UNITED STATES GEOLOGICAL SURVEY

TEI-67

RECONNAISSANCE OF RADIOACTIVE ROCKS OF VERMONT, NEW HAMPSHIRE, CONNECTICUT, RHODE ISLAND AND SOUTHEASTERN NEW YORK

By
Frank A. McKeown

This preliminary report is released without editorial and technical review for conformity with official standards and nomenclature, to make the information available to interested organizations and to stimulate the search for uranium deposits.

June 1951

Prepared by the Geological Survey for the
UNITED STATES ATOMIC ENERGY COMMISSION
Technical Information Service, Oak Ridge, Tennessee

GEOLOGY AND MINERALOGY

In an effort to save you and your Government time and money, this report has been reproduced direct from copy as submitted to the Technical Information Service.

CONTENTS

	Page
Abstract	5
Introduction	5
Prospecting methods	7
Distribution of radioactivity	10
The Hudson and Housatonic radioactive province	11
Geology	11
Radioactivity	12
Hudson Highlands, southeastern New York	13
Bear Mountain area	13
Locality A	13
Locality B	20
Locality C and D	21
Conclusions	21
Traverse north of Bear Mountain	22
Housatonic Highlands of western Connecticut	22
The central New England radioactive province	23
Conclusions	24
Radioactive area near Milton, Vermont	25
Geology	25
Radioactivity	28
Description of Localities	30
Locality A	30
Locality B	30
Locality C and D	31
Locality E	31
Conclusions	32
Conclusions	32

ILLUSTRATIONS

Page

Figure 1. Radioactive rocks of Vermont, New Hampshire, Connecticut, Rhode Island, and southeastern New York .... (in pocket) 47

2. Radioactive rocks of the Bear Mountain area..... (in pocket) 48

3. Relation between radioactivity and uranium content of samples from the Bear Mountain area, New York........................ 15

4. Thorium-uranium ratios in samples from the Bear Mountain area, New York.................... 16

5. Gamma radioactivity profiles at Locality A, Bear Mountain, New York........................ 17

6. Sketch of outcrop at Locality A, Bear Mountain, New York.. 19

7. Radioactive localities near Milton, Vermont......... 26

TABLES

Page

Table 1. Radioactive localities north and northeast of the Bear Mountain area in the Hudson and Housatonic Highlands........................ 34

2. Radioactive localities in the central New England province.............................. 36

3. Results of radiometric and chemical analyses of samples listed by states.............. 41

RECONNAISSANCE OF RADIOACTIVE ROCKS OF VERMONT, NEW HAMPSHIRE, CONNECTICUT, RHODE ISLAND, AND SOUTHEASTERN NEW YORK

by

Frank A. McKeown

ABSTRACT

In 1948, 7,662 miles of roadside rocks and soils in Vermont, New Hampshire, Connecticut, Rhode Island, and southeastern New York were traversed with a car-mounted Geiger-Mueller counter. The observed distribution of the abnormally radioactive rocks and soils is limited to certain areas, herein called "radioactive provinces," that are separated from each other by areas of essentially nonradioactive rock. These provinces, and their maximum percent equivalent uranium are: (1) the Hudson and Housatonic Highlands of southeastern New York and western Connecticut, 0.240 equivalent uranium; (2) Central New England, 0.006 equivalent uranium; and (3) the Milton area of northwestern Vermont, 0.029 equivalent uranium. The distribution, grade, form, and uranium-thorium ratio of the radioactive deposits differ in each of the three provinces. Most of the radioactivity outside of the Milton area is caused by thorium.

INTRODUCTION

During the late summer and fall of 1948, the Geological Survey made a reconnaissance in Vermont, New Hampshire, Connecticut, Rhode Island, and part of southeastern New York, to gain a general knowledge of the d'ᵉ ribution of radioactive materials in the New England states. The objectives of this reconnaissance were twofold: (1) To define areas in which more detailed prospecting for uranium deposits is warranted, through the correlation of abnormal radioactivity with other geologic evidence; and (2) to test and evaluate the car-traverse method of radiometric measurement and prospecting.

The radioactivity of the roadside rocks and soils was measured with car-mounted Geiger-Mueller counters. A total of 7,662 miles of roads was traversed. The mileage was distributed as follows:

States	Miles
Vermont and New Hampshire	4,732
Connecticut and Rhode Island	1,458
Pennsylvania and New York (enroute to and from New England)	1,472
Total	7,662

Traverses in Vermont and New Hampshire were planned to cross all the major geologic formations on as many roads as possible. All numbered and a few unnumbered highways were traversed. It was necessary to curtail traverses in Connecticut and Rhode Island because of approaching winter weather and, therefore, as many geologic formations as possible were traversed on a limited number of highways. However, all of the formations that appear on the geologic maps of Connecticut and Rhode Island _/ were crossed several times on different roads.

_/ Rice, W. N. and Gregory, H. E., Manual of the Geology of Connecticut: Connecticut Geol. Survey Bull. 6, 1906.

Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, map, 1917.

John M. Nelson established most of the field procedures used and aided in much of the interpretation of the data that were collected. Harold Arndt assisted in the field work. Perry F. Narten aided in the preparation of the report. All sample analyses and mineralogic studies were made by the Geological Survey Laboratory.

PROSPECTING METHODS

The car-traverse equipment and its performance characteristics have been described in a report by Nelson _/. The equipment consists

_/ Nelson, J. M., Prospecting for uranium with car-mounted equipment: U. S. Geol. Survey Trace Elements Investigations Rept. 65, July, 1949.

of a counting-rate meter, an alarm circuit, and 2 Geiger-Mueller tubes, each tube having a response of 1,500 pulses per minute in areas of normal radioactivity. The alarm circuit can be adjusted so that a bell will ring at any predetermined reading of the counting-rate meter. This serves to give an aural signal to the operator when passing roadside rocks and soils of abnormal activity and allows him to give his attention to other tasks.

Changes of 0.001 percent equivalent uranium in the roadside rocks and soils can be detected at a traverse speed of 30 miles per hour. This degree of sensitivity requires a radioactively homogeneous band of soil or rock having an equivalent uranium content between 0.000 and 0.005 percent, and a width of about 150 feet parallel to the traverse. Higher-grade deposits less than 150 feet wide usually will show a car-measured radioactivity less than the actual activity. This deviation of measured from actual radioactivity is a function of several independent variables such as the geometrical relationship of the Geiger-Mueller tube to the outcrop and the physical and chemical characteristics of the rocks. The possible variations in relationships are infinite in number and cannot be rigorously evaluated.

Radioactive rocks and soils discovered with the car-traverse equipment were further investigated on foot with a portable 42 by 2-inch gamma tube and a counting-rate meter. Small veins, joints, or areas of rocks were checked for abnormal radioactivity with a beta-gamma tube and a counting-rate meter.

Correlation of counting-rate meter readings obtained when the gamma tube is placed on the outcrop, with measurements of radioactivity of samples taken from the outcrops, made it possible to estimate the equivalent uranium content of many outcrops without sampling. Most rocks that were thought to contain 0.005 percent or more equivalent uranium were sampled and assayed for uranium.

The approximate percentage of thorium can be calculated if the radioactivity of a sample is expressed in percent equivalent uranium and the percentage of uranium in a sample is known, assuming that the uranium is in equilibrium with its disintegration products. Thus, if a sample contains 0.020 percent equivalent uranium and 0.008 percent uranium, by subtraction 0.012 percent equivalent uranium may be attributed to potassium and thorium. The potassium activity in rocks containing 3 to 5 percent K_2O is assumed to be about 0.001 percent equivalent uranium, leaving 0.011 percent equivalent uranium due to thorium activity. As the beta activity of thorium is about one-quarter that of uranium, this figure is multiplied by the factor four and the calculated content is 0.044 percent thorium. Most analyses for thorium in the New England samples show an observed factor that ranges from three to five.

Although probably only a small part of the total number of radioactivity anomalies in the New England states has been found, it is believed that the method of prospecting used was successful in partly defining the areas of concentrated radioactive anomalies, and indicating the areas favorable for detailed investigation. General knowledge of the location and extent of the abnormally radioactive area has been gained. In addition, on the basis of Nelson's data and conclusions _/, obtained from relatively small low-grade deposits, it is very probable that few, if any, deposits containing tens of tons of radioactive material of a grade above 0.1 percent uranium were missed if they crop out within 25 feet of a traversed road.

_/ Nelson, J. M., op. cit., fig. 2, pp. 6-7.

DISTRIBUTION OF RADIOACTIVITY

Most of New Hampshire, Vermont, southeastern New York, Connecticut, and Rhode Island are underlain by pre-Cambrian and Paleozoic igneous, sedimentary, and metamorphic rocks. Mesozoic sedimentary and intrusive rocks are limited largely to the Connecticut Valley. Locally, the rocks are blanketed by glacial material but it is believed that the network of roads traversed is sufficiently close-spaced so that all of the major rock units were adequately scanned with the car-mounted instruments. Abnormally radioactive glacial material in places was found south of its radioactive bedrock source for distances up to 10 miles.

The distribution of the abnormally radioactive rocks and glacial materials is such that three areas are roughly delimited on the basis of radioactivity: (1) The Hudson and Housatonic Highlands of southeastern New York and western Connecticut; (2) a belt extending from central and eastern Connecticut and western Rhode Island northward to the Canadian border, herein called "Central New England;" (3) an area near Milton, Vt. These areas are designated as "radioactive provinces," in a usage similar to "metallogenic provinces." The deposits within each province are characterized by similar maximum equivalent-uranium content, by similar ratios of thorium to uranium, and in part by the rock types in which the deposits occur. The first two areas are large and are surrounded by essentially nonradioactive rocks. The third area, although isolated with respect to other radioactive rocks described in this report, may constitute a border phase of another province, as yet undefined.

THE HUDSON AND HOUSATONIC RADIOACTIVE PROVINCE

The Hudson and Housatonic Highlands of southeastern New York and western Connecticut form a radioactive province that is characterized by a highly variable equivalent uranium content and a highly variable thorium-uranium ratio (table 3, figs. 3 and 4). Radioactive anomalies of various intensities were found from the vicinity of Peekskill, N. Y., to Cornwall Bridge, Conn. (fig. 1).

Geology

The geology of the crystalline Highlands consists _/ of a

_/ Lowe, K. E., Storm King Granite at Bear Mountain, New York: Geol. Soc. America Bull., vol. 61., pp. 142-143, 148, 1950.

sequence of intercalated quartzitic, micaceous, and calcareous rocks that were severely metamorphosed during several periods of regional deformation and granitic intrusion. Most investigators _/ in the

_/ Berkey, C. P. and Rice, Marion, Geology of the West Point quadrangle: New York State Mus. Bull., Nos. 225-226, pp. 49-51, 1919.

Lowe, K. E., op. cit., p. 150.

Highland have concluded that the metamorphic rocks were of sedimentary origin and assign them to the Grenville series of pre-Cambrian age. The The present major northeastward structural trend of the Grenville series is thought to be the result of an early pre-Cambrian orogeny. The structures thus formed have controlled, to a large extent, all the successive igneous intrusions. _/

_/ Berkey, C. P., and Rice, Marion, op. cit., p. 81.
Lowe, K. E., op. cit., p. 164.

The granite intrusions have so altered the country rocks that in much of the area it is difficult to determine whether these rocks originally were of sedimentary or igneous origin.

Radioactivity

The pre-Cambrian rocks of the Hudson and Housatonic Highlands have an estimated average radioactivity between 0.002 and 0.003 percent equivalent uranium and an observed range of 0.001 to 0.240 percent equivalent uranium. In the samples taken the maximum content of uranium is 0.095 percent and the maximum content of thorium is 1.04 percent. The thorium-uranium ratio in the samples ranges from 1:1 to 40:1. Most of the highly radioactive deposits are in pegmatites, but a pegmatized gneiss contains as much as 0.064 percent equivalent uranium. The maximum observed radioactivity in gneiss and schist is 0.013 percent equivalent uranium, in granite about 0.006 percent equivalent uranium. The more radioactive deposits are in a belt trending northeast from the vicinity of Bear Mountain Bridge, N. Y., to the village of Cornwall Bridge, Conn. (fig. 1).

Southeastern New York, Hudson Highlands

Bear Mountain Area

Near Bear Mountain, N. Y., (fig. 2), quartz-feldspar-biotite gneisses, in places carrying garnet as a major constitutent, are interlayered with several varieties of schist and resemble bedded sediments. Quartz-feldspar-biotite pegmatites, 15 feet in greatest observed dimensions, are parallel to the schistosity and layering of the gneiss. Irregular discordant masses of pegmatite also are present. Granitic rocks, usually gneissic, occur throughout the area. At five roadside localities in a 3- by 6- mile area pegmatites and gneiss contained from 0.005 to 0.200 percent equivalent uranium. Parts of the granitic rocks probably contain an average of 0.005 percent equivalent uranium, but no highly radioactive granite or pegmatites within granite, were found.

Locality A. — Most of the rock at locality A (figs. 2, 5, and 6) is composed of quartz-feldspar-biotite gneiss and schist. The banding strikes about N. 20° E. and dips 30° - 40° SE. Concordant stubby lenticular-shaped bodies of quartz-feldspar-biotite pegmatite occur in the gneiss and schist. The maximum observed size of the pegmatites is approximately 3 feet in thickness by 15 feet in length.

The radioactive minerals in the pegmatites have not been identified. Mineral analysis of quartz-feldspar pegmatitic gneiss by M. E. Thompson of the Geological Survey shows abundant zircon, a lesser amount of opaque minerals, and an unidentified mineral or aggregate of minerals containing some uranium and thorium. The uranium-bearing mineral or aggregate of minerals is a dull yellowish crust that coats various grains of the pegmatite. The zircon also is radioactive. Chemical analyses (table 3, BM (A) - 15, - 16, - 19, - 20) show that thorium also is present and that the ratio between thorium and uranium in the samples is not constant. The variation diagrams (figs. 3 and 4) show this variable ratio. The difference that is shown in figure 3 between percent equivalent uranium and precent uranium is attributed to thorium, for the effects of potassium are essentially negligible. The diagrams, when compared to sample descriptions (see table 3), also indicate that the thorium-uranium ratio is not a direct function of lithology.

The distribution and relative gamma radioactivity of the material at locality A and the location of traverses across the radioactive area are shown on figure 5. The radioactivity of the rocks along the traverse lines was estimated by noting the instrument readings over a distance of little or no change in activity and recording the average activity. This method seems to be inherently more accurate than arbitrary grid-control methods for determining the relative size and shape of a radioactive deposit, because many control points are obtained where the change in radioactivity is greatest and few where the change is least. Chemical analyses of samples from this locality show that the uranium content ranges from 0.001 to 0.065 percent and the thorium content from 0.030 to 0.480 percent (see table 3).

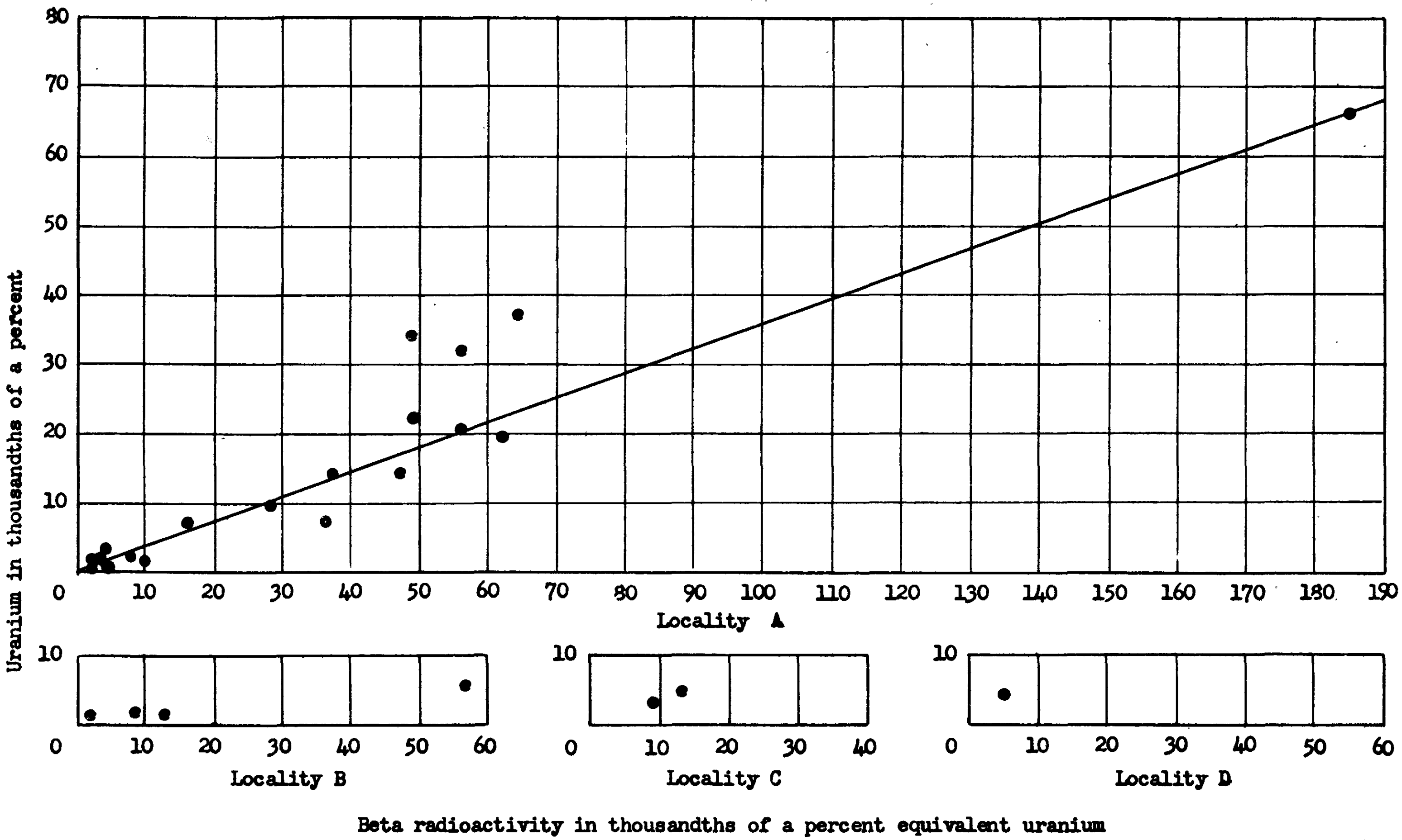


FIGURE 3. RELATION BETWEEN RADIOACTIVITY AND URANIUM CONTENT OF SAMPLES FROM THE BEAR MOUNTAIN AREA, NEW YORK

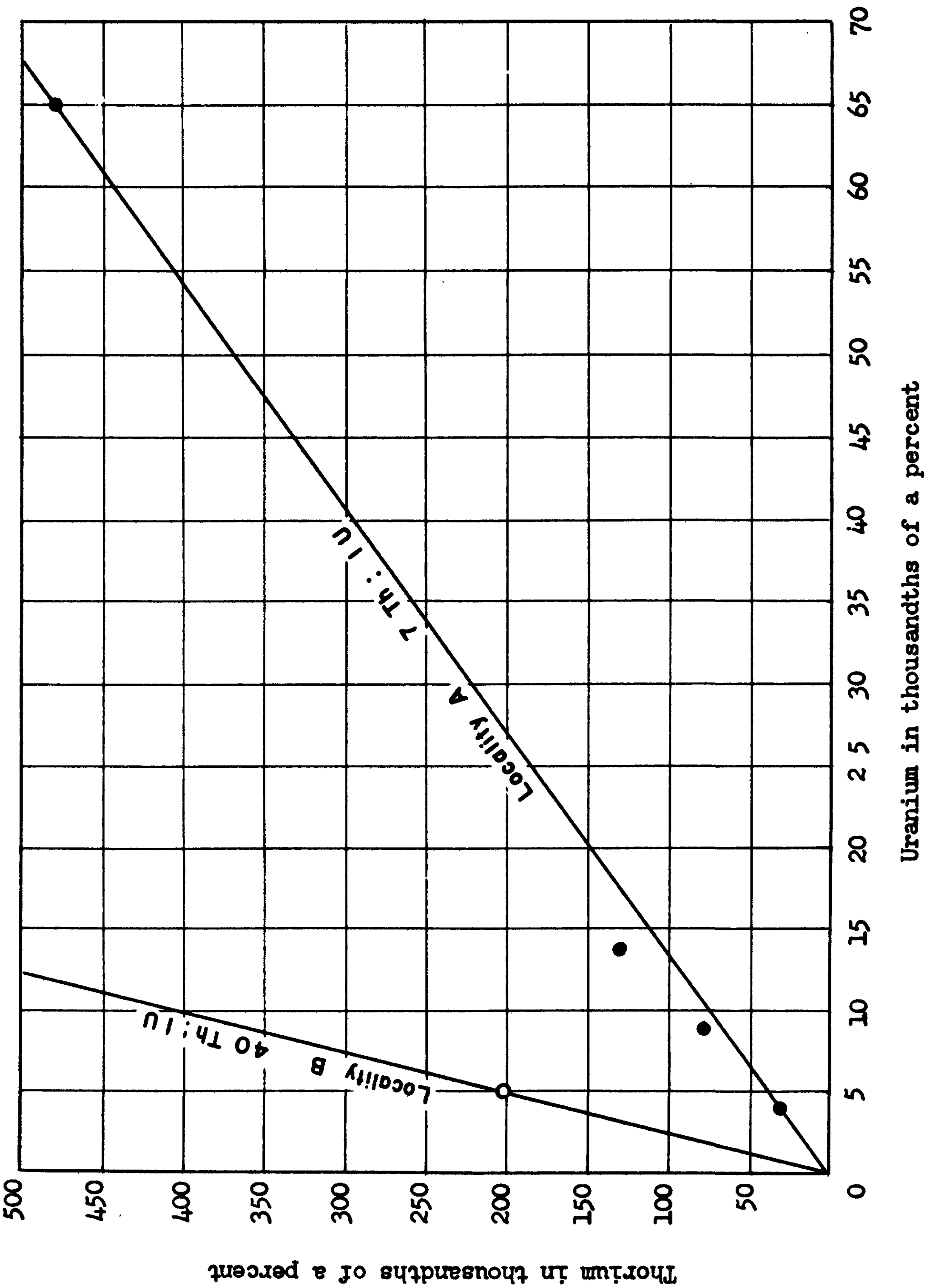
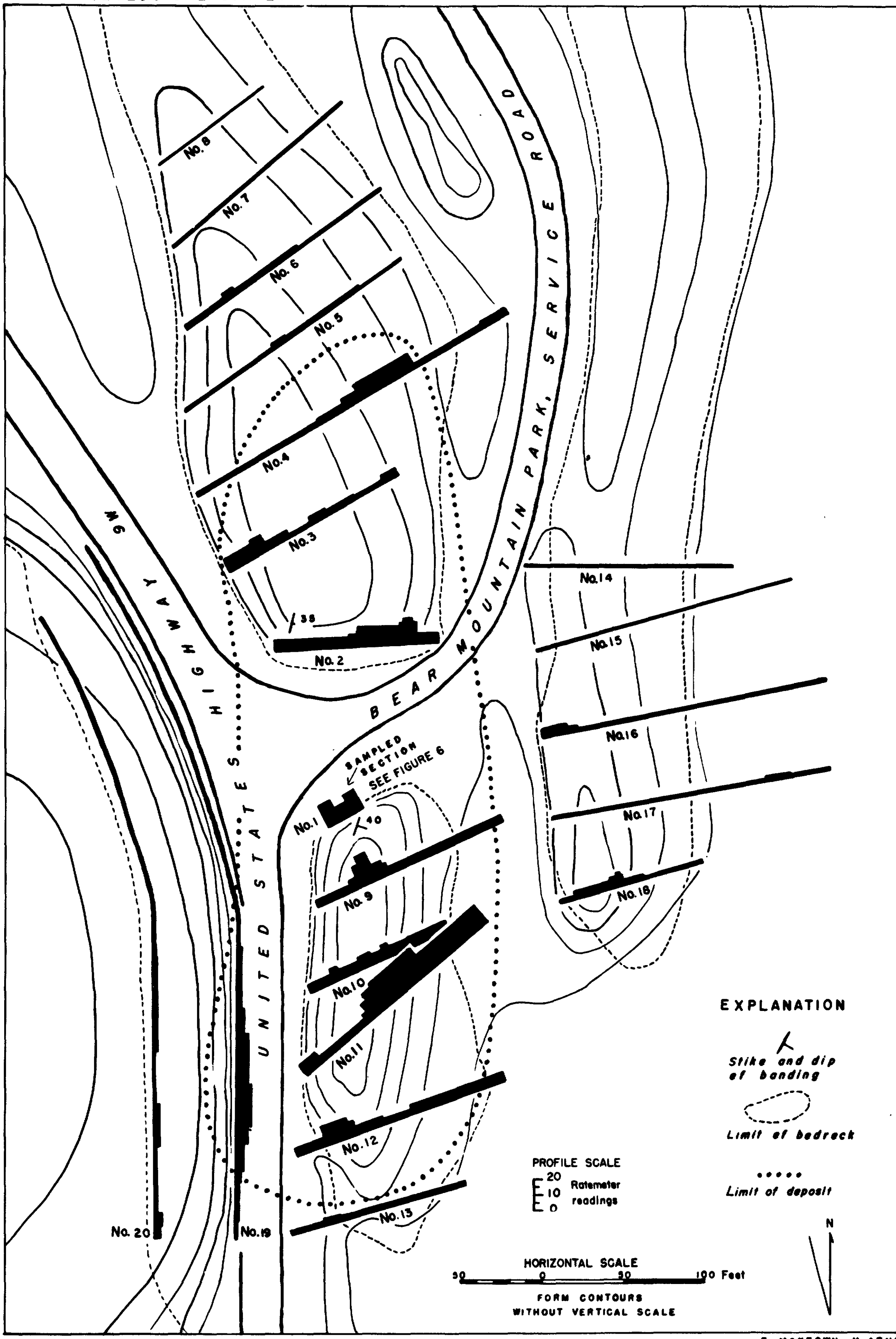


FIGURE 4. THORIUM-URANIUM RATIOS IN SAMPLES FROM THE BEAR MOUNTAIN AREA, NEW YORK

UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATIONS REPORT NO. 67



F. MCKEOWN, H. ARNDT

The geologic section (fig. 6) shows the lithology and location of samples at locality A. The hydrothermal zone at the center of the section has been thoroughly weathered and its composition was not determined except for a few resistant molybdenite-bearing quartz veins.

On the basis of extremely few data the deposit at locality A is estimated to contain 5,600 tons of rock per foot of depth averaging 0.045 percent thorium and 0.006 percent uranium. As most of the uranium and thorium is concentrated in pegmatite and adjacent gneiss, selective mining of the rock might result in raising the grade of ore to 0.160 percent thorium and 0.020 percent uranium.

The computations for these tonnage and grade calculations are shown below. It is assumed that the uranium-thorium ratio is constant throughout the zone. Basic instrument response (instrument response over a nonradioactive body of water) is only a small fraction of one ratemeter unit on the scale used in the determinations. It can be omitted in the following computations:

1. Grade:

(a) Average gamma activity of all traverses in the outlined deposit (fig. 5) is 7.7 ratemeter units.

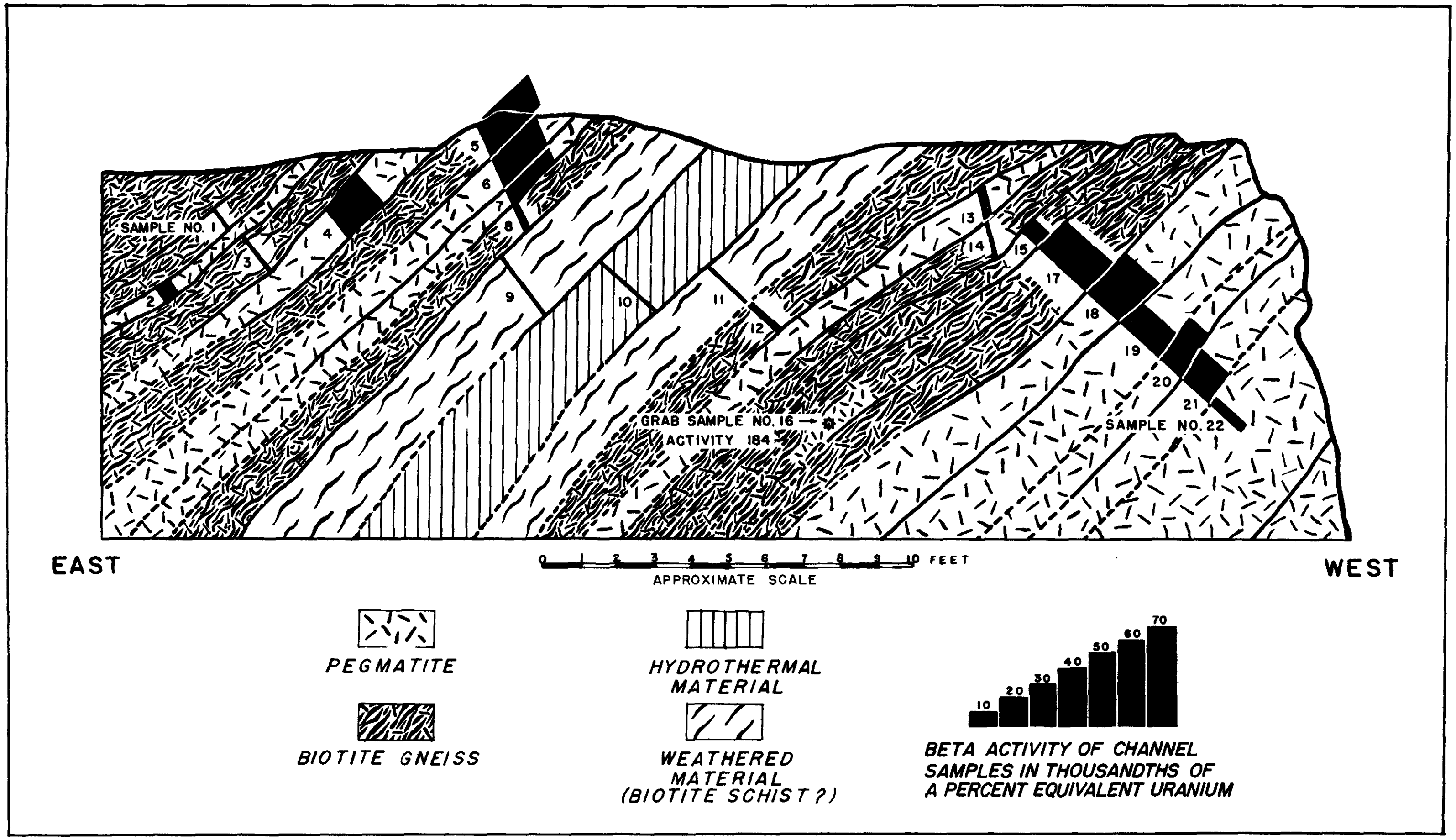
(b) Average gamma activity of traverse number 1 is 13 ratemeter units. By calculation, the average activity of the deposit is 7.7/13 times that of traverse number 1.

(c) Average chemical uranium content of channel samples from traverse number 1 is 0.011 percent. By calculation, the average chemical uranium content of the deposit is 7.7/13 times 0.011 or 0.0065 percent uranium.

(d) Thorium content averages about 7 times the uranium content. By calculation the average thorium is 7 times 0.0065 or 0.045 percent.

UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATIONS REPORT NO. 67



F. McKeown, H. Arndt

FIG. 6 SKETCH OF OUTCROP AT LOCALITY A, BEAR MOUNTAIN, NEW YORK

2. Tonnage:

Area of 72,850 square feet at 13 cubic feet per ton = 5,600 tons per foot of depth.

<u>Locality B.</u> -- At locality B (fig. 2) dark-gray quartz-feldspar-biotite gneiss is interbanded with a lesser amount of pinkish quartz-feldspar-biotite gneiss. Quartz-feldspar-biotite pegmatite masses and lenses are distributed at irregular intervals. Some of these crosscut and others are concordant to well developed sheeting and banding in the gneiss. The gneissic banding strikes about N. 20° E. and dips 30° - 50° SE.

Pegmatites contain the greatest concentration of radioactive material. Samples from this locality range from 0.002 to 0.057 percent equivalent uranium and from 0.001 to 0.005 percent uranium. Parts of the gneiss probably are radioactive, but the presence of nearby highly radioactive pegmatite prohibits detection of the lower radioactivity of the gneiss. In an area approximately 50 by 350 feet, it is estimated that the combined radioactivity of the gneiss and pegmatite is indicative or rock containing 0.005 to 0.020 percent equivalent uranium.

A possible radioactive area is located half a mile to the north of locality B, in a residential section of Highland Falls. No attempt was made to explore the locality or to take samples because it is in the front yard of a city residence. Measurements made with car traverse instruments indicate that the rock contains in excess of 0.010 percent equivalent uranium.

Localities C and D. — Localities C and D, although 2 miles apart (fig. 2), are similar in lithology and radioactivity and are discussed together. The rocks are massive fine-grained quartz-feldspar-biotite gneisses, the banding of which strikes N. 35° E. and dips 25°-35° SE. Both localities are probably in the Storm King granite _/. The abnormal

_/ Lowe, K. E., op. cit., pl. 1, 5.

radioactivity is limited to a few massive layers, 3 to 15 feet thick, and was traced along the strike of these layers 200-300 feet. Because of this apparent stratigraphic continuity, the radioactive elements are believed to be syngenetic with the enclosing metasedimentary rocks. Samples from the radioactive layers range from 0.006 to 0.013 percent equivalent uranium and from 0.003 to 0.005 percent uranium.

Conclusions: — The deposits at Localities A and B are in pegmatite and gneiss, and are of igneous or hydrothermal origin. At localities C and D the deposits appear to be in certain stratigraphic horizons in the gneiss, and may be of sedimentary origin. Other deposits in the Hudson Highlands area probably are similar in origin and occurrence and grade. The sample analyses show that most of the radioactivity is due to thorium-bearing minerals. Pitchblende, however, has been reported _/ near Locality D.

_/ Zodzc, Peter, Pitchblende near Peekskill, N. Y.: Rocks and Minerals, vol. 14, pp. 350-351, 1939.

Traverse north of Bear Mountain

In addition to the Bear Mountain area the Hudson Highlands were examined along a traverse to the north and northeast (fig.1). The results of this traverse are shown in Table 1. According to Berkey and Rice _/ complexes of the Grenville gneiss and the Canada Hill and

_/ Berkey, C. P. and Rice, Marion, op. cit., p. 28, map.

Reservoir granites are exposed along the traverse route.

Housatonic Highlands of western Connecticut

Two abnormally radioactive localities (fig. 1 and table 1) were found in the Housatonic Highlands of western Connecticut. Both localities are on approximate strike with each other in an area mapped _/ as

_/ Rice, W. N., and Gregory, H. F., The Geology of Connecticut: Connecticut Geol. and Nat. History Survey, Bull. 6, map, 1906.

the pre-Cambrian Becket gneiss which may be a possible correlative of the gneisses at Bear Mountain.

THE CENTRAL NEW ENGLAND RADIOACTIVE PROVINCE

The Central New England radioactive province extends from western Rhode Island and central and eastern Connecticut northward through central Massachusetts _/ into eastern Vermont and western and northern

_/ Johnson, D. H., Radioactive rocks of Massachusetts, U. S. Geol. Survey Trace Elements Investigations Rept. 69, map in preparation.

New Hampshire. It is characterized by a relatively low and constant content of equivalent uranium and uranium. The belt appears to follow the general regional structure but cuts across several lithologic types. This province is most radioactive in the area of greatest relief and rock exposure, the White Mountains of northern New Hampshire, where most of the rocks are estimated to contain from 0.003 to 0.006 percent equivalent uranium. Samples of radioactive rocks from the White Mountains have a maximum uranium content of 0.001 percent. Elsewhere in central New England the rocks contain more widely scattered deposits of similar equivalent uranium and uranium content. In Massachusetts _/

_/ Johnson, D. H., op. cit., map.

a much denser road coverage more clearly defines the northward trend of the radioactive area. The most radioactive sample collected in Massachusetts contained 0.011 percent equivalent uranium, 0.001 percent uranium, and 0.032 percent thorium.

The radioactivity of the rocks of the Central New England province is considered to be due mainly to thorium, as uranium analyses to date have not shown more than 0.001 percent uranium.

The Central New England province is separated from the Hudson and Housatonic Highlands, the Milton area, and the radioactive rocks of northeastern New York by a wide north-trending belt of rocks containing 0.003 percent equivalent uranium or less. Abnormally radioactive localities within the Central New England province are shown in figure 1 and briefly described in table 2.

The investigation of pegmatites previously reported to contain small amounts of radioactive minerals was not a part of the work done for this report. The pegmatites traversed in this belt, with one exception, showed about the same average radioactivity as the other rocks.

Conclusions

The rocks of the Central New England radioactive province are low in uranium and the province is believed to be unfavorable for the occurrence of commercial uranium deposits.

As calculated from the difference between the precent equivalent uranium and percent uranium there are billions of tons of rocks in the province that probably contain between 0.010 and 0.016 percent thorium. The only sample assayed for thoria (No. 511, table 3), however, contained a maximum of only 0.006 percent. As the calculated value for this sample would be 0.016 percent thorium, the sample presumably is out of equilibrium.

RADIOACTIVE AREA NEAR MILTON, VERMONT

The Milton dolomite in northwestern Vermont was found to be abnormally radioactive (up to 0.029 percent equivalent uranium along U. S. Highway 7, about 2½ miles north of the junction with U. S. Highway 2 and about 3½ miles southwest of Milton, Vt. All roads within 5 miles of this point were traversed by car and much of the interroad area was prospected on foot. The local geology _/ and distribution of

_/ Jacobs, E. C., The geology of the Green Mountains of northern Vermont: Vermont State Geologist 21st Rept. p.8, pl 2, 1938.

radioactive rocks are shown on figure 7.

Geology

The Milton dolomite is within a structural division of the rocks of northwestern Vermont known as the Central Sequence _/. The Central

_/ Keith, Arthur, Cambrian succession of northwestern Vermont: Am. Jour. Sci., 5th ser., vol. 5, no. 26, pp. 106-126, 1923.

_____________, Stratigraphy and structure of northwestern Vermont: Washington Acad. Sci. Jour., vol. 22, pp. 369-379, 1932.

Schuchert, Charles, Cambrian and Ordovician of northwestern Vermont: Geol. Soc. America Bull., vol. 48, no. 7, pp. 1001-1057, 1937.

Sequence is a narrow belt of formations extending from Snake Mountain, 5 miles west of Middlebury, Vt., north to the Canadian border. These

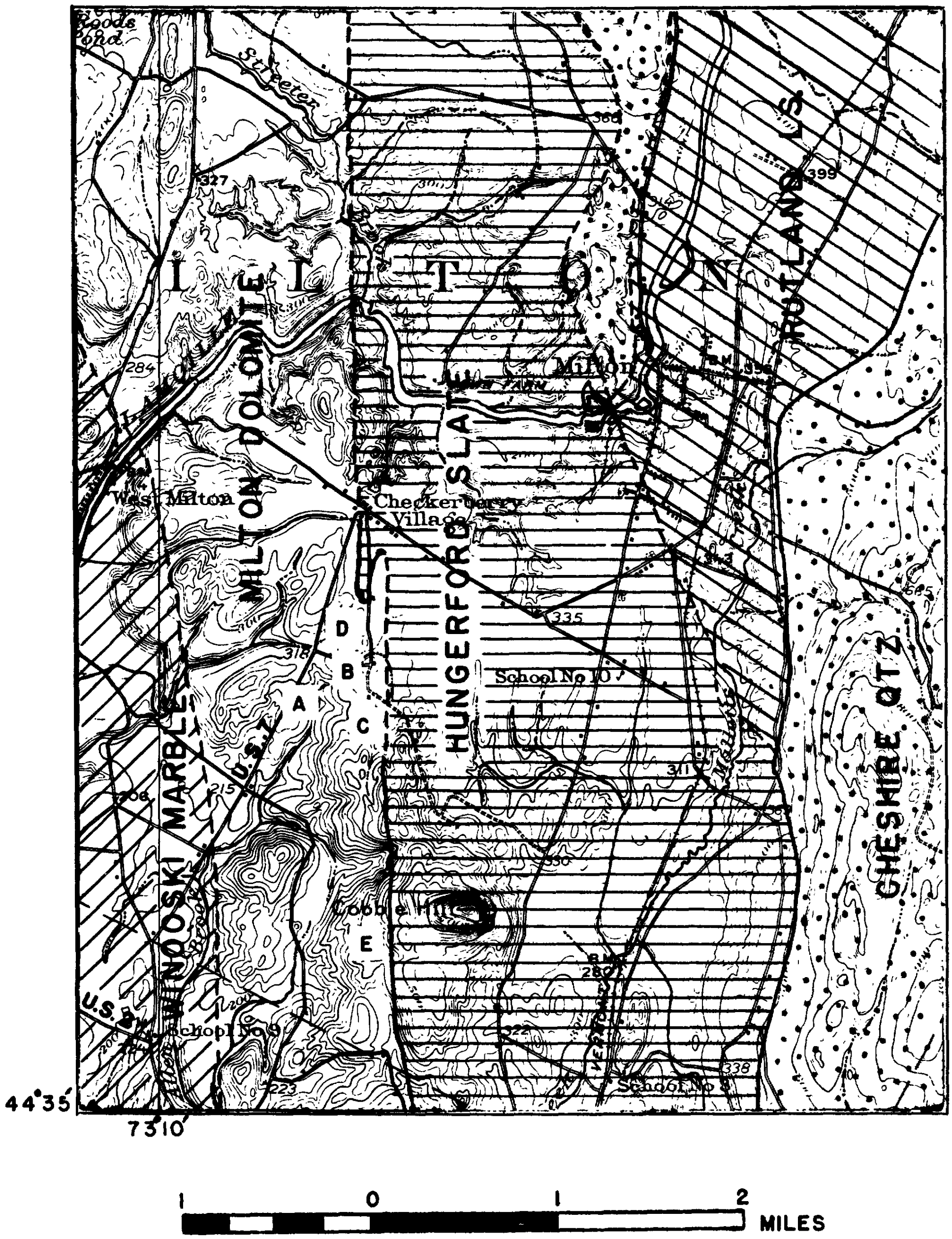


FIG. 7 RADIOACTIVE ROCKS NEAR MILTON, VERMONT

formations strike northward between the Champlain thrust fault and the Border Mountain fault. The strata are Cambrian and Ordovician dolomites and slates that have overridden one another because of the eastward movement of the Green Mountain massif.

The abnormally radioactive localities are in the Milton dolomite between Checkerberry Village and a point half a mile south-southwest of Cobble Hill (fig. 7). Keith _/ describes the Milton dolomite of

_/ Keith, Arthur, op. cit., pp. 113-114, 1923.

this area as follows: "The formation consists almost entirely of massive dolomite both fine- and coarse-grained. Most of the beds are thick (from 1 to 5 feet), especially in the lower part of the formation and as a rule the bedding is difficult to determine... A pecularity of the Milton is its considerable content of black chert. This forms small, irregular patches and pockets much broken during rock movements, and is very seldom found in layers. This chert weathers out in black spots which readily catch the eye... Another pecularity of this dolomite is its large content of dolomitic conglomerate." The thickness of the Milton dolomite in this area has been given by Keith as 700 feet; Schuchert _/, however, thinks that it may be much less.

_/ Schuchert, Charles, op. cit., p. 1046, 1937.

Radioactivity

The abnormal radioactivity is directly associated with some black chert-like inclusions in intraformational breccias in sandy dolomite. Sample analyses show a maximum uranium content of 0.018 percent. Two types of inclusions have been recognized, one of which is radioactive. The radioactive inclusions are black calcareous clay galls and fragments that are syngenetic. They protrude from the weathered surface of the dolomite and have the appearance of chert. Upon treatment with hydrochloric acid, 4 parts water to 1 part acid, these fragments crumble to a black spongy mass, and a thin film of oil is formed. The nonradioactive inclusions that were tested are actual fragments of black chert. Upon treatment with hydrochloric acid, the chert fragments become porous but remain hard, and no oil film is formed. Much of the rock at locality E (fig. 7) is covered with a phosphate bloom, which seems to be more profuse where the radioactivity is greatest. Phosphate bloom was not noticed at the other localities, but the samples from locality A (fig. 7) contain as much as 7.19 percent P_2O_5.

Although soil cover masks much of the radioactive zone, the radioactive chert-like clay galls in the intraformational breccia apparently are confined to a distinct stratum or to strata of similar age. The thickness of such a stratum, or strata, was not apparent except in the stream bed at locality B (fig. 7) where the radioactive breccia had a stratigraphic thickness of about 3 feet. Elsewhere, abnormally radioactive outcrops and soil are present as patches, 10 to 50 feet across, that may be isolated from one another by distances of several hundred yards. Other such patches may occur within 25 to 50 feet of each other and form a belt of distinct linearity. One such belt, at locality E, is about 1,000 feet long and 50 feet wide. The longer dimension is parallel to the general strike of the Milton dolomite. The wideness of this belt at this locality presumably is the result of the low angle of dip of the dolomite rather than its thickness.

The manner in which the radioactive elements are combined with other elements in the rock is not known. Alpha radiographs of thin sections of the most radioactive samples made by the Geological Survey Laboratory show that there are no apparent centers of radioactive concentrations and that the amount of radioactivity is variable throughout the radioactive rock. The fact that the radioactive material apparently has a wide areal and narrow stratigraphic distribution and is disseminated in its immediate host rock suggests that the radioactivity is a feature of the original sediments. This association of abnormal radioactivity with black chert-like petroliferous calcareous clay galls and phosphate in intra-formational breccia suggests that the radioactive material may have been concentrated there along with the phosphate, sand grains, and dolomite fragments as a residue during erosion of the underlying sandy dolomites. If this is true, then other intraformational breccias and disconformities which are characteristic of the Central Sequence also should be examined for abnormal radioactivity.

Chemical analyses of the more radioactive samples (table 3, Vermont samples) indicate that uranium accounts for about two-thirds of the radioactivity. The remainder of the activity is, by inference, attributable to thorium and potassium.

Description of localities

Locality A

An abnormally radioactive zone of soil and float extends for about 20 feet along U. S. Highway 7, near the center of a patch of woodland on the east side of the road at locality A (fig. 7). This zone is 2.2 miles north of the junction of U. S. Highways 2 and 17. Radioactive soils and rocks also are distributed irregularly throughout the woodland. Samples of dolomite with black chert-like fragments from this locality contained from 0.002 to 0.020 percent equivalent uranium (table 3, samples 506-509). The most radioactive sample contains 0.018 percent uranium. Phosphate analyses made on these samples indicate that there may be direct relationship between the uranium and phosphate contents.

Locality B

The roadside soil is abnormally radioative at locality B, about 0.3 mile northeast of locality A, along a lane that extends east from U. S. Highway 7 (fig. 7). The outcrops in the bed of an intermittent stream are radioactive for a distance of approximately 300 feet south of this point. Several places on the hilltop east of the stream also are abnormally radioactive. A few scattered crystals of purple fluorite were noted. Samples of black chert-like material, dolomite with intraformational black chert-like breccia, and dolomite with black chert-like breccia and inclusions of fluorite, contain from 0.001 to 0.020 percent equivalent uranium and from 0.000 to 0.018 percent uranium (table 3, samples 516S1-518E).

Localities C and D

Locality C (fig. 7) is defined by an abnormally radioactive soil zone approximately 0.4 miles south-southeast of locality B near a clump of small trees 200 yards south of a barn. A small outcrop 300 feet farther south also is radioactive. Locality D consists of three areas of abnormally radioactive soils at 150, 300, and 600 feet north of the lane at locality B. No samples were taken at localities C and D and the estimated radioactivity is of the same magnitude as at the other localities.

Locality E

Radioactive rocks crop out about half a mile S. 75° W. of the top of Cobble Hill. The geology at this locality has been described by Schuchert _/. Much of the bedrock is coated by a phosphate bloom.

_/ Schuchert, Charles, op. cit., pp. 1057-1058.

Grab samples of dolomite with black chert-like intraformational breccia from this locality contain as much as 0.015 percent equivalent uranium and 0.009 percent uranium (table 3, samples 513, 514, 519, and 520).

Conclusions

Black petroliferous phosphatic calcarous clay galls in an intraformational breccia in the Milton dolomite southwest of Milton, Vt. contain up to 0.018 percent uranium. The manner of occurrence and the areal distribution of the uranium in the breccia is indicative of syngenetic deposition. The deposits, as they are now known, are too small and spotty to be of economic importance.

CONCLUSIONS

The radioactive rocks of the New England States investigated occur in three distinct radioactive areas. These have been designated as the Hudson and Housatonic Highlands province (southeastern New York and western Connecticut), the Central New England province (parts of Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island), and an area near Milton, Vt. Within these provinces many types of rocks are abnormally radioactive; in adjacent areas, similar rocks are essentially nonradioactive.

The radioactive provinces are characterized by the following relations:

1. The dominant radioactive element varies from province to province. In the Hudson and Housatonic Highlands, the radioactivity is caused by both thorium and uranium; the ratio of thorium to uranium is highly variable, but in general thorium is predominant. In the Central New England province, the radioactivity probably is caused largely by thorium; at the Milton, Vt., area, uranium is the dominant radioactive element.

2. The range in intensity of radioactivity differs between provinces. In the Hudson and Housatonic Highlands, the range of radioactivity is from 0.001 to 0.240 percent equivalent uranium. In the Central New England province, the range is from 0.003 to 0.006 percent equivalent uranium.
3. The concentration of the radioactive materials differs between provinces. In the Hudson and Housatonic Highlands, most of the rocks contain about 0.002 percent equivalent uranium, and only a fraction of one percent of the rocks contains high radioactivity. In the Central New England province, the radioactivity of most of the rocks ranges from 0.003 to 0.006 percent equivalent uranium.
4. The type of rock that is most radioactive in one province is different from the type that is the most radioactive in another. In the Hudson and Housatonic Highlands, pegmatites tend to be highly radioactive. In the Central New England province, the pegmatites tend to have about the same amount of radioactivity as the surrounding rocks.

Table 1.—Radioactive localities north and northeast of the Bear Mountain area in the Hudson and Housatonic Highlands.

State	Locality	Material	Radioactivity (eU _/) estimated at outcrop (percent)	Sample analyses (percent)	Remarks
New York	Road traverse on Highways 301 and 52	Gneissic rock	0.002		Average radioactivity of outcrops and glacial debris.
			.005		Nine outcrops of gneissic rock
	Carmel; a 100-foot road cut on Highway 301, $4\frac{1}{2}$ miles east of Highway 9	Gneiss and quartz veins	.006		Highest radioactivity of rock in place
		Quartz, schistose gneiss, and quartz sulfide rock		0.24 eU .095 U 1.04 ThO_2	Major constituents are quartz and pigeonite; minor amounts of pyrite, chlorite, talc, and very radioactive monazite; and trace amounts of graphite and gypsum. Sample is from road shoulder and may be from material covered by road bed.
	50-foot outcrop about $3\frac{1}{2}$ miles west of Carmel along Highway 301	Quartz-feldspar pegmatite in garnetiferous quartzite and hornblende-magnetite gneiss.	.004		Average radioactivity of pegmatite.
		Biotite segregations in the pegmatite	.01		Biotite segregations represent about 1 percent of the pegmatite and have a maximum length of 1 inch.

Table 1.—(Continued)

State	Locality	Material	Radioactivity (eU /) estimated at outcrop (percent)	Sample analyses (percent)	Remarks
Connecticut	Cornwall Bridge, near Cornwall Bridge on Highway 4 about 1.8 miles west of the junction with U. S. Highway 7	Samples from the north side of road where radioactive zone disappears under soil			Radioactive zone is 4 feet wide and parallel to bedding..
		Quartzite		0.008 eU .001 U .02 ThO_2	Amount of radioactivity varies irregularly within the gneiss and quartzite layers, and in some of the biotite-rich layers.
		Quartz-biotite-feldspar gneiss		.013 eU .001 U .048 ThO_2	
		South side of road	0.005		
	Kent, near Kent on Highway 341, about 500 feet west of the Housatonic River.	4-foot zone of pegmatite body in quartz-feldspar-biotite gneiss		.018 eU .003 U .052 ThO_2	From top to bottom the section exposes quartzite, muscovite schist, and gneiss. Stringers and irregular masses of pegmatite accompany the gneiss. Two-inch lenses of pegmatite also occur along the contact between the quartzite and schist. The radioactivity is confined to small zones in the quartzite and gneiss layers.
		Impure quartzite		.008 eU .002 U .024 ThO_2	

/ (eU) = Equivalent uranium

Table 2.--Radioactive localities in the Central New England province

Observed rock type	Mapped rock type	Estimated percent equivalent uranium	Location	Remarks
Connecticut				
Medium-grained biotite granite	Branford granite gneiss (pre-Cambrian) (?) 1/	0.004 - 0.006	Vicinity of Branford on U. S. Highway 1 and Highways 142 and 143. An area of about 12 square miles	Two phases are present. 2/ The "Lighthouse granite" phase is the more radioactive. The "Branford granite" phase was sampled (see table 3)
Pegmatite	Middletown gneiss (Carboniferous)(?) 1/	.005	Near North Guilford along Highway 80	Pegmatite is 100 feet long
Schists and granitic rocks	Scotland muscovite schist, Eastford granite gneiss (Late or post-Carboniferous) 1/	.003 - .004	About 3 miles along Highway 6 west of Clark's Corner	Includes 1 mile of Schist and 2 miles of gneiss 1/
Rhode Island				
Aplitic and pegmatitic gneiss	Sterling granite gneiss 3/	.003	Along Highway 165, 2 miles northwest of Arcadia.	
Schist	Do.	.003	About 3 miles along Highways 14 and 102 in the vicinity of Clayville	The Schistose Bellingham conglomerate is intruded by the Sterling granite in this area 1/
Vermont				
Phyllite	Orfordville formation (Middle Ordovician) 4/	.003 - .005	About 5 and 8 miles north of Brattleboro on U. S. Highway 5 near the Connecticut River	Two outcrops

Table 2.—(Continued)

oserved rock type	Mapped rock type	Estimated percent equivalent uranium	Location	Remarks
Vermont				
ine-grained ray gneiss	Baker Pond gneiss, Oliverian magma series (Upper Devonian) 5/	0.003	About 6 miles south of Bradford on U. S. Highway 5.	Exposed in 320 foot cliff
ight-gray dium-rained bio-ite gra-ite	Granite (Silurian-Carboniferous) 6/	.003-.005	Near Lake, a 4 mile zone along Highway 114 beginning 5 miles south of the Canadian border.	
acial eposit	Schist and phyllite 6/	.003-.005	About 18 miles between Island Pond and Bloomfield on Highway 105.	No rock exposures. Foot traverses show the abnormal radioactivity to be spotty. Glacial material is probably derived in part from the radioactive granite to the north.
ew Hampshire				
lacial eposits	Schist and phyllite 6/	.003-.005	Along Connecticut River from near Columbia southward about 28 miles on U. S. Highway 3 to Lancaster.	No rock exposures
caceous late	Metamorphosed early Paleozoic sediments 6/	.003	Through Dixville Notch for about one mile along Highway 26.	Across the strike
chist	Do.	.003	About 5 miles southwest of Pittsburgh on U. S. Highway 3	One outcrop

Table 2.— (Continued)

Observed rock type	Mapped rock type	Estimated percent equivalent uranium	Location	Remarks
New Hampshire				
Crystalline and metamorphic rocks	Partridge gneiss; Littleton schist; Oliverian monzonites; and Bickford, Chatham, and Conway granites 7/	0.003-0.005	A radioactive area extending southward from West Milan on Highway 110 to Berlin and on Highway 19 to West Ossippee. This area extends eastward to the Maine border and westward to Jefferson on U. S. Highway 2 and Fabyan House on U. S. Highway 302.	Intrusive rocks are of the Oliverian, New Hampshire, and White Mountain magma series; samples were taken at the Conway granite. (See table 3, New Hampshire.) The level of radioactivity is essentially the same for nearly all rock types traversed.
Granitic rocks and schists	Conway granite, Kinsman quartz monzonite, and Littleton schist 8/, 9/	.003- .005	From Plymouth 40 miles northward on U. S. Highway 3 to a point 12 miles north of North Woodstock.	The road essentially follows the strike of the Littleton schist for 22 miles. The remaining mileage is about divided between the granite and monzonite.
Schist and glacial material	Littleton schist 9/	.003- .005	From Plymouth south for 11 miles along Highway 25.	Few outcrops; most of radioactivity is in glacial material.
Fine-grained light-buff granite	Conway granite of post-Lower Devonian age 10/	.003- .005	About 6 miles along an unnumbered road between South Wolfeboro and Farmington.	
Granite	Do. 11/	.003- .005	Between West Acton and Guilford for 3 miles along Highway 11A, beginning 3 miles west of the junction with Highway 11.	
Schist	Hubbardston granite with Brimfield schist 3/ or Concord granite and Littleton schist 12/	.003	North of Greenville for about 2 miles along Highway 31.	Granite outcrops which border the schist contain about 0.002 percent equivalent uranium. (Mapped reference is inferred from adjacent areas.)

Table 2.—(Continued)

Observed rock type	Mapped rock type	Estimated percent equivalent uranium	Location	Remarks
New Hampshire				
edium-grained yellow granite	Hubbardston granite 3/	0.004	About 5 miles east of Peterborough on Highway 101.	250-foot outcrop.
Coarse-grained white ranite in chist	Granodiorite of Oliverian magma series 4/	.005	On Highway 10 about 1 mile North of Keene.	Granite present in pegmatite and graphic phases. Radioactive area is about 200 by 75 feet. Sample described in table 3.
egmatite ikes in ranite neiss	Pre-Cambrian or early Paleozoic schists 6/	.010- .015	On Highway 103, 3 miles north of Bradford.	Outcrop is 100 feet along road. Pegmatite dikes are several inches to about 2 feet in thickness.

1/ Rice, W. N., and Gregory, H. E., The geology of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 6, pp. 114-115, map, 1906.

2/ Ward, F., Lighthouse granite near New Haven, Connecticut: Am. Jour. Sci., 4th ser., vol. 28, no. 164, pp. 131-132, 1928.

3/ Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, p. 229, pl. 10, 1917.

4/ Moore, G. E., Jr., Structure and metamorphism of the Keene-Brattleboro area, New Hampshire-Vermont: Geol. Soc. America Bull., vol. 60, no. 10, p. 1620, pl. 1, 1949.

5/ Hadley, J. B., and Chapman, C. A., The geology of the Mt. Cube and Mascoma quadrangles: New Hampshire Plan. and Devel. Comm., 28 pp., Concord, N. H., 1939.

6/ Stose, G. W., and others, Geologic map of the United States: U. S. Geol. Survey, map, 1:2,500,000, 1932.

7/ Billings, M. P., Mechanics of igneous intrusion for New Hampshire: Am. Jour. Sci., Daly vol. 243-A, p. 42, 1945.

Table 2.—(Continued)

8/ Billings, M. P., and Williams, C. R., Geology of the Franconia quadrangle, N. H.: New Hampshire Plan. and Devel. Comm., 35 pp., Concord, N. H., 1935.

9/ Moke, C. B., Geology of the Plymouth quadrangle, N. H.: New Hampshire Plan. and Devel. Comm. 21 pp., Concord, N. H., 1946.

10/ Quinn, Alonzo, and Stewart, G. W., Igneous rocks of the Merrymeeting Lake area of New Hampshire: Am. Mineralogist, vol., 26, no. 11, pp. 633-645, 1941.

11/ Modell, David, Ring-like complex of the Belknap Mountains, N. H.: Geol. Soc. America Bull., vol. 47, p. 1908, 1936.

12/ Billings, K. F., Geology of the Mt. Monadnock quadrangle, N. H.: New Hampshire Plan. and Devel. Comm., map, Concord, N. H., 1949.

Table 3.—Results of radiometric and chemical analyses of samples listed by states

Sample number	Locality	Description	eU 1/ (percent)	Uranium (percent)	Oxide (percent) and remarks
	Connecticut				
558	Along U. S. Highway 1, 12.8 miles west of junction of Highway 1 and State Highway 79 near Branford	Branford granite gneiss	0.005	0.001 .003	
581	Along Highway 4, 1.8 miles west of junction with Highway 7 near Cornwall Bridge	Quartz-biotite-feldspar gneiss	.013	.001	0.048 ThO_2
582	Same locality as 581	Quartzite	.008	.001	.020 ThO_2
583	On Highway 341, 500 ft. west of Housatonic River near Kent	Quartzite with muscovite	.008	.002	.024 ThO_2 .022 ThO_2
584	Same locality as 583	Quartz-feldspar-biotite pegmatite	.018	.003	.052 ThO_2
585	Same locality as 583	Quartz-feldspar-biotite pegmatite		.003	.036 ThO_2 <.01 V_2O_5
	New Hampshire				
505	2 miles east of Kearsarge Post Office, along unnumbered road to Kimbal Pond	Conway biotite granite	.005	.001	
510	Along Highway 10, 1.2 miles north of junction of Highways 9 and 10 in Keene	Very coarse-grained quartz-feldspar-muscovite granite	.005	<.001	
511	Granite quarry 1 mile northeast of Redstone	Conway biotite granite	.006	.001	.002 ThO_2 .003 ThO_2 .006 ThO_2

Table 3.—(Continued)

Sample number	Locality	Description	eU 1/ (percent)	Uranium (percent)	Oxide (percent) and remarks
	New York				
218	Along Highway 301, 4.5 miles east of the junction of High- 9 and 1 (Carmel locality)	Quartz-sulfide rock	0.240	0.095	1.04 ThO_2
BM(A)-1	Bear Mountain locality A	Biotite gneiss and quartzite veins	.002	.002	
BM(A)-2	Do.	Pegmatite	.017	.007	
BM(A)-3	Do.	Biotite gneiss	.004	.002	
BM(A)-4	Do.	Biotite-rich pegmatite	.049	.034	
BM(A)-5	Do.	Biotite gneiss and hydrothermal material	.064	.037	
BM(A)-6	Do.	Pegmatite, rich in quartzite	.056	.032	
BM(A)-7	Do.	do.	.056	.021	0.12 ThO_2
BM(A)-8	Do.	Biotite gneiss	.004	.002	
BM(A)-9	Do.	Weathered material rich in biotite	.003	.001	
BM(A)-10	Do.	Molybdenite-bearing quartz	.003	.002	
BM(A)-11	Do.	Weathered material rich in biotite	.004	.003	
BM(A)-12	Do.	Biotite gneiss	.005	.002	
BM(A)-13	Do.	Pegmatite, rich in feldspar	.008	.002	

Table 3.—(Continued)

Sample number	Locality	Description	eU 1/ (percent)	Uranium (Percent)	Oxide (percent) and remarks
	New York				
BM(A)-1	Bear Mountain locality A	Biotite gneiss	0.004	0.001	
BM(A)-15	Do.	do.	.018	.004	0.03 ThO_2
BM(A)-16	Do.	Pegmatite	.184	.065	.48 ThO_2
BM(A)-17	Do.	Mixture of biotite gneiss and pegmatite	.037	.014	
BM(A)-18	Do.	do.	.049	.022	
BM(A)-19	Do.	Pegmatite	.028	.009	.08 ThO_2
BM(A)-20	Do.	do.	.047	.014	.13 ThO_2
BM(A)-21	Do.	do.	.036 .062	.007 .019	2 samples from this bed
BM(A)-22	Do.	do.	.010	.002	
BM(B)-1	Bear Mountain locality B	Biotite gneiss	.009	.001	
BM(B)-2	Do.	Pegmatite	.057	.005	0.20 ThO_2
BM(B)-3	Do.	Mixture of biotite gneiss and pegmatite	.013	.001	
BM(B)-4	Do.	Biotite gneiss	.002	.001	
BM(C)-1	Bear Mountain locality C	do.	.009	.003	.005 ThO_2
BM(C)-2	Do.	do.	.013	.004	.024 ThO_2

Table 3.—(Continued)

Sample number	Locality	Description	eU 1/ (percent)	Uranium (percent)	Oxide (percent) and remarks
	New York				
BM(D)-1	Bear Mountain locality D	Biotite gneiss	0.006	0.005	
BM(D)-2	Do.	do.	.007		
	Rhode Island				
557	Along Highway 165, 7.7 miles east of the junction of Highways 165 and 95	Sterling granite gneiss	.003	.001	
	Vermont				
506	Milton locality A	Dolomite with chert-like breccia	.022	.019	0.003 ThO_2 .03 V_2O_5 7.0 P_2O_5
507	Do.	do.	.009	.004 .006	0.002 ThO_2 .01 V_2O_5 3.34 P_2O_5
508	Do.	Dolomite with chert-like breccia, light gray	.002	.003	0.01 V_2O_5 2.34 P_2O_5
509	Do.	Darker gray part of sample 508	.005	.010	0.01 V_2O_5 7.19 P_2O_5
513	Milton locality E	Dolomite with black chert-like breccia and phosphate bloom	.010		
514	Do.	do.	.015		
515	Summit of Cobble Hill, 4 miles south of Milton	Dolomite with black breccia	.003	.002	0.11 P_2O_5 .03 V_2O_5
516S1	Milton locality B	Dolomite with black chert-like breccia	.010	.004	Chip sample from 3 in. layer

Table 3.—(Continued)

Sample number	Locality	Description	eU 1/ (percent)	Uranium (percent)	Oxide (percent) and remarks
	Vermont				
516S2	Milt n locality B	Dolomite with black chert-like breccia	0.016	0.007	Chip sample from 4 in. layer under 516S1
516S3	Do.	do.	.004	.002	Chip sample from 4 in. layer under 516S2
516S4	Do.	Dolomite with black chert-like breccia and inclusions of fluorite	.012	.004	Chip sample from 12 in. layer under 516S3
516S5	Do.	Dolomite wi h inclusions of black chert-like fragments and fluorite	.004	.003	Chip sample from 6 in. layer under 516S4
516S6	Do.	Dolomite with inclusions of black chert-like fragments	.003	.002	Chip sample from 4 in. layer under 516S5
517S2	Do.	Black chert-like fragments	.001	.000	From oval-shaped structure
517S3	Do.	do.	.001	.000	Do.
517S4	Do.	do.	.001	.000	Do.
517S5	Do.	do.	.001	.000	Do.
517S6	Do.	do.	.008	.003	Randomly distri
517S7A	Do.	do.	.012	.007	Do.
517S7B	Do.	do.	.015	.008	Do.

Table 3.—(Continued)

Sample number	Locality	Description	eU 1/ (percent)	Uranium (percent)	Oxide (percent) and remarks
	Vermont				
517S7C	Milton locality B	Black chert-like fragments	0.017	0.014	Randomly distributed
517S3W	Do.	do.	.010	.005	Do.
517S8	Do.	do.	.001	.002	Do.
517S9	Do.	do.	.009	.005	Do.
517S10	Do.	do.	.001	.000	
517S11	Do.	do.	.001	.000	Randomly distributed
517S12	Do.	do.	.019	.010	Do.
517S13	Do.	Sandy dolomite	.001	.000	
518A	Do.	Dolomite with inclusions of black chert-like fragments	.001	.000	
518B	Do.	do.	.029	.018	
518C	Do.	do.	.001	.000	
518D	Do.	do.	.019	.014	
518E	Do.	do.	.001	.000	
519	Milton locality E	do.	- - -	.009	0.04 V_2O_5 8.06 P_2O_5
520	Do.	do.	0.015	.007	
521	Do.	Dolomite and black chert-like inclusions with phosphate bloom	- - -	.006	0.001 ThO_2 .01 V_2O_5 4.86 P_2O_5

1/ Equivalent uranium (eU)