Rare-Earth-Bearing Apatite at Mineville Essex County New York

GEOLOGICAL SURVEY BULLETIN 1046-B

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By F. A. McKEOWN *and* HARRY KLEMIC

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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By F. A. McKeown and Harry Klemic

ABSTRACT

Dumps and tailings piles of six mines and underground workings of three mines in the Mineville district, Essex County, N. Y., were tested for radioactivity and sampled to determine the extent of the occurrence of rare-earth-bearing apatite. One of the mines currently operated by the Republic Steel Corporation is in the "lower" Old Bed magnetite ore body; six levels were tested and sampled. Radioactive elements and rare earths occur in apatite in this bed everywhere it was tested. Samples and radioactivity tests in part of the abandoned Smith mine indicate that it may contain the same type of apatite-rich magnetite ore as the Old Bed.

Laboratory studies indicate that most of the rare earths, thorium, and uranium in Old Bed ore are in fluorapatite. Monazite, bastnaesite, and hematite fill fractures in and form rims around some of the apatite, but are so fine grained and intergrown that separation of them from apatite and from one another has not yet been achieved. Fourteen samples of apatite separated from magnetite ore from the Mineville district average 0.032 percent uranium, 0.15 percent thorium, and 11.14 percent rare earth oxides. Scatter diagrams of sample data show that there is a direct, but poor, correlation of phosphorous, uranium, thorium, and rare earths with radioactivity.

Two types of magnetite ore occur in the Mineville district, one high in phosphorus and one low. None of the low-phosphorus ores are radioactive. Four of the six high-phosphorus ores tested are radioactive. Two of these, the lower Old Bed and Upper Joker, are essentially the same ore body. Ore from the Smith mine is very similar to Old Bed ore and is radioactive. Some apatite-rich magnetite ore from the Cheever mine is radioactive, but it is unlike Old Bed ore. No structural or lithologic controls for the abundance or composition of the apatite have been recognized.

INTRODUCTION

Analyses of a few samples of tailings and ore, collected during reconnaissance for uranium in the Adirondack Mountain area in 1952, showed that apatite in magnetite ore from the Old Bed in the Mineville district, Essex County, N. Y., contained a high percentage of rare earths, and a small percentage of thorium and uranium. In 1953, in order to learn more about this apatite, particularly the extent of its occurrence, parts of six levels in the lower Old Bed and Harmony Bed ore bodies and one level in the Upper Joker ore body were sampled and tested with a scintillation counter and Geiger counter. Tailings from these beds were also tested and sampled. The Harmony Bed, Old Bed, and Upper Joker ore bodies, connected by underground workings, are referred to as "Mineville mines" on figure 5. Rock

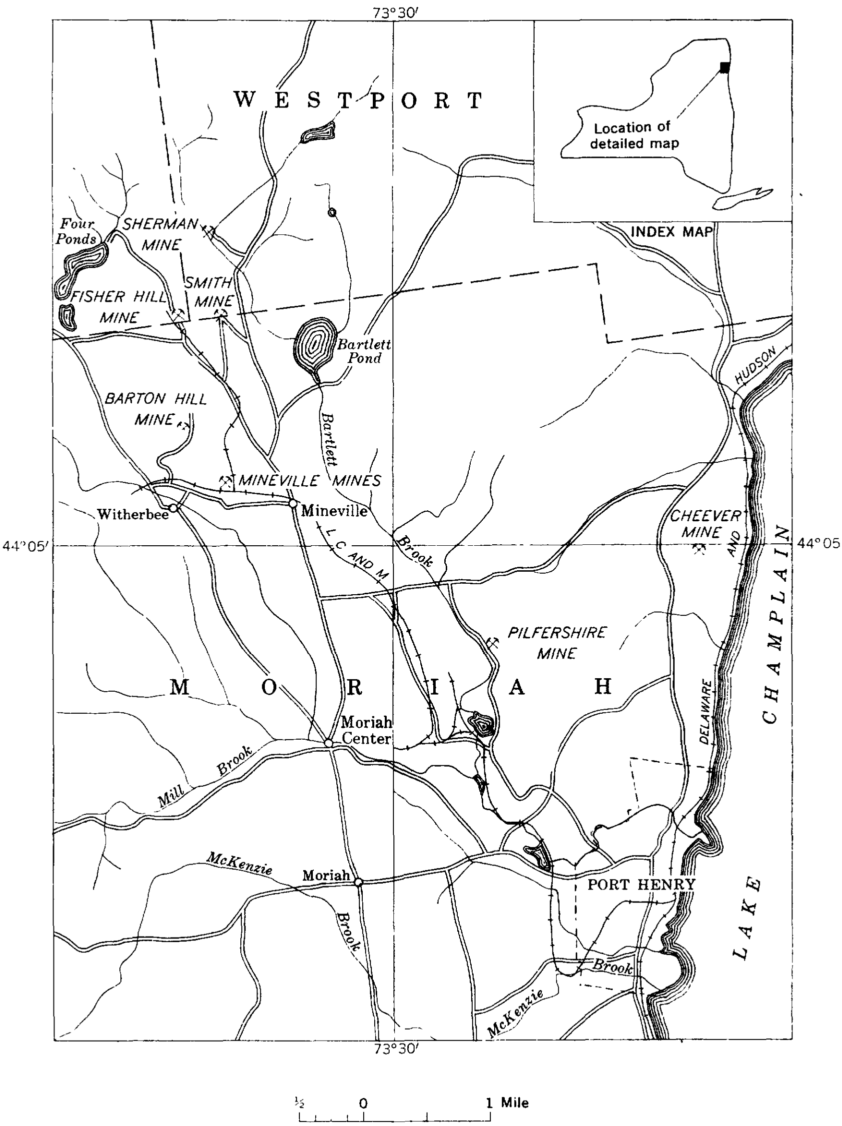

FIGURE 5.—Index map of the Mineville district, Essex County, N. Y.

from one level and from tailings at the Smith mine were likewise sampled and tested. The dumps of the Smith, Sherman, and Pilfershire mines were examined because some geologic evidence suggests that these mines may be in Old Bed-type ore. Outcrops, dumps, and tailings at the Cheever mine also were tested.

All the mines examined by the writers are leased by the Republic Steel Corporation. The writers are grateful for information and guidance given them by personnel of this corporation, especially E. F. Fitzhugh, W. A. Blomstran, H. Butterfield, and S. LaMountain.

This report is based on work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

GEOLOGY

The magnetite deposits at Mineville are in complexly folded highly metamorphosed sedimentary rocks and interlayered igneous rocks of Precambrian age. Kemp (1908) described them as "augite syenites and related types." The "related types" have a more granitic to dioritic composition. Norms recalculated from analyses, however, indicate that the rocks are not syenitic, and Buddington (1939, p. 130) suggests that they are the kind "found locally in contact zones between granite and Grenville sediments or metagabbro * * *." Alling (1925) also suggests that the rocks are a mixture of igneous intrusive and Grenville sedimentary rocks.

A generalized sequence of rock types at Mineville from the stratigraphically lowest type upward is grabbo, magnetite ore of the Old Bed, and granite gneiss that grades through a dioritic facies into gabbro and magnetite ore of the Harmony Bed. The gabbro is the equivalent of Kemp's basic syenite (1908, p. 64) and contains microperthite, augite, hornblende, pypersthene, and accessory magnetite, titanite, apatite, and zircon. The granitic facies, which is Kemp's "21" gneiss, is the hanging wall of the Old Bed; its percentage composition is microperthite 19, microcline 7, plagioclase 34, quartz 32, sphene 1, green augite 1, and magnetite 6 (Buddington, 1939, p. 130). Republic Steel Corporation geologists report that albitization of the feldspar is common (oral communication, E. F. Fitzhugh). This is borne out by analyses that show a high soda content (4.55 to 6.36 percent of Na_2O) of both the gabbroic and granitic rocks at Mineville (Buddington, 1939, p. 131). Probable correlatives of the same rocks several miles away contain less than 3 percent of Na_2O, indicating that the high soda content is peculiar to the rocks at Mineville (Buddington, 1939).

Detailed geologic mapping, by Republic Steel geologists, of observed structures in the mines as well as surface outcrops, shows an intensely folded structure that includes the lower Old Bed ore body and pitches southwestwardly and downward at 25° and lies on the upper limb of a large southerly pitching overturned fold.

MINERALOGY

All studies to date, which include X-ray, spectrographic (see table below), and optical analyses, indicate that fluorapatite in Old Bed magnetite ore contains an anomalously high percentage of rare earths, thorium, and uranium. Small percentages of monazite, bastnaesite, and hematite are included in the apatite. Complete chemical analysis and more detailed mineralogic study are still in progress, and the results will be given in a subsequent report. Most of the mineralogic work in the present study was done by Harry Klemic. Other Geological Survey personnel are credited for their contributions as mentioned in the text.

The apatite occurs as slightly distorted rice-shaped grains from about 1 to 3 mm long. Megascopically they are transparent, white, light green, or reddish brown. Microscopic examination shows that the reddish-brown coloration is due to mineral inclusions and coatings. Some of the apatite is biaxial negative rather than uniaxial negative, which is normal for apatite. Jerome Stone, of the Geological Survey, found that the omega index of refraction ranges from 1.65 to 1.68. Much of the apatite is fractured. As estimated from the optical orientation of many grains, most of the fracturing is apparently subparallel to the 0001 plane. Another set of fractures are at an oblique angle to the 0001 plane fractures, much as feather joints are oblique to a fault. Both types of fractures commonly contain reddish-brown minerals, very thin pieces of which are transparent and amber red.

Some of the apatite has a rim, about 0.05 mm thick, of reddish-brown nearly opaque minerals. In places these minerals replace an entire grain of apatite. X-ray powder patterns, made by D. D. Riska of the Geological Survey, of apatite grains with these rims and inclusions, show only apatite. Presumably the quantity of reddish-brown minerals in the apatite is less than 5 percent, and therefore they do not produce lines intense enough to be detected in the presence of the remaining 95 percent of apatite. Leaching of apatite especially rich in the reddish-brown minerals with hot 6 normal hydrochloric acid for about 6 hours dissolves the apatite. X-ray powder patterns, made by D. D. Riska, of the reddish-brown residue from this treatment show monazite, bastnaesite, and hematite. Because these minerals are so fine grained and intergrown, attempts to separate them by mechanical methods have not been successful. The thickness of the rims and abundance of the inclusions do not seem to be related to the size, shape, or environment of the clear apatite with which they are associated. Magnetite commonly surrounds the apatite, both with and without the rims, but in a few places green augite is the adjacent mineral. The contact of the reddish-brown rim with magnetite or augite is sharp; whereas the change

TABLE 1.—*Semiquantitative spectrographic analyses, in percent, of apatite separated from magnetite ore, Mineville, N. Y.*

[Analysts, K. E. Valentine and Joseph Haffty, U. S. Geological Survey. For description of samples from which the apatite was separated see corresponding sample number (without letter suffix) in table on p. 21]

Sample No.	XO.	X.	.X	.OX	.OOX	.OOOX
FK3—21A	P, Ca	Ce, Si, La, Nd, Y.	Fe, Al, Pr, Mg, Dy, Er, Gd, Yb, Th.	As, Sr, Pb, Co, Ni, Mn, B, Tm, Lu, Sm, Eu, Ho.	Sc, Cu, Ba	
24A	P, Ca	Nd, Na, Y, Ce, La.	Pr, Si, Fe, Al, Mg, As, Gd, Dy, Er.	Yb, Sr, B, Sm, Tm, Co, Ni, Mn, Lu, Pb, Ho.	Eu, Cu, Ba, Sc.	
25B	P, Ca	Na, Ce, La, Y, Nd.	Pr, Si, Fe, Al, Th, As, Mg, Dy, Er, Gd.	Yb, B, Sr, Lu, Tm, Pb, Sm, Mn, Ho, Co, Ni.	Eu, Ba, Sc	
25AB	P, Ca	Si, Na, Ce, La, Nd, Y.	Th, Pr, Gd, Mg, Fe, As, Yd, Al, Er, Dy.	Sr, Ho, Pb, Tm, Eu, Sm, Co, Lu, B, Ni, Mn.	Sc, Ba	
26A	P, Ca, Ce	Si, La, Na, Nd, Y, Pr.	Th, Al, Mg, Fe, Gd, Yb, Er, B, Dy.	Sm, Sr, Tm, Lu, Ho, Mn, Eu, Pb.	Sc, Be, Ba	
40A	P, Ca	Ce, Na, Si, La, Nd, Y.	As, Th, Fe, Pr, Yb, Al, Mg, Dy, Gd, Er.	B, Sr, Pb, Lu, Mn, Ho, Tm, Sm, Ni, Co.	Eu, Cu, Sc, Ba.	
41A	Ca, P	Si, Ce, Y, La, Nd, Na, Th.	Gd, Pr, Yb, Er, Fe, As, Dy, Mg, Al.	B, Sr, Pb, Sm, Ho, Tm, Lu, Mn, Co, Eu, Ni.	Sc, Cu, Ba	Be.
42A	Ca, P	Si, Y, Ce, La, Nd, Na, Th.	Gd, Pr, Er, As, Yd, Fe, Al, Dy, Mg.	Sr, Pb, Sm, Ho, Tm, Lu, Mn, B, Eu, Co, Ni.	Sc, Cu, Ba	Be.
43A	P, Ca	Na, Y, Si, Nd, Ce, La.	As, Fe, Yb, Pr, Er, Gd, Al, Mg.	Sr, Dy, Th, B, Mn, Tm, Ho, Pb, Lu, Co, Sm.	Eu, Ni, Cu, Sc, Be, Ba.	
44A	P, Ca	Na, Ce, Y, La, Si, Nd.	Fe, Th, Al, Er, As, Gd, Pr, Yb.	B, Mg, Dy, Sr, Mn, Ho, Pb, Tm, Lu, Sm, Co.	Eu, Ni, Cu, Sc, Ba.	Be.
45A	P, Ca, Ce	La, Si, Y, Mg, Nd, Fe.	Th, Na, Yb, Al, B, Pr, Gd, Er.	Dy, Sr, Sm, Tm, Ho, Pb, Mn, Lu, Eu, Ni.	Sc, Co, Cu, Be, Ba.	
46A	P, Ca	Ce, Si, La, Y, Mg, Nd, Na, Fe.	Al, Yb, Th, Pr, B, Gd, Er.	Dy, Sr, Sm, Tm, Ho, Pb, Mn, Lu, Eu, Ni.	Sc, Co, Cu, Be, Ba.	
48A	P, Ca	Na, Al, Si, Ce, Nd, La.	Y, Fe, Mg, As, Gd, Pr, Er.	Dy, Sr, Th, Yb, B, Tm, Mn, Sm, Pb, Ho, Co, Lu, Ba.	Eu, Ni, Sc, Cu.	Be.
49A	P, Ca	Si, Na, Ce, Nd, La.	Y, Fe, Mg, Gd, As, Pr, Rr.	Al, Dy, Sr, Th, Yb, Sm, Tm, Mn, Pb, Ho, Co, B, Lu.	Eu, Ni, Sc, Ba, Cu.	Be.

from the rim to clear apatite is gradational. The innermost part of the rim is yellow or cloudy white. Leaching polished sections of magnetite ore containing apatite with cold 6 normal hydrochloric acid for several days dissolves the clear white and green apatite leaving the reddish-brown rims and inclusions.

Within some of the reddish-brown zones pyrite occurs as minute grains in a line that follows in detail the shape of the grain of apatite. A few grains of pyrite may rarely be found between magnetite grains. Augite, albite, quartz, tourmaline, and hornblende are minor gangue minerals of the magnetite ore but are so scarce that thin sections of apatite-rich ore contain little or none of them.

Magnetite surrounds apatite and fills interstices between grains of apatite, indicating that magnetite crystallized later than apatite. The relationship of the other minerals in the ore is not determinable from the specimens available for study.

ORE DEPOSITS

Two distinct types of ore occur in the Mineville district; one is high in phosphorus, (more than about 0.50 percent) the other low (less than about 0.50 percent). Each type is represented by several ore beds which may or may not be coextensive with one another. Ore with low phosphorus content includes the Harmony Bed, Fisher Hill deposit, and New Bed of the Barton Hill mine. Ore with high phosphorus content came from the Old Bed, Upper Joker mine bed and, probably, the abandoned Pilfershire, Sherman, Smith, and Cheever mines. The gangue minerals in low-phosphorus ore are primarily quartz, feldspar, and pyroxene; those in high-phosphorus ore are apatite, feldspar, pyroxene, and quartz.

In Old Bed ore the persistence of apatite, independent of the variations in percentage of other minerals, is notable. There is no obvious relation between percentage of magnetite and apatite; some apatite is always present, even where all other gangue minerals are absent. The apatite content of small blocks of ore, measuring less than about 1,000 tons, ranges widely. This is apparent both by radioactivity measurement and visually. Blocks of ore larger than 1,000 tons tend to have about the same average apatite content. Coarse-grained high-grade ore generally contains the least percentage of apatite and other gangue minerals. Medium- to fine-grained ore (magnetite grains less than 2 mm across) contains apatite-rich layers and stringers, as well as disseminated apatite.

Magnetite ore from the Cheever mine is reported to be rich in phosphorus, about 0.5 percent (Kemp, 1908, p. 71), though not as rich as Old Bed ore which contains about 0.7 percent. Pieces of ore found on the dump are mineralogically similar to Old Bed ore except that quartz is more abundant and all of the apatite is green or white. The dump is only slightly radioactive, averaging about 0.04 mr per hr.[1] Large pieces of apatite-rich magnetite ore on the dump are commonly as radioactive as 0.07 mr per hr; a few outcrops of ore in the hanging wall are as radioactive as 0.15 mr per hr in places. The paucity of radioactive ore on the dump and at outcrop suggests that the Cheever mine does not contain much of it. Because the mine is inaccessible, however, its potential as a source of radioactive material is unknown.

The Smith mine is accessible from the Fisher Hill mine through the Fisher Hill-Smith mine crosscut. Several hundred feet of the left and right branches of the cross cut were tested for radioactivity. All parts of the underground workings were about as radioactive (averaging about 0.10 mr per hr) as workings in the Old Bed. Parts of the dump were radioactive; a few pieces of ore gave readings as high as 0.17 mr per hr. Green apatite is more common in the ore on the dump of the Smith mine than in Old Bed ore; otherwise the two ores are about the same mineralogically. Further, analyses (FK3–48A, –49A, tables 1 and 2) show that the same elements are present in the

TABLE 2.—*Partial chemical and radiometric analyses, in percent, of apatite separated from magnetite ore from Mineville, N. Y.*[1]

Sample No.	U [2]	ThO_2 [2]	Th	Re [2]	eU [3]
FK3–21A	0.055	[4] n. d.	n. d.	n. d.	0.088
24A	.009	0.01	0.01	5.61	.018
25B	.018	.14	.12	5.92	.044
25AB	.026	.30	.26	8.52	.070
26A	.027	n. d.	n. d.	n. d.	.067
40A	.025	n. d.	n. d.	n. d.	.047
41A	.11	.38	.33	17.2	.204
42A	.078	.36	.32	12.9	.153
43A	.009	.06	.05	4.28	.023
44A	.025	.18	.16	7.90	.063
45A	.026	.36	.32	32.4	.102
46A	.027	.05	.04	18.4	.068
48A	.009	.03	.03	4.79	.015
49A	.011	.03	.03	4.69	.027
Average	.032	.17	.15	11.14	.070

[1] For description of samples from which the apatite was separated see corresponding sample number, without letter suffix, in table on p. 21.
[2] Uranium (U), thorium dioxide (ThO_2), and total rare-earth oxides (Re) analyses by Harry Levine, U. S. Geological Survey.
[3] Equivalent uranium (eU) analyses by B. A. McCall, U. S. Geological Survey.
[4] Not determined.

[1] For equivalence between milliroentgens per hour (mr per hr) and percent equivalent uranium (eU) see figure 6.

two ores in about the same quantities. Because of the mineralogic similarity and certain interpretations of the complex structure of the Old Bed and Smith mine magnetite bodies, Republic Steel Corp. geologists (oral communication, E. F. Fitzhugh) have considered the possibility that these two ore bodies are part of the same deposit. Similar trace-element contents of these ore bodies also tend to support this hypothesis.

The dumps of the Sherman and Pilfershire mines contain no radioactive rock. A small amount green fine-grained apatite is present in some of the Pilfershire ore, but the most abundant gangue mineral is feldspar. According to Kemp (1908, p. 71), the ore and the geologic features of the Pilfershire mine are very much like those at the Cheever mine. The maximum radioactivity measurement on the dump was 0.04 mr per hr. The Sherman mine has been considered (Kemp, 1908, p. 88) the northern extension of the Smith mine ore body. On the basis of radioactivity, however, this does not seem probable, because the maximum radioactivity measured on the dump of the Sherman mine was only 0.03 mr per hr whereas pieces of ore in the dump of the Smith mine measured as much as 0.17 mr per hr. A grab sample (FK3–39) of the ore from the Sherman mine contains 0.001 percent equivalent uranium.

Part of the underground workings, dump, and tailings of the Fisher Hill deposit, and dumps of rock and ore from the New Bed, were tested for radioactivity. Neither, however, contained any material that measured more than 0.03 mr/per hr.

INTERPRETATION OF DATA

To visualize the various relationships between radio-activity, phosphorous, uranium, thorium, and rare earths in apatite in Old Bed ore and tailings, the available data are plotted on scatter diagrams (figs. 5–10).

Figure 5 shows the relationship between radioactivity of outcrops, expressed in milliroentgens per hour (mr/per hr), and laboratory analyses for equivalent uranium of corresponding samples. The measurements of outcrop radioactivity were made with a Geiger counter, sensitive to both beta and gamma rays, held on the outcrop; the gamma response of the counter was calibrated in milliroetgens per hour by comparison with a standard radium source. The radioactivity of the samples is given as percent equivalent uranium and was measured with laboratory equipment of the U. S. Geological Survey. The equation for the regression line for the data, as calculated by the least squares method, is $eU = 0.10$ mr per hr-0.002. This agrees closely with the equation computed from a similar set of data, collected and measured the same way, previously reported by McKeown

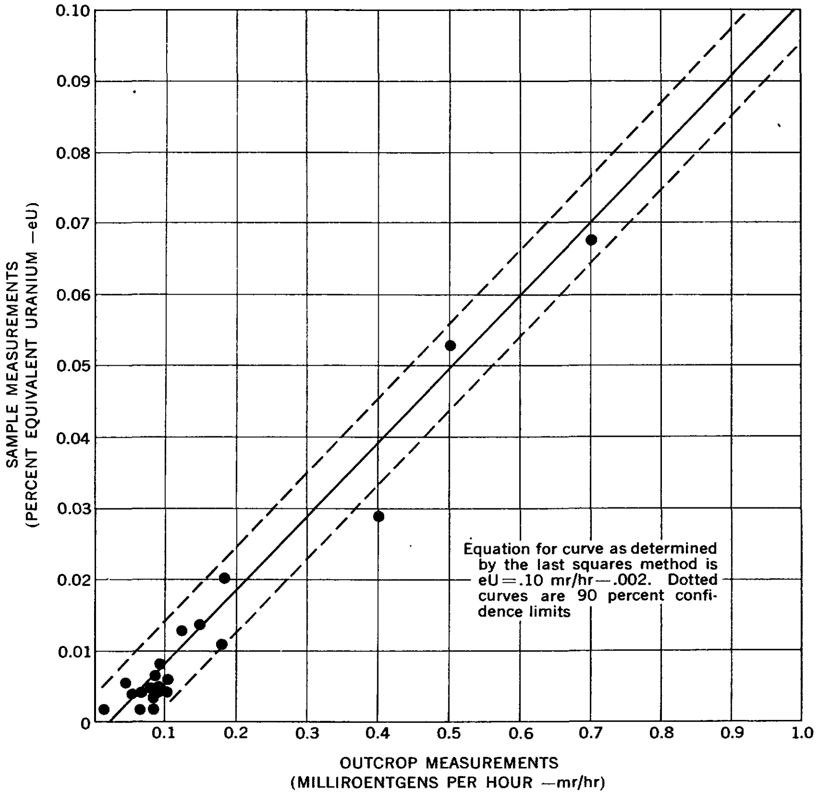

FIGURE 6.—Scatter diagram showing relation between outcrop and corresponding sample measurements of radioactivity.

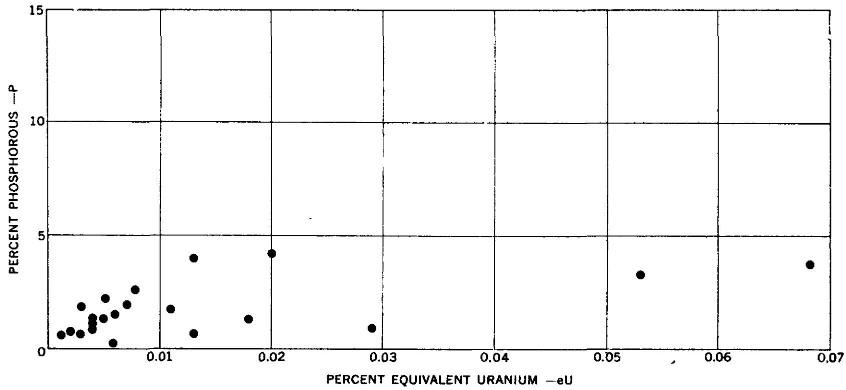

FIGURE 7.—Scatter diagram showing relation between phosphorus content and equivalent uranium tailings and magnetite ore from the Old Bed.

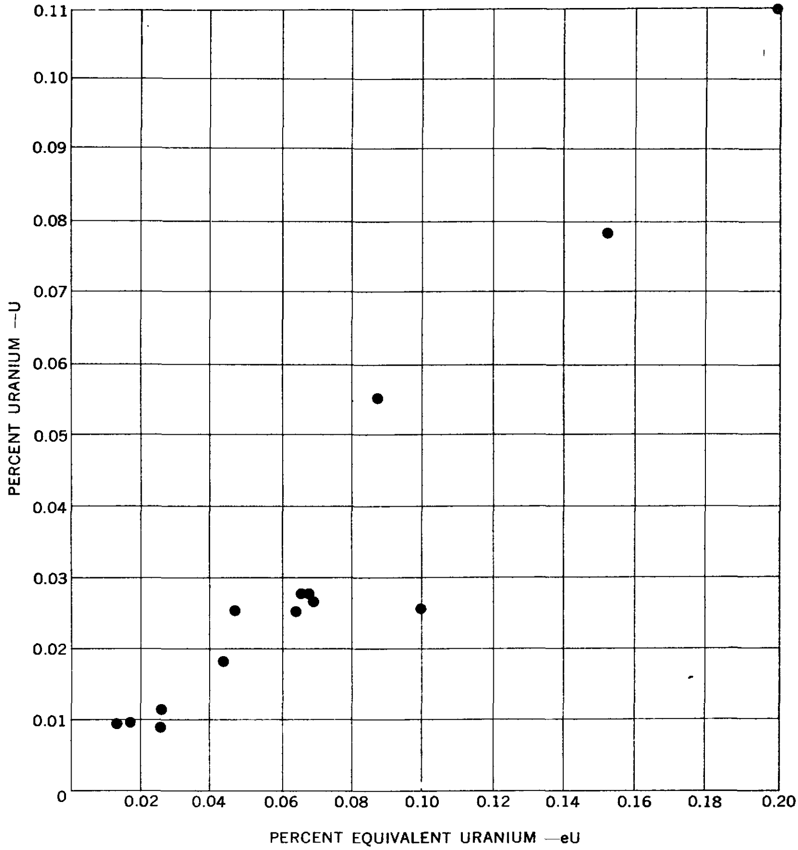

FIGURE 8.—Scatter diagram showing relation between uranium content and equivalent uranium of apatite.

and Klemic (unpublished report, 1953). The coefficient of correlation for the data in figure 6 is 0.98, where 1 is perfect correlation. Confidence limits are also plotted on the figure to show the approximate error to be expected when using the curve for correlation of radioactivity measurements.

Figures 7-10 are scatter diagrams showing the relation between radioactivity (expressed as equivalent uranium) and content of phosphorus, uranium, thorium, and total rare-earth oxides respectively. The data for figure 7 are from table 3 and the data for figures 8-10 are from table 2. Though each variable directly correlates to some degree with all other variables, the correlation is not close enough to use for computing percentage of one component from another—for example, percentage of thorium from that of equivalent uranium. Direct correlation among uranium, thorium, and rare earths can be inferred from the diagrams because each of these elements correlates roughly with equivalent uranium. This relationship is to be expected because of their geochemical similarity. Furthermore, in the Old Bed ore body they are probably genetically related; no evidence has yet been found suggesting that any one element was introduced earlier or later than another.

Samples FK3–41, –42, –45, and –46 have a lower ratio of phosphorus to equivalent uranium than all other samples. Apatite separated from them shows anomalously high rare-earth content compared with

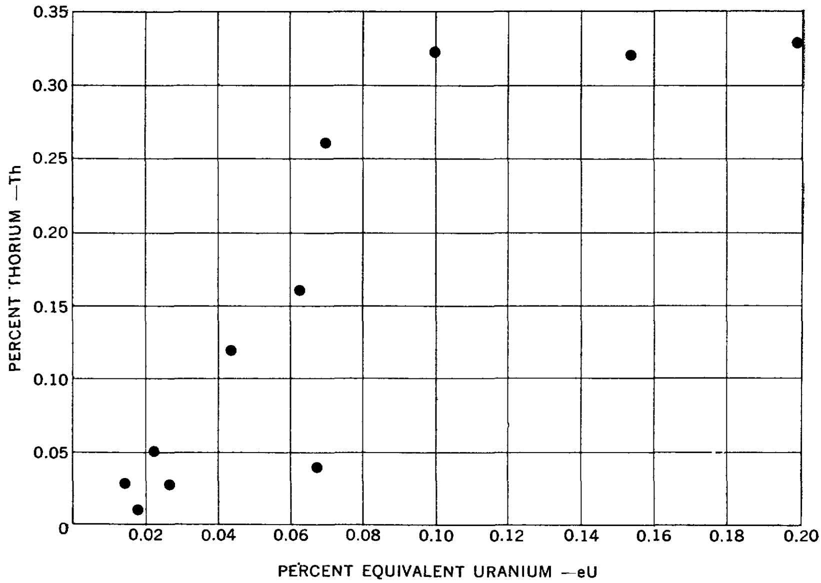

FIGURE 9.—Scatter diagram showing relation between thorium content and equivalent uranium of apatite.

other samples (table 2). These samples may have a higher content of monazite and bastnaesite than the others.

Radioactivity traverses were made and chip samples of magnetite ore were taken at six levels in the Old Bed ore body. Radioactivity traverses were also made in parts of the Harmony Bed ore body, but no samples were taken because neither the ore nor tailings (sample FK3–38) contain uranium. Typical magnetite ore as well as apatite-rich magnetite ore in the Old Bed was sampled. Analyses of the apatite from these samples (FK3–24A, –25AB, –25B, –26A, –40A, –41A, –42A, –43A, –44A, –45A, and –46A, table 2) show that all the apatite in Old Bed ore contains a high percentage of rare earths and some thorium and uranium.

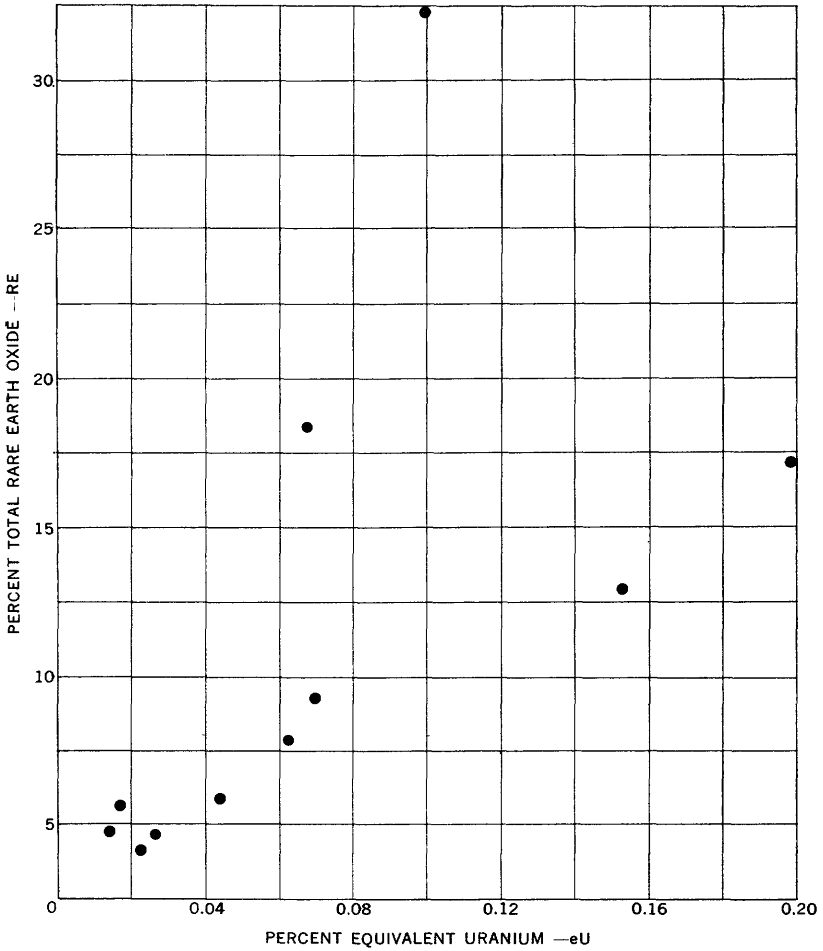

FIGURE 10.—Scatter diagram showing relation between total rare-earth content and equivalent uranium of apatite.

TABLE 3.—*Analyses of samples, in percent, from the Mineville district, Essex County, N. Y.*

[Equivalent uranium analyses by B. A. McCall, U. S. Geological Survey. Uranium and phosphorus analyses by Audrey Smith, Carmen Hoy, and Frank Cuttitta, U. S. Geological Survey. Measurement or radioactivity at the outcrop with beta-gamma Geiger counter, the gamma response of which was calibrated in milliroentgens per hour (mr per hr) by comparison with a standard radium source]

Sample No.	Description	eU	U	P	Average mr per hr
FK3-20	Tailings from No. 6 mill; probably from Old Bed and Upper Joker ore bodies.	0.013	0.005	4.0	0.12
21	Magnetite ore with red apatite; most radioactive piece found on dump of Smith mine.	.019	.008	[1] n. d.	.17
22	Magnetite-hematite(?) ore, fine-grained; from dump of Smith mine.	n. d.	n. d.	n. d.	.08
23	Magnetite ore from near hanging wall of Old Bed; +170 level.	n. d.	n. d.	n. d.	.04
24	Magnetite ore with red apatite(?); Old Bed, +170 level near scales.	.002	.001	.7	.08
25	Rich magnetite ore with apatite; Upper Joker ore body, +430 level near Clonan shaft.	.005	.003	2.2	n. d.
25A	Apatite-rich magnetite ore; Upper Joker ore body, +430 level near Clonan shaft.	.020	.006 .008	4.3	.18
26	Apatite-rich magnetite ore; Old Bed, −200 level between 1 and 8 slopes.	.011	.004	1.7	.18
27	Tailings from No. 5 mill, Old Bed and Upper Joker ore; top and east end of pile about 450 ft south of Joker shaft.	.004	.003	1.1	.09
28	Tailings; top of tailings pile and about 200 ft west of FK3-27.	.005	.002	1.3	.08
29	Tailings; top of tailings pile and about 200 ft west of FK3-28.	.001	n. d.	n. d.	.03
30	Tailings; top of tailings pile and about 200 ft west of FK3-29.	.004	n. d.	n. d.	.05
31	Tailings; top of tailings pile, west end and about 100 ft southwest of FK3-30.	.006	.003	1.6	.08
32	Tailings; about 15 ft above base of pile and 150 ft north of FK3-31.	.008	.004	2.7	.09
33	Tailings; 10 ft above road level, at turn at west end of pile.	.002	.001	n. d.	.06

See footnotes at end of table.

TABLE 3.—*Analyses of samples, in percent, from the Mineville district, Essex County, N. Y.*—Continued

Sample No.	Description	eU	U	P	Average mr per hr
FK3-34----	Tailings; 15 ft above road level, about 200 ft east of FK3-33.	0.003	0.001	0.6	0.08
35----	Tailings; 15 ft above road level, about 200 ft east of FK3-34 and about 100 ft south of Joker Shaft.	.004	.001	n. d.	.07
36----	Tailings; 10 ft above parking lot, east end of pile.	.006	.003	1.61	.1
37----	Tailings; north end of Harmony bed tailings pile; some Old Bed tailings mixed in.	n. d.	n. d.	n. d.	.07
38----	Tailings; south end of Harmony Bed tailings pile.	.006	.000	.31	.04
39----	Magnetite ore; dump of Sherman mine.	.001	n. d.	n. d.	n. d.
40----	Typical magnetite ore from near top of Old Bed; −1185 level.	.004	.003	1.22	.1
41----	Apatite-rich magnetite ore; Old Bed, −1185 level.	.068	.033	3.71	.7
42----	Apatite-rich magnetite ore; Old Bed, −1335 level in crosscut at top of raise 12.	.053	.025	3.36	.5
43----	Magnetite ore, coarse-grained with red feldspar(?); Old Bed, −1650 level at 34 contract.	.003	n. d.	1.96	.01
44----	Magnetite ore; Old Bed, −1650 level at contract 40.	.005	.003	1.05	.08
45----	Apatite-rich magnetite ore, very coarse-grained; Old Bed −1650 level, at "Y" between contracts 46 and 50.	.029	.006	.79	.4
46----	Apatite-rich magnetite ore; Old Bed, −1650 level at contract 46.	.018	.005	1.22	n. d.
47----	Tailings from June 10, 1953 production of Old Bed ore; 50 pound sample.[2]	.006	.003	1.96	n. d.
48----	Magnetite ore; +1100 ft level of Smith mine, at left branch of Fisher Hill-Smith mine crosscut.	.013	.006	.65	.15
49----	Magnetite ore; +1100 ft level of Smith mine, in right branch of Fisher Hill-Smith mine crosscut.	.001	.001	.52	n. d.

[1] Not determined.
[2] This sample also contains 0.023 percent of ThO_2 and 1.10 percent total rare earths.

CONCLUSIONS

Earlier and recent analyses, radioactivity traverses, and geologic studies made by Republic Steel Corp. geologists have not revealed any distinct structural or lithologic controls to the distribution, abundance, or composition of the apatite. More detailed testing and sampling correlated with a detailed map of the mine may show such controls, but the available data strongly indicate that no strong large-scale controls exist. Also, no significant variation in the phosphorous content of the Old Bed ore seems to exist; production figures show that the average phosphorus content has not changed appreciably since the mine has been in operation. Though monazite and bastnaesite are present, they do not seem to occur in sufficient quantity to account for the major part of the rare earth, thorium, and uranium content of the Old Bed ore. Apatite must therefore be the chief contributor of the rare elements. The uranium, thorium, and rare-earth content of Old Bed tailings is low compared with other sources of these elements such as monazite-bearing placers or veins.

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