BEYERITE FROM COLORADO*

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Abstract

Bismutite is a common accessory mineral in pegmatites in Colorado and northern New Mexico. In three pegmatites in south-central Colorado (Mica Lode and School Section deposits, Fremont County, and Meyers Ranch body, Park County) beyerite is intergrown with bismutite. These minerals are supergene alterations of late, hydrothermal, metallic minerals—native bismuth, bismuthinite, and various bismuth-bearing sulfosalts. Beyerite, which is analyzed for the first time, has the composition (Ca, Pb) $Bi_2(CO_3)_2O_2$, two molecules of which are contained in the unit cell.

Introduction

During the fall of 1942 and the spring of 1943 the writer examined pegmatite deposits in south-central Colorado for the Geological Survey, United States Department of the Interior. During these investigations bismuth carbonates were observed as accessory pegmatite minerals. A preliminary note on their occurrence has been recorded (Heinrich, 1946). Field work on Colorado pegmatites was resumed in the summer of 1946 under a grant from the Brodrick Fund of Harvard University. The work centered around the Eight Mile Park area, just west of Canon City (Heinrich, 1947, and Wolfe and Heinrich, 1947) but other pegmatite districts in Colorado also were examined. The occurrence of bismuth minerals in the pegmatites was studied in detail. The purpose of this paper is to describe the geology and mineralogy of the rare mineral beyerite and to record the pegmatite occurrences of bismuth carbonate minerals.

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Bismuth Carbonate Minerals in Pegmatites

Bismuth carbonates, chiefly as bismutite, appear to be widespread supergene accessory minerals in pegmatites. Frondel (1943, pp. 529 and 532) lists pegmatite localities in New Mexico (Petaca District), North Carolina (Cashiers Valley District), Colorado (Salida region), Connecticut (Hales Quarry, Portland), California (Pala), and Arizona (pegmatite ?). Jahns (1946*A*, pp. 67–68 and 1946*B*), who has described the occurrence of bismutite in the pegmatites of the Petaca district, New Mexico, reports that it has been found in 48 deposits there and in a number of pegmatites in the nearby Ojo Caliente district. A detailed description of the mineralogy of the Petaca deposits is in progress (Heinrich and Jahns, 1947). Bismutite also occurs as a common accessory mineral in the Harding pegmatite, Taos County, New Mexico, where it forms as an alteration of native bismuth.[1] According to Jahns,[2] " . . . both bismutite and native bismuth occur in several pegmatites in the general Sangre de Cristo area. Rather impressive quantities fill fractures in parts of the Rociada lepidolite occurrence . . . ." A brief note on these occurrences has been published (Jahns, 1946*C*).

Some pegmatites contain both bright yellow and bright green bismutite. Spectrographic analyses show that the green varieties contain a higher percentage of copper as an impurity:

	% CuO in bright yellow bismutite	% CuO in bright green bismutite
Harding pegmatite, N. M.	.05%	>1.0%
Devils Hole pegmatite, Colo.	0.2%	0.5%

Table 1 summarizes the occurrences of bismuth carbonate minerals in Colorado pegmatites. In all of these deposits the carbonates are clearly secondary minerals formed by the alteration of native bismuth, bismuth sulfide, or a bismuth-bearing sulfosalt. Although details regarding the conditions of formation of the original bismuth minerals are generally absent, the mineral association and manner of occurrence of the alteration products (generally as fracture fillings) serve to indicate that the original materials were late hydrothermal pegmatite minerals.

Previous Work on Beyerite

The name, beyerite, was applied by Frondel (1943, p. 532) to a new species of bismuth carbonate, " . . . first found as pulverulent earthy

[1] Checked by *x*-ray powder photographs, by the writer.
[2] Jahns, Richard H., private communication, 1947.

TABLE 1. OCCURRENCES OF BISMUTH CARBONATE MINERALS IN COLORADO PEGMATITES

Deposit	Mineral*	Color	Texture	Host Mineral	Associated Minerals	Original Mineral
1. Wood Gulch pegmatite, Gunnison Co.	bismutite	bright yellow, greenish-gray	earthy	quartz	albite, muscovite, columbite, garnet	?
2. Yard pegmatite, Trout Creek Pass, Chaffee Co.	bismutite	gray, brown, green	earthy	quartz	monazite, euxenite, fluorite, albite, malachite	probably a copper-bismuth sulfosalt
3. Meyers Ranch pegmatite, Park Co.	(a) bismutite	yellow, brown	earthy	quartz	albite, beryl, muscovite	?
	(b) beyerite	gray	waxy	quartz		?
4. Rosemont pegmatite, Micanite, Park Co.	bismutite	white, gray, green	earthy	quartz	muscovite, albite, garnet, malachite	possibly a copper-bismuth sulfosalt
5. Devils Hole pegmatite, Fremont Co.	bismutite	yellow, green, gray, black	waxy, and as minute green fibers	quartz	albite, muscovite	spectrographic analysis and needle-like form indicate cosalite
6. School Section pegmatite, Eight Mile Park, Fremont Co.	(a) bismutite	gray	earthy	albite	albite, muscovite, black tourmaline, chalcocite, malachite, native silver (tr)	probably a copper-bismuth sulfosalt
	(b) beyerite	gray	earthy	albite		
7. Mica Lode pegmatite, Eight Mile Park, Fremont Co.	(a) bismutite	gray	earthy	muscovite	albite, muscovite, chalcocite, native bismuth (tr), malachite	probably a copper-bismuth sulfosalt
	(b) beyerite	greenish-gray	waxy	muscovite		
8. Meyers Quarry, Eight Mile Park, Fremont Co.	bismutite	yellow, green, gray	earthy	microcline	albite, muscovite, malachite	possibly a copper-bismuth sulfosalt
9. Border Feldspar No. 1, Eight Mile Park, Fremont Co.	bismutite	green	earthy	albite	muscovite, beryl, black tourmaline, sericite	?
10. Burroughs pegmatite, Jefferson Co.	bismutite	gray, green	earthy, as rods	quartz	malachite	probably aikinite
11. Bigger pegmatite, Jefferson Co.	bismutite	yellow	earthy	quartz	albite, muscovite, beryl	probably bismuthinite

* All determinations by x-ray powder photographs.

masses and drusy crystals on specimens from Schneeberg, Saxony and later . . . recognized in massive earthy form on a specimen from Pala, San Diego Co., California." Powder *x*-ray photographs established the material as a valid species, distinct from bismutite and other secondary bismuth minerals. The mineral was suggested to be a carbonate of bis-

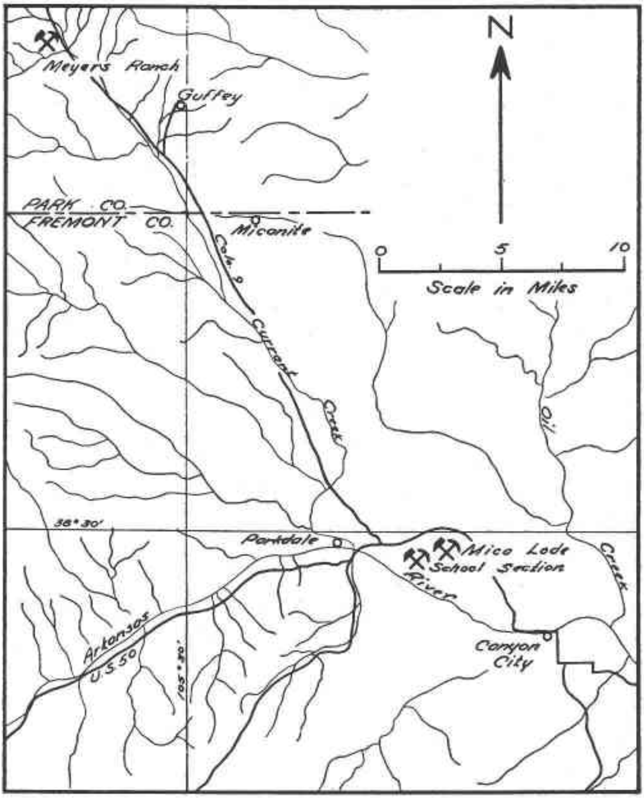

FIG. 1. Index map showing location of beyerite-bearing pegmatites in south-central Colorado.

muth and calcium but a chemical analysis could not be made because of insufficient material. As noted by Frondel (p. 533), an unnamed mineral from Schneeberg described in 1899 by Arzuni and Thaddéeff was probably beyerite, and another described by Bodenbender (1899) from Sierra de Santa Luis, near La Toma in Argentina may also have been that species. The latter material was obtained from a pegmatite dike, 6 to 10 centimeters wide, that contains quartz, feldspar, muscovite, and columbite. The bismuth carbonate occurs as yellow coatings and aggregates.

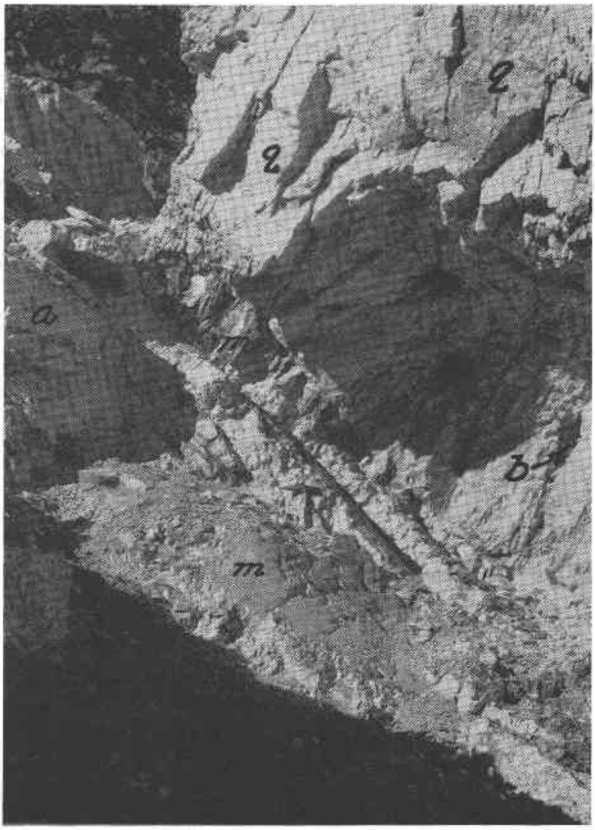

FIG. 2. Open cut in core-margin replacement unit, Meyers Ranch pegmatite, Park County, Colorado; *m*—fracture-controlled muscovite, *a*—albite, *q*—massive quartz of core. *b*—location of largest bismutite-beyerite mass.

The analysis by Bodenbender is as follows: Bi_2O_3 80.7%, CO_2 8.7%, H_2O 1.9% (variable), CaO 6.7%, MnO 0.8%, FeO 0.3%, Ce_2O_3 0.54%.

Colorado Occurrences of Beyerite

General

As shown in Table 1, beyerite was found in three deposits: the School Section and Mica Lode pegmatites of the Eight Mile Park area in Fremont County and the Meyers Ranch pegmatite in Park County. The location of these pegmatite bodies is shown in Fig. 1. In all three beyerite is a very rare mineral and occurs intimately associated with bismutite, with which it formed contemporaneously.

Meyers Ranch pegmatite

The Meyers Ranch pegmatite is in Park County on the west side of Colorado highway 9, northwest of Guffey (Heinrich and Hanley, 1943, and Hanley, 1946). The body is lens-shaped with inward-dipping footwall contacts. A core of white to pink quartz and blocky microcline is enclosed in a wall zone of medium-grained quartz and microcline. Along the contact between the two zones there has been formed a replacement unit that consists of albite, muscovite, beryl, columbite, and black tourmaline. Much of the muscovite in this unit occurs as fracture fillings and tabular fracture-controlled replacement bodies (Fig. 2). Several masses of bismuth carbonates were found in the massive quartz along the contact with the replacement unit. The largest, a wedge-shaped, highly fractured mass about 8 inches long, contained about five pounds of the minerals (Fig. 2).

This material, which consists of very intimately intergrown beyerite and bismutite, is gray, buff yellow, and brown in color and has an earthy to locally waxy texture. The beyerite and bismutite cannot be distinguished megascopically; indeed the presence of the former was not suspected until the characteristic lines were found in *x*-ray powder photographs.

X-ray powder photographs of seven different samples indicate that most of the material consists of about 90–95% bismutite and 5–10% beyerite. One of the samples, which photographs showed to be at least 95% beyerite, was selected for analysis (Table 4).

No vestiges of the original bismuth mineral were found. The original material appears to have formed as a late hydrothermal mineral, selectively replacing fractured quartz along the margin of the massive quartz core.

Eight Mile Park area

The geology of this area and its pegmatite bodies has been described by the writer (Heinrich, 1947). Bismutite was found in four of the deposits (Table 1) and beyerite in two of the largest pegmatites, the School Section and the Mica Lode (Fig. 3).

At the School Section quarry one- to two-inch nodules of gray bismutite occur with albite, muscovite, and black tourmaline in a replacement unit around a core pod of quartz and blocky microcline. Associated with the bismuth carbonate are secondary chalcocite and its alteration product, malachite. Rare, minute blebs of a white metallic mineral scattered throughout the chalcocite were found to be native silver by means of an *x*-ray powder photograph. *X*-ray powder patterns also indicate that the bismutite contains intergrown beyerite in minor quantities. A separation of the two minerals was not feasible.

In the Mica Lode pegmatite bismutite and beyerite are somewhat more abundant. They occur together in 2-inch pods, within aggregates of large blades of wedge muscovite. Some of the nodules are pure bismutite, some contain both bismutite and beyerite intimately intergrown, and some are pure beyerite. Those containing only beyerite are generally waxy in

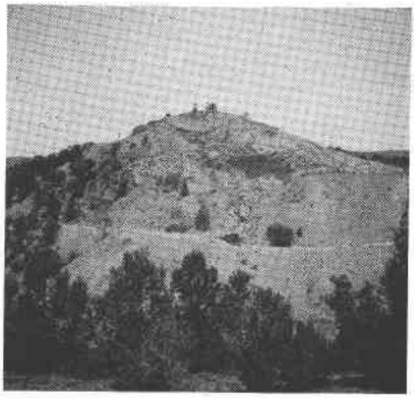

FIG. 3. Open cut in the Mica Lode pegmatite, Eight Mile Park, Fremont County, Colorado.

texture and greenish-gray in color, whereas the bismutite and bismutite-beyerite nodules are gray in color and characteristically earthy in texture. An analysis of beyerite from this pegmatite is given in Table 3.

The carbonates and associated muscovite aggregates occur as part of a pegmatite unit of albite-oligoclase, muscovite, beryl, and triplite which has been formed by replacement of the footwall half of a large microcline-rich core. Locally associated with the bismuth minerals is malachite-stained chalcocite, which also occurs elsewhere in the unit in six-foot masses intergrown with spessartite garnet. Traces of native bismuth occur in chalcocite.

MINERALOGY OF BEYERITE

The properties of Colorado beyerite as determined by the writer are in close agreement with those listed by Frondel (1943, pp. 532–533) for the type material from Schneeberg. The following is a composite, generalized description of the mineral:

Bright yellow in crystals, white, gray-green, and gray in massive form; white streak; waxy to vitreous luster; $G=6.08-6.56$; no cleavage observed; effervesces in dilute HCl; uniaxial negative or rarely anomalously biaxial with a very small 2V; $\omega=2.11-2.15$, $\epsilon=1.94-1.99$; pleochroism absent; $a_0=3.78$, $c_0=21.77$, and $a_0:c_0=1:5.759$; tetragonal centrosymmetrical (D_{4h}); primitive space lattice type.

Before chemical analyses were begun spectrograms were made by Dr. John C. Rabbitt in order to determine the major constituents:

TABLE 2. SEMI-QUANTITATIVE SPECTROGRAPHIC ANALYSES OF BEYERITE

	Mica Lode	Meyers Ranch
BeO	.03%	—
Bi_2O_3	major constituent	major constituent
Cr_2O_3	—	—
Co_2O_3	—	—
CuO	0.6%	.01%
HgO	—	—
MnO_2	0.1%	.02%
MoO_3	—	
NiO	—	—
PbO	2%	1.5–2.0%
SnO		—
CaO	>5%	>5%

TABLE 3

	1	2	3	4
Bi_2O_3	73.65	75.29	.162	1
CaO	8.85	9.05	.161 } .168	1
PbO	1.73	1.77	.007 }	
CuO	1.10			
MnO	0.12			
CO_2	13.59	13.89	.316	2
Insol.	0.79			
	99.83	100.00		

1. Analysis of beyerite from Mica Lode pegmatite, Eight Mile Park, Colorado, by F. A. Gonyer.
2. Analysis recalculated to 100% for Bi_2O_3, CaO, PbO, and CO_2.
3. Weight percentages divided by molecular weights.
4. Oxide ratios.

The spectrogram of the Meyers Ranch material also showed strong lines for Si, and weak to very weak lines for Ag, Fe, and Mg.

A sample of beyerite from the Mica Lode pegmatite was prepared for analysis by crushing selected parts of nodules and carefully hand picking fragments beneath the binocular microscope. A powder x-ray photograph of a portion of the two-gram sample showed that the material was nearly pure beyerite; bismutite lines were absent. Microscopic examination disclosed the presence of a small amount of quartz, less than 1%. This sample was then analyzed (Table 3).

A two-gram sample from the Meyers Ranch deposit was prepared in a similar manner. Microscopic examination showed that less than 1% of quartz was present, but that bismutite was present in a somewhat larger quantity. The two minerals could not be separated by hand picking or the usual gravimetric methods. An *x*-ray powder photograph of the sample did not reveal bismutite lines; probably the percentage of bismutite present as an impurity was of the order of 5%. The analysis of this sample is given in Table 4.

The formula of beyerite is therefore:

$$CaO \cdot Bi_2O_3 \cdot 2CO_2 \text{ or } (Ca, Pb)Bi_2(CO_3)_2O_2.$$

Lead appears to substitute to a very limited extent for calcium. Lead was also detected spectrographically in the Pala, California, beyerite (Frondel, 1943, p. 533). With the use of the cell dimensions and gravity measured on the Schneeberg crystals the number of molecules in the unit cell can be calculated:

$$n = \frac{VGN}{M}$$

$$n = \frac{(3.78)^2(21.77)(10)^{-24}(6.56)(.606)(10)^{24}}{610.08}$$

$$n = \frac{1234.89}{610.08} = 2.02 \text{ molecules per unit cell.}$$

Differential thermal analyses of bismutite (Petaca, N. M.) and beyerite (Mica Lode, Colo.) have been made by Dr. Carl W. Beck (1946, pp. 112, 114) who reports the following characteristics: for bismutite the curve consists of two merging endothermic curves. Decomposition begins at 400° C., reaches a peak at 530° C. and merges with the second curve which reaches a peak at 625° C., shoulders at 650° C. and returns to zero deflection at 695°. At 730° C. occurs the inversion of the decomposition product, β—Bi_2O_3, to an undetermined polymorph.

The curve for beyerite is considerably different: A large endothermic break begins at 485° C., reaches a peak at 570° C., returns to zero deflection at 625° C. (loss of CO_2). The second deflection, which represents the inversion of β—Bi_2O_3, begins at 660° C., attains its peak at 675° C. and returns at 700° C.

TABLE 4

	1	2	3	4
Bi_2O_3	76.61	78.98	.169	1
CaO	7.44	7.67	.137 } .143	1
PbO	1.25	1.29	.006 }	
CuO	0.25			
Fe_2O_3	0.84			
CO_2	11.70	12.06	.274	2
H_2O	0.96			
Insol.	0.84			
	99.89	100.00		

1. Analysis of beyerite with minor admixed bismutite, from Meyers Ranch pegmatite, Park County, Colorado, by F. A. Gonyer.
2. Analysis recalculated to 100% for Bi_2O_3, CaO, PbO, and CO_2.
3. Weight percentages divided by molecular weights.
4. Oxide ratios.

REFERENCES

1. BECK, CARL W. (1946), An improved method of differential thermal analysis and its use in the study of natural carbonates, Ph.D. Thesis, Harvard University.
2. BODENBENDER, W. (1899), Wismuthspat (cerhaltig) in Gangform: *Zeit. Prakt. Geol.*, 322–323.
3. FRONDEL, CLIFFORD (1943), Mineralogy of the oxides and carbonates of bismuth: *Am. Mineral.*, **28**, 521–535.
4. HANLEY, JOHN B. (1946), Beryllium and tantalum pegmatites of Colorado: (Abstr.) *Am. Mineral.*, **31**, 196–197.
5. HEINRICH, E. WM. (1946), Bismuth minerals in Colorado and New Mexico pegmatites: (Abstr.) *Am. Mineral.*, **31**, 198.
6. ——— (1947), Geology of the Eight Mile Park pegmatite area, Colorado, Ph.D. Thesis, Harvard University.
7. ———, AND HANLEY, JOHN B. (1943), The Meyers Ranch pegmatite near Guffey, Park County, Colorado. Manuscript Report in files, U. S. Geol. Survey.
8. ———, AND JAHNS, R. H. (1947, in preparation). The accessory minerals of the Petaca pegmatites, Rio Arriba County, New Mexico.
9. JAHNS, RICHARD H. (1946*A*), Mica deposits of the Petaca District, Rio Arriba County, New Mexico: *New Mexico Bureau Mines and Mineral Resources*, Bull. **25**.
10. ——— (1946*B*), Mica-bearing pegmatites of the Petaca district, northern New Mexico: (Abstr.), *Bull. Geol. Soc. Am.*, **57**, 1254.
11. ——— (1946*C*), Lithium-tantalum pegmatites in Mora County, New Mexico: (Abstr.) *Bull. Geol. Soc. Am.*, **57**, 1208.
12. WOLFE, C. WROE, AND HEINRICH, E. WM. (1947), Triplite crystals from Colorado: *Am. Mineral.*, **32**, (518–526).