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The carbonatite stock at Iron Hill, Gunnison County, Colorado--Chemical and mineralogical data

by

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Introduction

Chemical and mineralogical data for 28 samples of carbonatite from the carbonatite stock at Iron Hill, near Powderhorn, Gunnison County, Colorado, are presented in this report. These samples were collected in order to provide data on the thorium resources of the carbonatite stock (Armbrustmacher, 1979) part of a Department of Energy contract with the U.S. Geological Survey to provide resource data on the principal thorium deposits in the United States (Staatz and others, 1978).

The carbonatite stock at Iron Hill is part of an alkaline rock complex (fig. 1) originally described by Larsen (1942). The complex, which occupies an area of about 30 km^2, consists chiefly of pyroxenite, magnetite-ilmenite-perovskite segregations, uncompahgrite, ijolite, hybrid pyroxenite-syenite rocks, nepheline syenite, and carbonatite, listed oldest to youngest (Hedlund and Olson, 1961). Rocks of the complex were emplaced about 570 m.y. ago (Olson and others, 1977) into Precambrian X Powderhorn Granite and metamorphic rocks that are locally fenitized adjacent to the complex. Carbonatite dikes, martite-fluorapatite veins, and jasper-rich veins are found in and adjacent to the alkaline complex; and thorium-rich veins occur outside of the complex. Rocks of the complex and surrounding area have been mapped by Hedlund and Olson (1968, 1975) and Olson (1974).

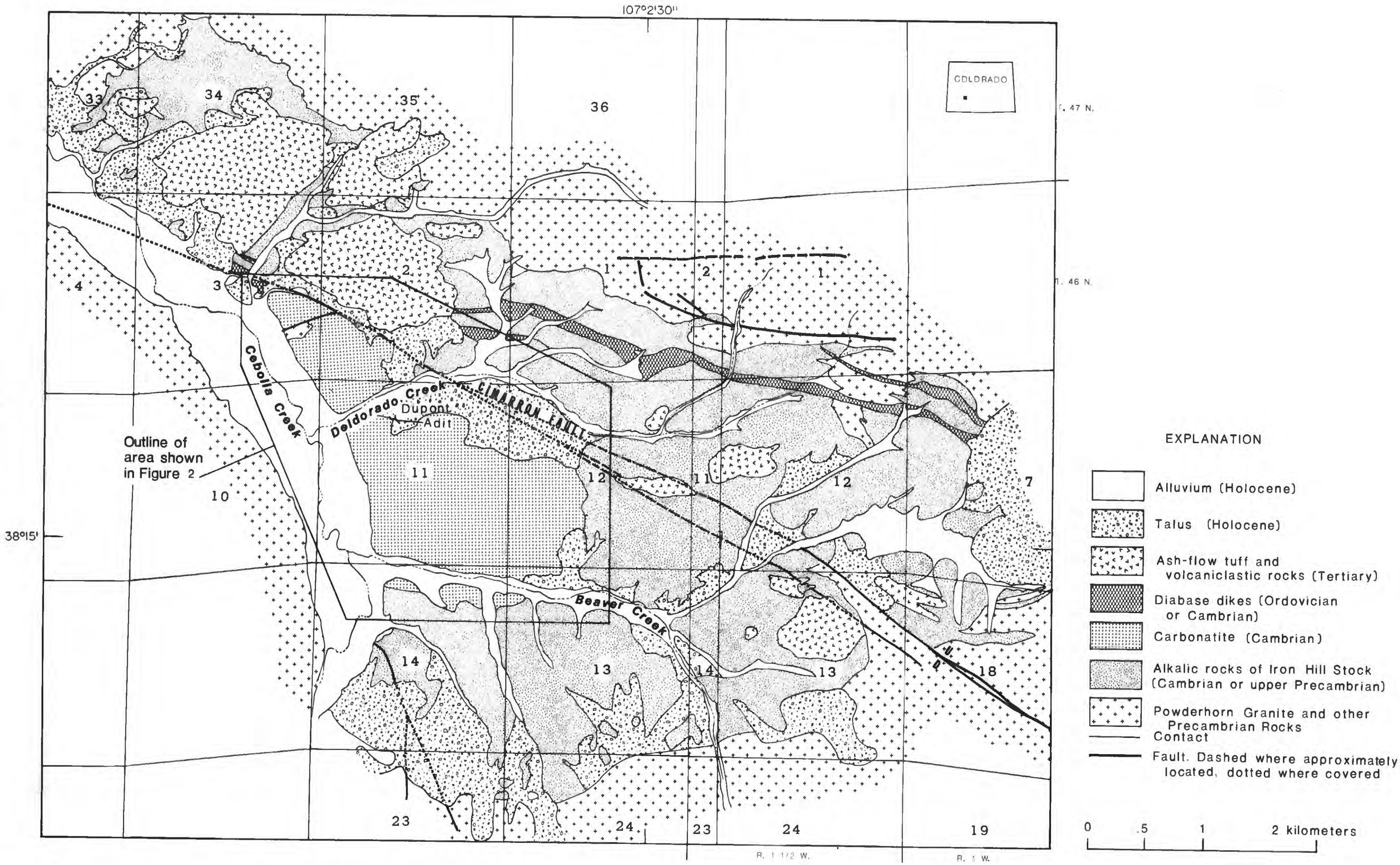

Figure 1.-Geologic map of the alkalic complex at Iron Hill, Gunnison County, Colorado. Modified from Hedlund and Olson (1975) and Olson (1974).

Potentially economic deposits of thorium, niobium, rare-earth elements (Hedlund and Olson, 1961), iron (Singewald, 1912), titanium (Rose and Shannon, 1960), and vermiculite are associated spatially and genetically with the alkaline complex.

Methods of study

The distribution of thorium in the carbonatite stock at Iron Hill was determined by field measurements of thorium abundances at 173 stations within or immediately adjacent to the carbonatite (fig. 2). Measurements were made with a Geometrics model DISA-400A portable differential four-channel gamma-ray spectrometer[1]. Details pertaining to operation of the spectrometer and data reduction are discussed by Armbrustmacher (1979). Results of these thorium measurements, summarized in figure 3, show that the carbonatite contains an average value of 36.2 ppm Th (0.0041 percent ThO_2), a median value of 31 ppm Th, a minimum value of 6 ppm Th, and a maximum value of 150 ppm Th.

Composite samples weighing about 1 kg were collected at 28 carbonatite localities (fig. 2) for additional chemical and mineralogical studies. The samples were ground to -20 mesh and split until an aliquot of approximately 150 g was attained. This aliquot was further ground to -100 mesh and submitted to the analytical laboratories for six-step semiquantitative spectrographic analysis. The remaining ground sample, at least 600 g, was analyzed for radium-

[1]Use of a brand name in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

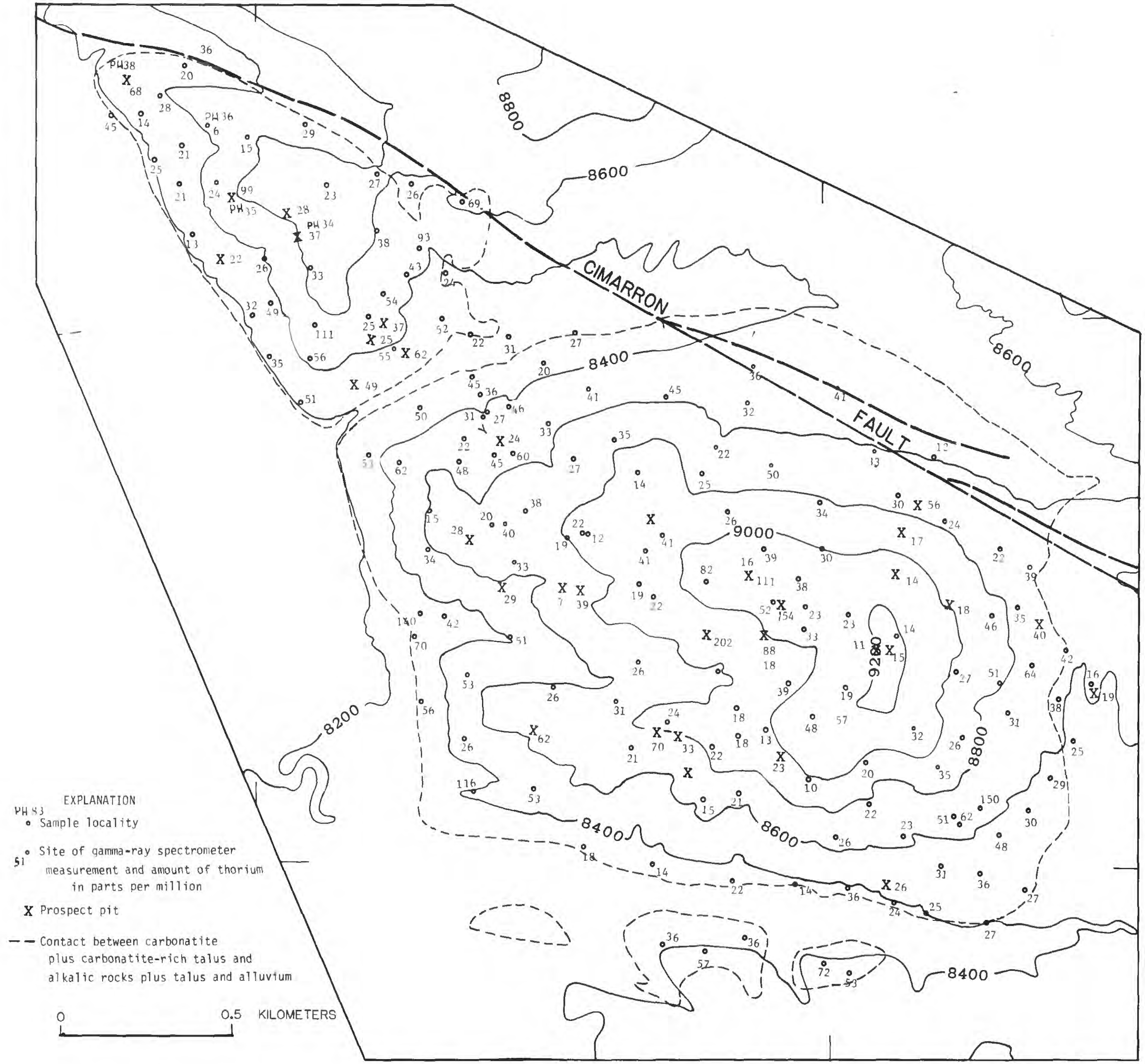

Figure 2.- Map showing sample localities and sites of gamma-ray spectrometer measurements. See Figure 1 for location of this map.

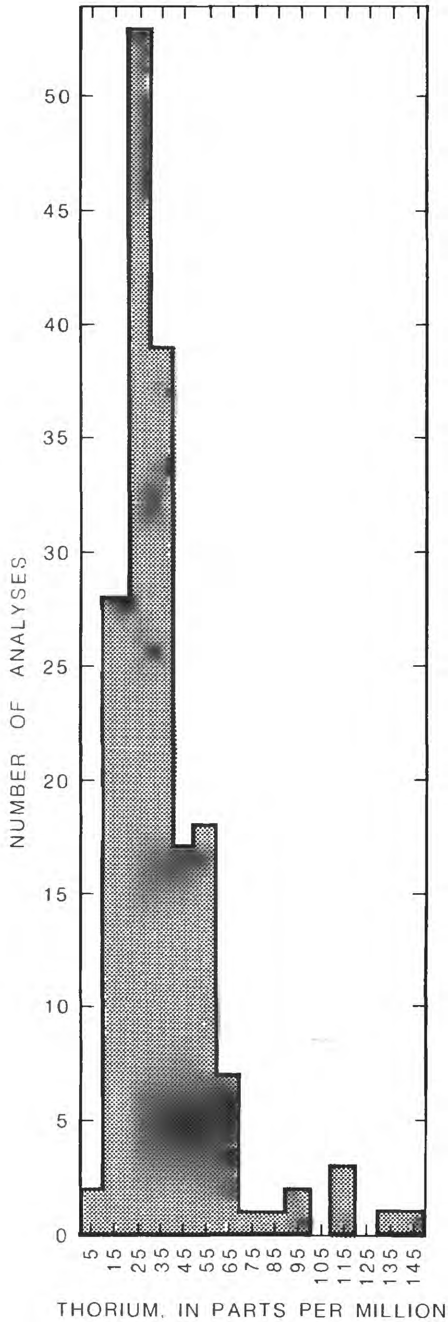

Figure 3.-Histogram of frequency distribution of 173 thorium values, in parts per million, determined by field gamma-ray spectrometry, from the Iron Hill Carbonatite. Thorium concentration values on the abscissa, represent the midpoints of intervals 10 ppm wide.

equivalent uranium and thorium using laboratory gamma-ray spectrometric techniques. Results of the analytical determinations are given in table 1.

The same sample that was used for gamma-ray spectrometric analysis was then passed through methylene iodide, and the fraction that was heavy enough to sink was split into two to five additional fractions by magnetic separation. Mineral components were then identified either by X-ray powder diffraction techniques or by sight (table 1). Measurements of alpha radiation were made of each mineral concentrate prior to X-ray. Rock textures were examined, and additional mineral identifications were made petrographically.

Chemical data

Results of the six-step semiquantitative spectrographic analyses and gamma-ray spectrometric analyses of 28 carbonatite samples are given in table 1. The spectrographic analyses report concentrations in six geometric steps having midpoints at 1.5, 2, 3, 5, 7, 10, 15, and so on. The precision of a given value is about plus- or minus-one step at 68 percent confidence. The gamma-ray spectrometric analyses are significant to three digits. Precision of radium-equivalent uranium and thorium analyses is 0.05 ppm plus 2 percent of the stated value. For calculating averages in table 1, values designated as G are replaced by a value equivalent to one spectrographic step greater than the upper detection limit; values designated as L or N are replaced by a value one spectrographic step below the lower detection limit; values given as a dash did not enter into the calculations.

Table 1.--Chemical and mineralogical data for carbonatite from Iron Hill, Gunnison County, Colorado

[G, greater than 10 percent; N, not detected at limit of detection; L, detected but below limit of detection; n.a., not analyzed; X, identified by x-ray powder fraction diffraction techniques; 0, identified either in thin section or in heavy-mineral separates; ?, identification uncertain; Leaders (---), not identified. Looked for but not detected: Ag, As, Au, B, Bi, Cd, Pd, Pt, Sb, Sn, Te, W, Ge, Hf, In, Li, Re, Ta, Tl. Semiquantitative spectrographic analyses by L. A. Bradley. Gamma-ray spectrometric analyses by C. M. Bunker and C. A. Bush]

Sample No.--	PH-2	PH-3	PH-4	PH-8	PH-9A	PH-10	PH-11	PH-12	PH-13	PH-14	PH-16	PH-19	PH-20	PH-22	PH-23
Semiquantitative spectrographic analyses, in percent															
Fe----------	3.	5.	5.	3.	5.	1.5	7.	7.	1.	5.	10.	3.	7.	1.5	G
Mg----------	5.	5.	.7	3.	3.	7.	3.	3.	5.	5.	.7	3.	1.5	5.	2.
Ca----------	7.	7.	7.	7.	7.	7.	G	7.	7.	7.	G	7.	G	7.	G
Ti----------	.15	1.	.5	.7	.2	.007	1.	.03	.0015	.3	.05	.05	.03	.007	.03
Mn----------	.15	.15	.07	.15	.3	.15	.3	.3	.15	.2	G	.15	G	.2	G
Ba----------	.15	.15	.7	.3	.3	.02	.7	5.	.02	5.	1.5	.07	3.	.07	2.
Be----------	N	.0007	.0007	.00015	.0005	N	.00015	N	N	.00015	.0015	N	.0015	N	.007
Co----------	.001	.002	.001	.0015	.001	.001	.003	.0015	L	.0015	.007	.0015	.015	L	.015
Cr----------	.003	.03	.01	.007	.007	.0003	.005	.007	.0005	.01	.003	.005	.003	.0015	.003
Cu----------	.007	.015	.007	.005	.005	.003	.01	.002	.0005	.003	.007	.003	.007	.0007	.015
La----------	.05	.07	.5	.07	.07	.007	.07	.15	L	.03	.03	.015	.03	.015	.15
Mo----------	.0003	.0005	.0015	N	.0007	N	N	N	N	N	.005	N	.007	N	.015
Nb----------	.02	.02	.07	.015	.015	.03	.015	.005	.003	.02	.1	.007	.07	.005	.03
Ni----------	.007	.02	.01	.0015	.005	.0015	.003	.0015	L	.005	.005	.003	.007	.001	.015
Pb----------	.01	.001	.007	L	.002	.0015	.003	.0015	N	L	.0015	N	N	N	.0015
Sc----------	.0015	.003	.003	.0015	.0015	.0007	.0015	L	.0007	.001	.0015	.0007	.0015	.0005	.002
Sr----------	.07	.07	.07	.15	.07	.15	.15	1.	.15	1.	.15	.5	.15	.3	.15
V-----------	.003	.01	.015	.01	.007	.0007	.015	.005	L	.007	.003	.007	.003	L	.003
Y-----------	.003	.002	.015	.005	.003	.0015	.015	.002	L	.001	.003	.0015	.003	.0015	.007
Zn----------	.15	N	.03	N	N	N	N	.15	N	.07	.03	N	N	N	.03
Zr----------	.003	.015	.015	.007	.007	.0015	.07	.001	L	.0015	.003	.03	N	.0015	.0015
Si----------	1.5	7.	G	10.	7.	.15	7.	1.5	.1	2.	10.	.3	G	.2	2.
Al----------	.2	1.5	1.	2.	.5	.03	3.	.15	.01	.7	1.	.07	.3	.05	.3
Na----------	.1	2.	.15	.7	.15	.07	.3	.3	L	.2	.15	.1	.1	.07	.15
K-----------	.7	3.	1.5	7.	.7	N	7.	.7	N	1.5	N	N	N	N	.7
P-----------	.7	.5	5.	.3	.7	.7	3.	1.5	N	.7	1.5	.3	1.5	.3	1.5
Ce----------	.07	.15	.7	.15	.2	.03	.15	.3	N	.1	.15	.07	.07	.05	.3
Ga----------	.0005	.0015	.0015	.0015	.0007	N	.0015	n.a.	N	.0007	n.a.	N	n.a.	N	n.a.
Yb----------	.00015	.00015	.0005	.00015	.00015	n.a.	.0007	n.a.	n.a.	n.a.	n.a.	N	N	L	n.a.
Pr----------	n.a.	n.a.	.07	n.a.	n.a.	n.a.	n.a.	.02	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	.07
Nd----------	.03	.05	.2	.07	.07	.007	.07	.1	n.a.	.03	.05	.015	.03	.02	.2
Sm----------	N	N	.03	.015	.01	N	.015	.015	n.a.	N	N	N	N	N	.03
Eu----------	N	N	L	N	N	N	N	N	N	N	N	N	N	N	L
RE---------	.1531	.2721	1.5155	.2551	.3531	.0685	.1157	.587	L	.151	.303	.0935	.133	.0865	.757
Gamma-ray spectrometric analyses, in parts per million															
RaeU[1]-----	29.7	25.5	22.8	3.2	9.0	39.8	13.8	1.68	2.20	1.94	15.5	3.28	5.98	2.98	24.4
Th--------	111.	45.2	340.	63.8	51.3	100.	97.6	5.20	5.46	11.8	62.1	6.51	21.4	2.5	161.
Mineralogy															
Dolomite----	X	X	X?	X	X	X	X	X	X	X	X?	X	X?	X	X
Calcite-----	X?	X	---	X	X	---	X	---	---	X	X	X?	X?	---	X
Apatite-----	X	X	X	---	---	X	---	X	---	---	X	X	X	---	X
Hematite----	X	---	X	X	X	X	X	X	X	X	X	X	---	X	X
Goethite----	X	X	X	0	---	X	---	X	X	X	X	X	X	---	X
Barite------	X?	X	X	X	X	---	X	X	X	X	X	X	X	X	X
Pyrochlore--	X	---	---	---	---	X	---	---	---	---	X	X	---	---	---
Quartz------	X	---	X	---	X	---	X	X?	---	X	---	---	X	---	---
Fluorite----	X	---	---	---	---	---	---	---	---	---	---	---	---	---	0?
Rutile------	X	---	---	X	---	---	X	---	---	---	---	---	---	---	---
Magnetite---	0	X	---	---	---	---	---	X	---	X	---	---	---	---	---
Aegirine----	---	X	---	X	---	---	---	---	---	---	---	---	---	---	---
Biotite-----	---	X	X	0	---	---	---	---	---	---	---	---	---	---	---
Pyrite------	0	0	---	0	---	---	---	---	---	---	---	---	---	---	---
Anatase-----	---	X	---	---	---	---	X	---	---	---	---	---	---	---	---
Synchisite--	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---
Bastnaesite-	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---
Zircon------	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---
Sphalerite--	---	---	---	---	---	---	---	X	---	---	---	---	---	---	---
Magnesite---	---	---	---	---	---	---	---	X?	---	---	---	---	---	---	---
MnOx--------	---	---	---	---	---	---	---	---	---	---	---	---	X	---	---

[1]Radium-equivalent uranium.

Table 1.--Chemical and mineralogical data for carbonate from Iron Hill, Gunnison County, Colorado--Continued

PH-24	PH-25	PH-32	PH-33	PH-34	PH-36	PH-37	PH-38	PH-40	PH-41	PH-43	PH-44	PH-45	Average	Sample No.
Semiquantitative spectrographic analyses, in percent--Continued														
3.	3.	G	G	3.	1.5	1.5	1.5	3.	G	3.	7.	1.5	5.4	Fe
3.	10.	2.	5.	3.	3.	5.	5.	10.	.5	G	1.	7.	4.3	Mg
G	G	10.	10.	7.	7.	7.	7.	G	G	G	G	7.	10.	Ca
.1	.015	1.	2.	.03	.003	.03	.015	.15	1.	.015	.2	.015	.3	Ti
.7	.7	.5	.7	.2	.15	.2	.1	.5	.15	.7	.2	.2	.58	Mn
.15	.07	.3	3.	7.	.15	.03	.05	3.	.07	1.	10.	.02	1.56	Ba
.0007	L	.003	.0015	L	N	N	N	.0007	.0003	N	.0005	N	.0007	Be
.0007	.0005	.007	.003	.0015	L	L	L	.001	.007	.002	.002	.0015	.0018	Co
.003	.0015	.015	.03	.0015	.0007	.0015	.0015	.005	.02	.003	.007	.001	.0065	Cr
.003	.0015	.007	.007	.0015	.0007	.0015	.0007	.003	.015	.0015	.002	.0005	.005	Cu
.03	.03	.2	.5	.15	.007	.015	.015	.07	.07	.03	.007	.015	.085	La
.0015	.0007	.002	.0015	N	N	N	N	N	N	N	.0007	N	.0013	Mo
.05	.05	.15	.07	.015	.01	.007	.005	.07	.2	.03	.03	.015	.04	Nb
.003	.0015	.015	.01	.001	.0007	.0015	.0005	.003	.015	.002	.01	.0005	.0053	Ni
L	L	.003	.003	.0015	L	N	N	.0015	N	.003	.003	N	.0018	Pb
.0015	.0015	.005	.005	.002	.0007	.0007	.0007	.0015	.0007	.0007	.0015	L	.0015	Sc
.15	.2	.15	.2	.7	.2	.15	.1	.2	.3	.3	.1	.15	.27	Sr
.0015	.0007	.015	.015	.0015	L	.0007	.0007	.007	.1	L	.01	N	.005	V
.003	.003	.007	.007	.0015	L	.001	L	.005	.007	L	.003	.001	.0037	Y
N	N	N	N	.05	N	N	N	N	.07	N	N	N	.028	Zn
.0015	.0015	.01	.02	.0015	N	N	N	.003	.003	.0015	.005	.0015	.0064	Zr
7.	2.	10.	5.	1.	.1	.2	.15	3.	1.	.2	G	.07	4.4	Si
.3	.15	1.	3.	.05	.02	.07	.03	.3	.5	.1	1.5	.01	.64	Al
.1	.07	.2	.3	.1	.15	.15	.15	.1	.15	.07	.3	.07	.23	Na
N	N	1.5	3.	N	N	N	N	N	.7	N	1.5	N	1.2	K
2.	1.5	3.	3.	.7	N	.3	N	.7	7.	N	N	.3	1.2	P
.07	.07	.3	1.	.2	.02	.03	.03	.15	.3	.05	L	.03	.17	Ce
N	N	n.a.	n.a	N	N	N	N	L	n.a.	N	n.a.	N	<.0005	Ga
L	L	n.a.	n.a.	L	N	N	N	.0001	n.a.	N	.0001	n.a.	<.0001	Yb
n.a.	n.a.	.03	.15	.015	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	.013	Pr
.03	.03	.15	.3	.07	L	.015	.01	.07	.15	.01	.007	.01	.067	Nd
N	N	.015	.03	N	N	N	N	L	n.a.	N	N	N	<.01	Sm
N	N	L	L	N	N	N	N	N	N	N	N	N	<.01	Eu
.153	.133	.702	1.987	.4365	.03	.031	.055	.295	.657	.09	.04	.056	.34	Re
Gamma-ray spectrometric analyses, in parts per million--Continued														
9.67	18.2	9.96	7.15	10.2	2.75	2.84	1.50	4.25	22.6	3.63	4.65	2.50	10.8	RaeU[1]
11.6	23.7	21.5	33.4	39.7	4.59	9.89	13.9	35.6	27.5	9.02	14.3	12.0	47.9	Th
Mineralogy														
X	X	0	0	X	X	X	0	X	0	X	X	X	---	Dolomite
X	X	---	---	---	---	---	---	X	---	X	X	---	---	Calcite
X	X	X	---	---	---	---	---	---	X	---	---	---	---	Apatite
---	X	X	X	X	---	X	---	X	---	---	---	---	---	Hematite
X	X	X	X	X	X	X	0	X	0	0	0	X	---	Goethite
X	X	X	X	X	X	X	X	X	---	X	X	X	---	Barite
X	X	X	---	---	X	X	X	---	---	X	---	X	---	Pyrochlore
---	X	X	---	X?	---	X	X	---	X?	---	X	---	---	Quartz
---	---	X	---	---	---	---	---	---	---	---	---	---	---	Fluorite
---	---	---	---	---	---	---	---	---	---	---	---	---	---	Rutile
---	---	---	---	X	---	---	X	0	---	---	---	---	---	Magnetite
---	---	---	---	---	---	---	---	---	---	---	---	---	---	Aegirine
---	---	X	0	---	---	---	---	---	---	0	---	---	---	Biotite
---	---	---	---	---	0	0	0	---	---	0	0	X	---	Pyrite
---	---	---	---	---	---	---	---	---	---	---	---	---	---	Anatase
---	---	---	---	---	---	---	---	---	---	---	---	---	---	Synchisite
---	---	---	---	---	---	X	X	---	---	---	---	---	---	Bastnaesite
---	---	---	---	---	---	---	---	---	---	---	---	---	---	Zircon
---	---	X	---	---	---	---	---	---	---	---	---	---	---	Sphalerite
---	---	---	---	---	---	---	---	---	---	---	---	---	---	Magnesite
---	---	---	---	---	---	---	---	---	---	---	---	---	---	MnOx

Mineralogical data

Lists of minerals identified in each sample are also given in table 1. Additional minerals could almost certainly be found at similar sample localities and probably even in the same samples. The mineralogy of the carbonatite at Iron Hill has also been described by Temple and Grogan (1965) and Nash (1972).

References

Armbrustmacher, T. J., 1979, Abundance and distribution of thorium in the carbonatite stock at Iron Hill, Powderhorn district, Gunnison County, Colorado: U.S. Geological Survey Open-File Report 79-536.

Hedlund, D. C., and Olson, J. C., 1961, Four environments of thorium-, niobium-, and rare-earth-bearing minerals in the Powderhorn district of southwestern Colorado: U.S. Geological Survey Professional Paper 424-B, p. B283-B286.

______1968, Geologic map of the complex of alkalic rocks at Iron Hill, Gunnison County, Colorado: U.S. Geological Survey Open-File map.

______1975, Geologic map of the Powderhorn quadrangle, Gunnison and Saguache Counties, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1178.

Larson, E. S., Jr., 1942, Alkalic rocks of Iron Hill, Gunnison County, Colorado: U.S. Geological Survey Professional Paper 197-A, p. 1-64.

Nash, W. P., 1972, Mineralogy and petrology of the Iron Hill carbonatite complex, Colorado: Geological Society of America Bulletin, v. 83, p. 1361-1382.

Olson, J. C., 1974, Geologic map of the Rudolph Hill quadrangle, Gunnison, Hinsdale, and Saguache Counties, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1177.

Olson, J. C., Marvin, R. F., Parker, R. L., and Mehnert, H. H., 1977, Age and tectonic setting of Lower Paleozoic alkalic and mafic rocks, carbonatites, and thorium veins in south-central Colorado: U.S. Geological Survey Journal of Research, v. 5, p. 673-687.

Rose, C. K., and Shannon, S. S., Jr., 1960, Cebolla Creek titaniferous iron deposits, Gunnison County, Colorado: U.S. Bureau of Mines Report of Investigations 5679, 30 p.

Singewald, J. T., Jr., 1912, The iron ore deposits of the Cebolla district, Gunnison County, Colorado: Economic Geology, v. 7, p. 560-573.

Staatz, M.H., Armbrustmacher, T. J., Olson, J. C., Brownfield, I. K., Brock, M. R., Lemons, J. F., Jr., Coppa, L. V., and Clingan, B. V., 1979, Principal thorium deposits in the United States: U.S. Geological Survey Circular (in press).

Temple, A. K., and Grogan, R. M., 1965, Carbonatite and related alkalic rocks at Powderhorn, Colorado: Economic Geology, v. 60, p. 672-692.