ART. VII. — *Notes on Powellite and Molybdite*; by
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1. *Powellite from Llano Co., Texas.*—The specimens of powellite from Barringer Hill, Texas, described in this paper were received through the kindness of Mr. Wm. E. Hidden and represent a small lot that was found in January, 1907. According to Mr. Hidden, who generously placed the material at the writer's disposal, the specimens are similar to those found by him in 1889 and referred to molybdite.† The reinvestigation of this mineral was undertaken as it had been suggested that it was probably a natural occurrence of the trioxide of molybdenum, the writer having shown in a previous paper‡ that molybdite was a hydrous ferric molybdate. Analysis showed, however, that this mineral from Barringer Hill is a calcium molybdate and is referable to powellite.

As received by the writer, the mineral is in loose pieces, some over a centimeter wide, associated with, coating and often entirely replacing, molybdenite. In fact, the powellite forms a pseudomorph after the sulphide of molybdenum, the foliated structure of the latter being frequently retained. The dirty white to gray mineral, sometimes stained brown by iron oxide, breaks up into small glistening scales which, when rubbed between the fingers, crumble to a pearly powder which adheres to the skin and resembles in appearance some varieties of fine-grained talc. Under the microscope, the mineral shows double refraction but no crystal outline. The individual crystal units are very minute, the specimens being aggregates of very fine scales.

A density determination was made on about 0.8 gram of the powdered sample. The pycnometer method was used and the determination was carried out with care at a temperature of 25°. The value obtained for the sample is 4.153, which when corrected for impurities, as described beyond, gives 4.23. Hidden§ found the value 4.004, which would indicate that his sample contained more impurities than the writer's.

Analysis of this mineral gave the following results, the mineral dissolving readily in HCl. Qualitative tests failed to show the presence of any tungstic oxide. The mineral is difficultly fusible and gives, at the most, only a trace of water in the closed tube.

CaO	27.46
MoO ₃	67.90
Loss on ign.	2.33
MoS ₂	1.50
SiO ₂	.88

100.07

* Published by permission of the Director of the U. S. Geological Survey.

† This Journal, xxxviii, 485, 1889.

‡ Ibid., xxiii, 297, 1907.

§ Ibid., xxxviii, 485, 1889.

The ratio of CaO to MoO_3 is 1:0.96, giving the formula CaMoO_4 .

What is probably a similar occurrence of powellite has recently been described* as possibly a natural occurrence of MoO_3 , the mineral differing in its physical properties from the hydrous ferric molybdate. It forms a white or grayish alteration product of molybdenite, which it sometimes covers and after which it is pseudomorphous, preserving the form of the molybdenite. The luster is pearly and the mineral is semi-translucent, difficultly fusible to a gray scoria, soluble in nitric acid and does not contain any iron or water. The material was too scanty for analysis.

2. *Powellite from Nye Co., Nevada.*—The powellite from Nevada was received through Mr. F. L. Hess of the U. S. Geological Survey, who states that the specimens were sent him by Mr. F. O. Byor of Columbia, Nevada. The locality is given as 2 miles south of Oak Springs, Nye County, Nevada.

The powellite occurs in a vein about $1\frac{1}{2}$ " wide in a soft earthy mass which seems to be some altered rock. In this rock are occasionally found irregular masses of powellite which sometimes are several centimeters across. The mineral is dull in appearance, grey in color, and occurs in platy masses often bent and twisted in different directions.

Imbedded in this vein of powellite and also as small masses and veins in the altered rock matrix, are found grey to white masses of scheelite showing good cleavage surfaces with a highly vitreous to adamantine luster, often having also a decided greasy appearance. The association of scheelite with powellite side by side was thought to be a most unusual one, but other specimens showed that the powellite, like the Texas mineral, was a secondary one being formed, *in situ*, from molybdenite; it is in fact a pseudomorph after the sulphide of molybdenum. Some other specimens showed the various stages of alteration very well, the amount of unaltered molybdenite varying from considerable to none at all. The association of molybdenite with scheelite is one well known and when the molybdenite alters to powellite the association, powellite-scheelite, necessarily follows. The agencies affecting the change from molybdenum sulphide to calcium molybdate are apparently without effect on the scheelite. This pseudomorphous character of the powellite accounts for its occurrence in platy masses, the structure of the original molybdenite being retained. On some of the specimens, notably those on which there is still a considerable amount of molybdenite remaining, the powellite often has a reddish color due to iron stain.

* Molybdate from the Ilmen Mts., G. Gagarine, Bull. Acad. Imp. Sci., St. Petersburg, 6 ser., 287-88, 1907.

The dull grey powellite can easily be separated by hand picking from the shining greasy scheelite, and a sample so selected was used for analysis. A thin section showed, under the microscope, some quartz, hematite and limonite as impurities.

The density of the mineral was determined by weighing a test tube containing about six grams of the mineral in water. The value obtained is 4.026, which when corrected for impurities, as described beyond, becomes 4.24.

The analysis yielded the following figures, the small amount of tungstic oxide present being probably due to admixed scheelite.

CaO	26.44
MoO ₃	62.43
Fe ₂ O ₃	1.17
Loss on ign.	2.69
SiO ₂	6.80
WO ₃	trace
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	99.53

The material insoluble in HCl was tested with HF and found to be almost entirely silica. The ratio CaO to MoO₃ is 1:0.92, giving the formula CaMoO₄.

3. *Density of Powellite.*—The sample of powellite from Texas gave the value 4.153 as its density. This figure is corrected on the basis of the following composition of the sample to 4.23.

Silica	density	2.65 =	.88
Water	"	1. =	2.33
Molybdenite	"	4.7 =	1.50
Powellite		=	95.29
			<hr/>
			100.00

The presence of the water as such is, of course, an assumption and the final value, 4.23, is necessarily uncertain, depending on the assumptions made.

The powellite from Nevada gave 4.026 as its density and from the analysis the composition of the sample was found to be as follows:

Silica	density	2.65 =	6.80
Water	"	1. =	2.69
Iron oxide	"	3. =	1.17
Powellite		=	89.34
			<hr/>
			100.00

Allowing for impurities, the value is raised to 4.24, which, like the preceding case, is dependent on certain assumptions.

As powellite and scheelite are doubtless isomorphous we may be justified in assuming that they have nearly the same molecular volume. Considering the molecular volumes as identical and taking the gravity of scheelite as 6.14, the density of powellite then becomes as calculated by Melville,* 4.267.

As all previous analyses of powellite showed the presence of tungstic oxide, the densities given are all too high for the pure calcium molybdate. The two values obtained by the writer, though uncertain as they are based on some assumptions made in applying the corrections, agree so well not alone with each other, but also with the calculated value, that the average of the three values (4.24, 4.23, 4.27), namely 4.25, may be taken as being very close to the true density of the pure calcium molybdate, CaMoO_4 .

4. *Molybdate from a new locality.*—A sample of molybdate from Hortense, Colorado, was received through the kindness of Mr. F. L. Hess. The yellow mineral occurs in lumps, several of which have a diameter of over 2^{cm}. With the molybdate are associated molybdenite, quartz and a mica. The sample looks earthy, but under the microscope is seen to be well crystallized and shows the characteristic optical properties of molybdate as described in a previous paper. A sample was selected as pure as possible, but which was found on analysis to still contain a large amount of insoluble matter. The powdered specimen caked together in the sample tube and probably contained some extraneous water. The analysis also showed too high a water content for molybdate. Below are given (I) the analysis; (II) the same with the insoluble matter deducted and the analysis recalculated to 100 per cent; and (III) the percentage calculated for $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 \cdot 7\frac{1}{2}\text{H}_2\text{O}$.

	I	II	III
H_2O	15.87	20.19	18.57
Fe_2O_3	15.95	20.30	22.01
MoO_3	46.77	59.51	59.42
MoS_2	5.50		
SiO_2	16.51		
	<hr/> 100.60	<hr/> 100.00	<hr/> 100.00

The residue, insoluble in HCl , was roasted in an open crucible to change the MoS_2 into MoO_3 and then weighed. The oxide of molybdenum was then dissolved by HCl , leaving the silica, which was tested with HF for its purity. The determination of water was made in two ways, by loss in weight and

* This Journal, xli, 138, 1891.

by direct weighing. It was found that the water given off at 110° by heating the mineral in a glass tube in a toluene bath while a current of dry air was passed over the mineral and collecting and weighing the water (shown in *a* below), was considerably greater than the amount given off at 110° by heating the mineral in a crucible in a toluene bath, and determining the water by loss in weight (shown in *b* below). The results are shown below:

	Amt. given off at 110°	at 200°	total
<i>a</i>	13.77	2.23	16.00
<i>b</i>	11.39	4.34	15.73

In the previous paper on the composition of molybdic ocher, the writer determined the water given off at 110° by loss in weight to be six molecules of the total $7\frac{1}{2}$. From the results given above, it seems probable that this is not necessarily the correct amount and that the temperature at which different parts of the entire water content are given off still remains to be determined.

The density of the powdered sample was determined with a pycnometer, using 3 grams of material. The value obtained is 3.026. This is corrected on the following basis, the sample being composed of

Molybdenite density	4.7	=	5.50
Silica	"	2.65	= 16.51
Molybdite			= 77.99
			<hr/>
			100.00

The corrected value becomes 2.99, in which, however, no allowance is made for the extraneous moisture.

An experiment was made to determine approximately the solubility of molybdite in water. About 3 grams of the mineral were stirred in a beaker for a day with 760° distilled water at room temp. (about 25°), and then filtered repeatedly. The final filtrate showed a very faint cloudiness. It was evaporated down in platinum, the residue dissolved in HCl and the iron precipitated as hydroxide with ammonia and weighed. The 760° of water contained .0051 gram of Fe_2O_3 . On the assumption that this all came from the mineral, it is calculated that the solubility of molybdite in water is approximately 1 to 33,000, so that the mineral is rather insoluble.

Continued attempts to form the crystallized mineral $\text{Fe}_2\text{O}_3 \cdot 3\text{MoO}_3 \cdot 7\frac{1}{2}\text{H}_2\text{O}$, by heating the amorphous precipitated ferric molybdate in a closed tube at a high temperature have so far been completely unsuccessful, and the writer does not, at present, intend to continue the attempts to prepare this mineral artificially in a crystallized condition.