the author in describing the rock has noted the presence of an excess of alumina and has offered various explanations to account for it.

Some years ago it was suggested[9] that this excess of alumina in nephelite syenites, in which apparently there was no mineral present to account for it, might be due to the presence of beryl, which had been mistaken for nephelite, the beryllia having been weighed with and thought to be alumina.

Beryl and nephelite closely resemble each other in many respects. In thin section they are both colorless, without cleavage, and untwinned. They are both hexagonal in crystallization. Optically they are both negative, with very similar refractive indices and birefringence, especially for beryl low in alkalies.[10] Indeed, optically they are so much alike that they might readily be mistaken for one another, if optical characters alone are depended on and if the examination is not very painstaking and exact. Both minerals, also, are usually associated with rocks high in soda.[11]

The two minerals, however, differ much in habit. Nephelite is usually anhedral and interstitial in plutonic rocks, but it forms euhedral phenocrysts in such rocks as phonolite; while beryl occurs typically in well-formed, generally prismatic crystals, although it is also granular to compact. It is said not to occur in microscopic crystals.[12] They differ, also, in that nephelite occurs only in igneous rocks, either plutonic or effusive, in some cases the former having been metamorphosed to gneiss; while beryl is most commonly observed in granitic pegmatites, but it also occurs in metamorphic rocks. Beryl is usually associated with quartz, but not with nephelite, the latter never being associated with primary quartz.

But beryl is not the only beryllium-bearing mineral that is to be considered in this connection. Indeed, its general association with quartzose pegmatities, rather than with nephelite, if this be in reality not occasionally possible, is adverse to the idea that beryl may account for the excess of alumina, although it is not impossible that it holds good in some cases.

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[9] Washington, *Trans. Am. Inst. Min. Eng.*, **39**, 753, 1909.

[10] Cf. Ford, *Am. Jour. Sci.*, **30**, 128, 1910; Lacroix, *Min. de Madagascar*, **1**, 545, 1922.

[11] Clarke and Washington, *U. S. Geol. Survey, Prof. Paper* **127**, 103, 1924.

[12] Rosenbusch-Mügge, *Mikr. Phys.*, **I**, (1), 276, 1925. It is noteworthy that beryl is not mentioned in earlier editions of Rosenbusch.

Bauer's observation that a notable amount of beryllium is present in the vesuvianite of Franklin, and that it is probably present in other vesuvianites, would serve to explain the normative excess of alumina in the Almunge nephelite syenite.[13] This excess amounts to 5.30 per cent, and Quensel found it difficult to account for it, as no corundum is present and there is but a trace of biotite. But much of this syenite, including the specimen analyzed, contains a considerable amount of vesuvianite. If this is beryllium-bearing, like that of Franklin, which, as indicated by Palache and Bauer, is likely to be the case with other vesuvianites, the explanation of the excess of alumina is obvious—the beryllia has been weighed with and reported as alumina, both in the rock and in the calculation of the norm. Quensel gives no figures as to the mode of this specimen, so that quantitative estimates are impossible, but if the quantity of vesuvianite present is like that shown in his illustration of a thin section (Plate IX, Fig. 1), and if the percentage of beryllium in the vesuvianite is equal to that found at Franklin, there should be easily enough vesuvianite present to account for the 5.30 per cent excess of alumina. Incidentally, the normative anorthite is, at least in large part, to be referred to the vesuvianite, as the feldspars are said to be "principally" soda-potash feldspars, and there is but little pyroxene.

It is also possible that the presence of beryllium-bearing vesuvianite may account for the excess of alumina in the Vizagapatam nephelite syenite.[14] The amount of this is so large ($C = 4.08$) that Walker suggests the possible presence of corundum, although none was seen in the thin sections. The feldspar in this rock shows certain peculiarities, to which Walker calls attention. "No twinning is to be observed," and the feldspar breaks up, between crossed nicols, into two parts, a series of similarly oriented lenses in a groundmass of uniform grain.

Walker found that 38.84 per cent of the rock powder was soluble in warm dilute hydrochloric acid, "corresponding to a nepheline content of about 37 per cent," about 1 per cent of calcite being present. This result is interesting and possibly significant, because only 23.57 per cent of nephelite is present in the norm. This discrepancy of about 13 per cent, as well as the excess of alumina, is

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[13] Quensel, *Bull. Geol. Inst. Upsala*, **12,** 186, 1924; *Neues Jahrb.*, **1915,** 203.

[14] T. L. Walker, *Rec. Geol. Surv. India*, **36,** 22, 1908.

explicable if a beryllium-vesuvianite, partially soluble in acid, is present in the rock, in analogy with the Almunge syenite.

Vesuvianite is partially decomposed by hydrochloric acid, according to Dana and other authorities, while, according to others, it is not attacked. Such divergence might be expected, in view of the great variation in the composition of the mineral. Similarly, the range in the refractive indices is large, from about 1.705 to 1.732 for ω. Also, while most vesuvianites are optically negative, some varieties are positive.

Dr. Tom. F. W. Barth has kindly examined a thin section of my specimen of the nephelite syenite of East Cape, Siberia, which shows 2.96 percent of excess aluminain the norm,[15] but novesuvianite could be detected, so that the excess alumina is most probably to be ascribed to the hydronephelite that is present, as was suggested in the original description. According to Thugutt[16] hydronephelite is a mixture of natrolite, hydrargillite, and a little diaspore. Whether this is the case, or if the mineral has the composition originally assigned to it by Clarke, it contains an excess of alumina over that needed for nephelite or feldspar.

But besides vesuvianite there are several other minerals that are now known to contain beryllium as an essential constituent in which its presence was not suspected at first. Thus, barylite was first described as a barium aluminum silicate, but was found by Aminoff[17] to be a silicate of barium and beryllium, the beryllia having been in the first analyses weighed with and mistaken for alumina, the mineral as analyzed by Aminoff containing 16.01 per cent of BeO and only 0.05 of Al_2O_3. This was confirmed by Bauer in the barylite of Franklin, New Jersey.[18]

There are several other minerals that are not usually considered as containing beryllium, but in some varieties of which it has been shown to be present in recent analyses. Among these are: a fluorine-free humite of the Allalin Region in Switzerland,[19] titanolivine of the Val d'Ala in Piedmont,[20] and titanolivine of Christian-

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[15] Washington, *Am. Jour. Sci.*, **13**, 175, 1902. This specimen is now in the Petrographical Reference Collection, of the U. S. National Museum.

[16] Thugutt, *Neues Jahrb., Beil. Bd.*, **9**, 612, 1895; *Neues Jahrb.*, **1910**, I, 27.

[17] G. Aminoff, *Geol. För. Förh. Stockholm*, **45**, 124, 1923.

[18] Palache and Bauer, *Am. Mineral.*, **15**, 32, 1930.

[19] Jannasch and Locke, *Zeit. Anorg. Chem.*, **7**, 92, 1894. R. W. Schäfer, *Tsch. Min. Pet. Mitth.*, **15**, 126, 1896.

[20] Zambonini, *Bull. Soc. Franç. Minér.*, **42**, 269, 1919.

sand in Norway.[21] Machatschki[22] speaks of the Val d'Ala mineral as clinohumite, and thinks that the beryllium replaces or functions as silicon.

From these examples it is clear that beryllium is almost certainly more abundant and wide-spread than it has hitherto been thought to be, and that a former estimate that about 0.001 per cent of beryllium is present in the earth's crust[23] is too low. Also, the questions of the replacement of silicon or magnesium by beryllium in humite and olivine, and of calcium in vesuvianite, as well as the simplification of the formula of the latter, are of great interest and of some theoretical importance.

It would thus appear to be advisable, for several reasons, to look for and determine beryllium in silicate minerals and in igneous rocks more often than has been done in the past. In this we would be following Hillebrand's "Plea for greater completeness in chemical rock analysis," a paper published as early as 1894,[24] in which he stresses the importance of the determination of the rare elements in rocks for the solution of broad petrological problems. The importance of such determinations is also pointed out by Clarke[25] and by the present writer.[26]

The separation of beryllia from alumina is not difficult and there are several satisfactory methods, that of Parsons and Barnes[27] being one of the best and the one most frequently used, while a more recent method is that using 8-hydroxyquinoline.

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[21] Barth, *Norsk Geol. Tidsskr.*, 8, 99, 1925.

[22] Machatschki, *Neues Jahrb.*, *Abt. A*, **1930,** 198.

[23] Clarke and Washington, *U. S. Geol. Survey, Prof. Paper* **127,** 20 and 25, 1924.

[24] Hillebrand, *Jour. Am. Chem. Soc.*, **16,** 90, 1894. Also, *U. S. Geol. Survey, Bull.* **422,** 18, 1910.

[25] F. W. Clarke, *U. S. Geol. Survey, Bull.* **591,** 17, 1915.

[26] Washington, *U. S. Geol. Survey, Prof. Paper* 99, 16, 1917. Chemical Analysis of Rocks, 4th ed., 1930, 7.

[27] Parsons and Barnes, *Jour. Am. Chem. Soc.*, **28,** 1589, 1906. Cf. Hillebrand-Lundell, *Applied Inorganic Analysis*, **1929,** 405. Washington, *Chemical Analysis of Rocks*, **1930,** 273.