UNITED STATES GEOLOGICAL SURVEY,

trace elements investigations report,
TEI-69

RECONNAISSANCE OF RADIOACTIVE ROCKS OF MASSACHUSETTS

By
Donald H. Johnson

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.

December 1951

DEPARTMENT OF THE INTERIOR
March 3, 1849

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.

RECONNAISSANCE OF

RADIOACTIVE ROCKS OF MASSACHUSETTS

By

Donald H. Johnson

ABSTRACT

During the 1948 and 1949 field seasons radiometric car traverses were made along the numbered federal and state highways and along many unnumbered roads of Massachusetts.

Near Worcester pegmatitic rocks are estimated to contain about 250 pounds of uranium and 8,500 pounds of thoria per foot of depth. Near Southbridge pegmatitic rocks are estimated to contain about 6,500 pounds of thoria per foot of depth.

A central belt was estimated to contain about 0.003 percent equivalent uranium but less than 0.001 percent uranium in nearly all roadside materials.

Several smaller localities of radioactivity similar to that of the central belt were found but none appear to be important economically.

Massachusetts is not considered a favorable area for uranium deposits, although some low-grade deposits of thorium are present.

INTRODUCTION

During the 1948 and 1949 field seasons Donald H. Johnson, Russell R. Flowers, and Francis A. McKeown of the U. S. Geological Survey made a radiometric reconnaissance, by car traverse, of the state of Massachusetts.

The objectives of the survey were to evaluate new equipment and techniques _/ used in the field work, to detect abnormally radioactive

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

rocks, to delineate favorable and unfavorable areas for radioactive deposits, and to estimate the reserves of any radioactive deposits that might be discovered.

All numbered federal and state highways and many unnumbered roads (fig. 1) were traversed by car, and all formations shown on the geologic map of Massachusetts _/ were crossed by one or more of the traverses.

_/ Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pl. X, 1917.

Several road cuts, quarries, and old mines were examined and selected samples were taken for analysis.

Uranium- and thorium-bearing minerals have been reported in several towns in Massachusetts. Among these are autunite, columbite, microlite, torbernite, and uraconite in Chesterfield, monazite in South Orange, columbite in Goshen, fergusonite in Rockport, polymignite and columbite in Beverly, columbite in Northfield, yttrocerite in Bolton, and gadolinite in Becket. _/ As the examination of reported occurrences was

_/ Dana, E. S., The system of mineralogy of J. D. Dana, 6th ed., pp. 182, 728, 730, 735, 743, 858, 1892.

_/ DeMent, Jack and Dake, H. C., Handbook of uranium minerals, p. 14, Portland, Oreg., Mineralogist Publishing Co., 1947.

_/ Emerson, B. K., A mineralogical lexicon of Franklin, Hampshire, and Hampden Counties, Massachusetts: U. S. Geol. Survey Bull. 126, pp. 30-31, 57-58, 110-112, 167, 172, 1895.

_/ Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pp. 256, 261, 1917.

_/ Hitchcock, Edward, Geology, mineralogy, botany and zoology of Massachusetts, pp. 310, 495, Amherst, J. S. and C. Adams, 1835.

_/ Shepard, C. U., Treatise on mineralogy, 2d. ed., pp. 105, 109, 119-120, 143-144, 248, 252-253, 256, 261-262, 287-288, New Haven. B. L. Hamlen, 1852.

---

outside the scope of this investigation, these localities were not studied.

Acknowledgments

The work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. The radiometric and chemical assays given in this report were made by the Trace Elements Section Washington Laboratory of the U. S. Geological Survey. Perry F. Narten and Robert L. Boardman, of the Survey, assisted in the review of the manuscript.

EQUIPMENT AND METHODS

The traverses were made with two brass-cathode Geiger-Mueller tubes, 2 inches in diameter and 42 inches long, mounted on the sides of a sedan delivery truck. These tubes were connected in parallel and were attached to a modified Victoreen type 263-A ratemeter. The ratemeter was connected to an alarm circuit that could be adjusted to ring a bell at any designated ratemeter reading.

The Victoreen instrument and one of the 42-inch tubes were used for outcrop studies on foot. A Beckman model MX-5 survey meter also was used during the 1948 field season.

Channel samples were taken at outcrops, and grab samples were taken of unconsolidated materials. Radiometric analyses were made of all samples as follows: The samples were first crushed to minus 1/8-inch in a portable jaw crusher and poured into a cylindrical sample holder, surrounding a thin-walled Geiger-Mueller tube. The counting was done by means of a Beckman ratemeter or a neon "scaler" made from the Victoreen ratemeter by John M. Nelson of the Geological Survey. The equivalent uranium content of the samples was determined in the field by comparing the counts from the samples to the counts from a standard of known radioactive content. This standard was prepared by mixing finely ground pitchblende with Portland cement and water, crushing the hardened mass to minus 1/8-inch, and determining its equivalent uranium content.

THE CENTRAL BELT

A north-trending belt of abnormally radioactive rocks extends from the northeastern edge of Connecticut to north-central Massachusetts (figs. 1 and 2). The rocks within this central belt are Carboniferous schist and late or post-Carboniferous granites _/ and glacial material;

_/ Emerson, B. K., op. cit., pl. X, 1917.

all are estimated to have an average radioactivity of about 0.003 percent equivalent uranium. There is little variation in the amount of radioactivity between areas where bedrock crops out and areas covered by glacial debris.

The geology of central Massachusetts, _/ the localities sampled, and

_/ Emerson, B. K., op. cit., 1917.

the estimated radioactivity along the roads traversed are shown in figure 2.

Formations found to be abnormally radioactive are listed below:

Formation /	Age
Coys Hill granite Hubbardston granite Hardwick granite	Late Carboniferous or post-Carboniferous
Brimfield schist Paxton quartz schist	Carboniferous

/ Emerson, op. cit., pp. 62, 68, 69, 233-235, 238, 240, 1917.

The distribution of radioactivity in the central belt appears to be fairly uniform; at any place along roads in the belt the radioactivity does not differ markedly from the average value of 0.003 percent equivalent uranium. The samples from within the belt are generally representative of the maximum radioactivity at a given locality; they were collected primarily for instrument calibration. In the central belt all of the localities sampled, except the locality near Stafford, Conn., are identified by name on figure 1 and by sample number on figure 2. Descriptions of samples and analytical results are given in table 1. The radioactivity of the central belt is believed to be due almost entirely to thorium. Chemical analyses of samples 11 and 13 within the belt, and sample 14 just outside, show abnormal amounts of thorium (0.018, 0.030, and 0.032 percent ThC_2, respectively) and little or no uranium.

The origin of the radioactive material is not known. The abnormal radioactivity neither is confined to former sedimentary rocks, such as the Brimfield schist and Paxton quartz schist, which it should be if the radioactive material were syngenetic, nor does it appear to be associated exclusively with any igneous rock.

Table 1.— Localities sampled and analytical results 1/

Locality name	Sample number	Description of sample (formation from Emerson 2/)	Equivalent uranium (percent)	Uranium (percent)	ThO_2 (percent)	Remarks
Mount Greylock		Ordovician Greylock schist, a mica-chlorite-quartz schist with knots and veins of massive milky white quartz:				The schist is sporadically radioactive along the road for about 2 miles
	2	Schist	0.003	3/	3/	
	3	Schist near quartz veins	.003	3/	3/	
	4	Vein quartz	.001	3/	3/	
	5	Schist and vein quartz	.002	3/	3/	
North Adams	6	Ordovician Hoosac dark mica-feldspar schist from the Hairpin Turn in North Adams	0.003	3/	3/	The schist is radioactive for about ½ mile along the road. No correlation of the bedding with radioactivity was observed
Brimfield	7	Rusty-colored soil derived from the Carboniferous Brimfield schist	0.002	3/	3/	
North Brookfield C	8,9	Much decomposed Brimfield schist	0.003	3/	3/	Near West Brookfield
A	10	Typical Brimfield schist	0.004	3/	3/	Near New Braintree
B	11	Carboniferous Paxton quartz schist, biotitic, and impregnated with considerable clear feldspar	.006	.001	.018	do.

Table 1.-- (Continued)

Locality name	Sample number	Description of sample (formation from Emerson 2/)	Equivalent uranium (percent)	Uranium (percent)	ThO_2 (percent)	Remarks
Stafford, Conn.	12	Rusty biotite schist with bands of fine- to coarse-grained gray granite; probably Carboniferous Brimfield schist and Hubbardston granite	0.003	3/	3/	Locality not shown on maps. It is just south of Monson, shown in fig. 1
Southbridge	13	Carboniferous pegmatite in hornblende gneiss near Mashapang Pond	0.011	0.000	0.030	Described in text
Worcester	14	Coarse feldspar-biotite pegmatite in biotite gneiss of unknown age	0.011	0.001	0.032	Described in text
Graniteville		Late- or post-Carboniferous Ayer granite				
	15	Chip sample from Fletcher quarry face	0.007	0.000	0.013	Known commercially as "Chelmsford granite"
	16	Grab sample of trimming waste	.004	3/	3/	
	17	Grab sample from waste of minus 1/8 inch rock	.004	3/	3/	

Table 1.— (Continued)

Locality name	Sample number	Description of sample (formation from Emerson 2/)	Equivalent uranium (percent)	Uranium (percent)	ThO_2 (percent)	Remarks
Pigeon Cove	18,19	Grab samples from Pigeon Cove of early Carboniferous Quincy dark hornblende granite	0.003	0.0004	0.001	All Quincy granite on Cape Ann is estimated to contain 0.003 percent eU
Quincy	20	Grab sample of Quincy granite from Swingle quarry in West Quincy	0.003	0.0004	0.001	Same granite is also similarly radioactive in Quincy and Milton

1/ Analyses made by the Trace Elements Section Washington Laboratory of the Geological Survey. All analytical results are filed under lot number 1603.

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

3/ Not determined

The Southbridge locality contains the most radioactive rocks within the central belt and is described below.

Southbridge locality

The Southbridge locality is on Massachusetts and Connecticut Highways 15 at the state boundary (fig. 1). The locality extends about 1,500 feet northeast along the highway and about 900 feet normal to the highway. Outcrops make up about 5 percent of the area, but the nature and placement of these outcrops indicate that the entire area is underlain by similar rocks with only a thin soil cover.

Emerson _/ mapped the rocks in the area as Paxton quartz schist

Emerson, B. K., op. cit. pl. X, and pp. 62, 233-236, 1917.

(Carboniferous), but the rocks more closely resemble his description of rocks in the contact zone of the Hubbardston granite (late Carboniferous or post-Carboniferous) and the Brimfield schist (Carboniferous).

The rocks consist of dark-gray, hornblende-feldspar gneiss interspersed with very light-gray pegmatite. In places the gneiss is highly garnetiferous, and there are a few bands of clear pink garnets in the pegmatite. The pegmatite consists almost entirely of feldspar with small amounts of biotite in coarse flakes. In many places, the biotite is grouped into streaks and knots. A few pegmatites contain abundant quartz in massive layers.

Generally the gneiss and the pegmatite occur as alternating layers that range from 1 inch to several feet in thickness. The foliation in the gneiss tends to parallel the banding of the rocks. The rocks commonly strike about N. 40° E. and dip about 80° W. In places, particularly in those outcrops near the highway, the contacts between the gneiss and the pegmatite are gradational and marked by considerable lensing, pinching, and swelling of the layers. Some foliae of dark minerals in the gneiss can be traced across the contacts a short distance into the pegmatites. Streaks of biotite in the gneiss resemble cross-bedding.

In outcrops farther from the highway, most of the contacts are sharp and parallel to the foliation of the gneiss, which gives the rocks the appearance of alternating strata. Outcrops are too sparse to determine accurately the continuity of these layers. In a few places, the contacts are gradational, and in others, sharp contacts occur at angles to the foliation, cutting off the foliae of the gneiss abruptly at the contacts. A few small pockets of pegmatite are enclosed in the gneiss, marked generally by gradational contacts and less commonly by sharp contacts. In several places, veinlike seams of pegmatite cut across the foliation of the gneiss.

Radioactivity measurements of the gneiss were consistently low. The pegmatite material is the most radioactive, ranging from 2 to 5 times background. The more radioactive parts of the pegmatite comprise about 10 percent of all the outcrops of the area.

A channel sample (table 1, sample 13) across one of the more radioactive pegmatite bands contained 0.011 percent equivalent uranium by field and laboratory radiometric analysis. Chemical analysis of the sample showed 0.030 percent ThO_2 and essentially no uranium.

If it is assumed that the entire 1,500- by 900-foot area is underlain by similar rocks, 10 percent of which is the more radioactive pegmatite material, and if a factor of 12 cubic feet per ton of rock is used, there is about 11,000 tons of the more radioactive pegmatite material per foot of depth. If the sample analyzed is representative of the whole, this pegmatite contains about 6,500 pounds of ThO_2 per foot of depth.

An unsuccessful attempt was made to find additional abnormally radioactive outcrops in the Southbridge area. A few thousand feet to the east, however, several large blocks of abnormally radioactive pegmatite occur. These blocks are believed to be float, although some may be bedrock. The depth and shape of the deposit of radioactive material in the Southbridge area are not known.

OTHER LOCALITIES

In addition to the occurrences of radioactive material in the central belt several smaller occurrences of rocks containing from 0.003 to 0.011 percent equivalent uranium were found. Descriptions of samples and analytical results are shown in table 1 (samples 2-6, and 14-20). The name of each locality and the corresponding highest radioactivity in equivalent uranium are shown on figure 1. The highest radioactivity was noted in material at the Worcester locality, described in detail below.

Worcester locality

The Worcester locality (figs. 1 and 2) includes land on and adjacent to the Worcester sewage-disposal plant in the town of Milbury, about 3 miles south of Worcester. The rocks are best seen in a roadcut on U. S. Highway 20. These rocks strike roughly N. 30° E. and dip about 70° W. although there are considerable minor variations. They have been mapped _/ as

---

_/ Emerson, B. K., op. cit., pl. X and pp. 78-79, 1917.

gneisses and schists of undetermined age.

On the western edge of the roadcut the outcrop contains dark-gray biotite-garnet gneiss and a rusty biotite schist which resembles the Carboniferous Brimfield schist. Neither the gneiss nor the schist are appreciably radioactive. Also present in the outcrop are alternate layers of dark-gray biotite-feldspar gneiss and abnormally radioactive coarse white pegmatite. The pegmatite layers consist of feldspar and coarse flakes of biotite, which in places forms streaks and knots. Quartz occurs in small veins and pods more abundantly in the pegmatite than in the gneiss. Pyrite, chalcopyrite, bornite, and other sulfides occur in both the gneiss and pegmatite; however, only in the pegmatite are they associated with quartz.

The layers of gneiss and veins of quartz in the pegmatite have low radioactivity. The pegmatite layers are from $1\frac{1}{2}$ to 5 times more radioactive than the gneiss. The most radioactive parts of the pegmatite are rich in biotite, but several other biotite-rich parts of the pegmatite are only slightly radioactive. The radioactivity in the pegmatite appears to increase in the areas of sulfide mineralization. A channel sample (table 1, number 14) cut across one of the more radioactive layers, contained 0.011 percent equivalent uranium, 0.001 percent uranium, and 0.032 percent ThO_2.

The best exposure of the rocks is in the north wall of the roadcut. Other exposures are in the south wall of the cut and scattered a few hundred feet north and south of the road. Rapid traversing of the surrounding area disclosed two outcrops of similar rocks, both abnormally radioactive, about 3/4 mile and 1 mile south-southwest of the cut. These outcrops lie approximately along the strike of the rocks at the roadcut and are believed to be parts of the same series of layered rocks.

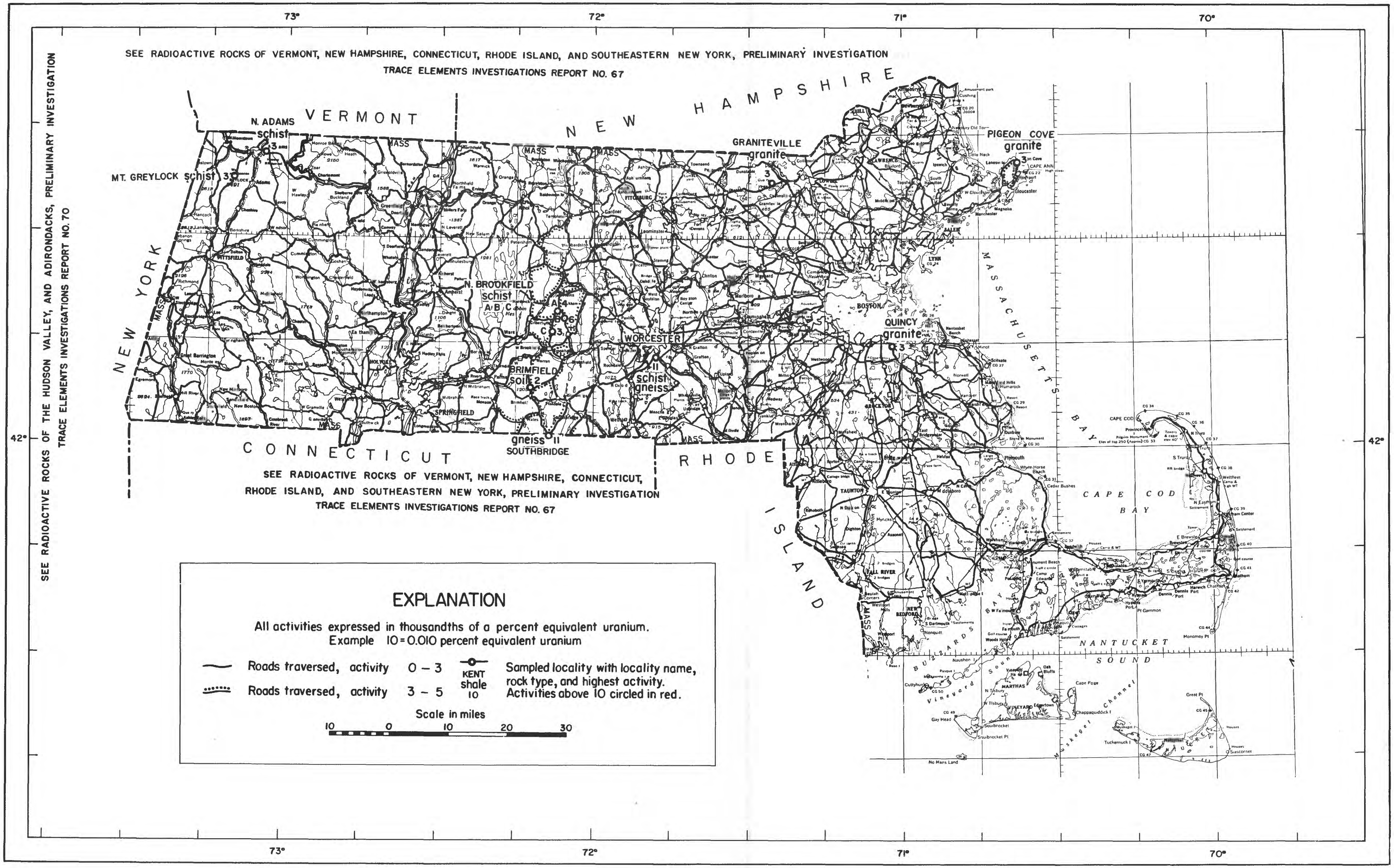
At the roadcut, the aggregate thickness of the radioactive pegmatite layers and the layers of gneiss separating them is about 200 feet; the highly radioactive pegmatite layers total about 50 feet in thickness. At the southernmost outcrop away from the roadcut, the aggregate thickness is about 40 feet and the total thickness of pegmatite layers exposed is about 10 feet. Based on the assumptions that the abnormally radioactive rocks are continuous over the mile from this outcrop to the roadcut, and that there are 12 cubic feet per ton of rock, it is estimated that there are about 13,000 tons of abnormally radioactive pegmatite per foot of depth. If sample number 14 is representative of the entire mass, each foot of depth contains about 250 pounds of uranium and 8,500 pounds of ThO_2.

The foliation in the gneiss is parallel to the banding of the outcrop, and the banding is in turn roughly parallel to the strike of the formations in this vicinity. No evidence of cross cutting or brecciation was found at the contacts between gneiss and pegmatite, and no inclusions were seen of gneiss within the pegmatite.

The origin of the radioactive material is unknown. The problem might be solved if the radioactive layers could be traced both stratigraphically and along strike to equivalent unreplaced beds. Extensive linear and limited stratigraphic extent would favor syngenetic origin. The city of Worcester, however, effectively prevents tracing the beds northward and lack of outcrops east-west limits determination of the stratigraphic extent.

CONCLUSIONS

In general the rocks of Massachusetts are estimated to average about 0.001 to 0.002 percent equivalent uranium. Several occurrences of slightly more radioactive rocks were found but none of these samples contained more than 0.001 percent uranium by chemical analyses. It is therefore believed that Massachusetts is not favorable as a source of significant uranium deposits.



Field work by Donald H. Johnson, Russell R. Flowers, and Frank A. McKeown

FIGURE 1. RADIOACTIVE ROCKS OF MASSACHUSETTS

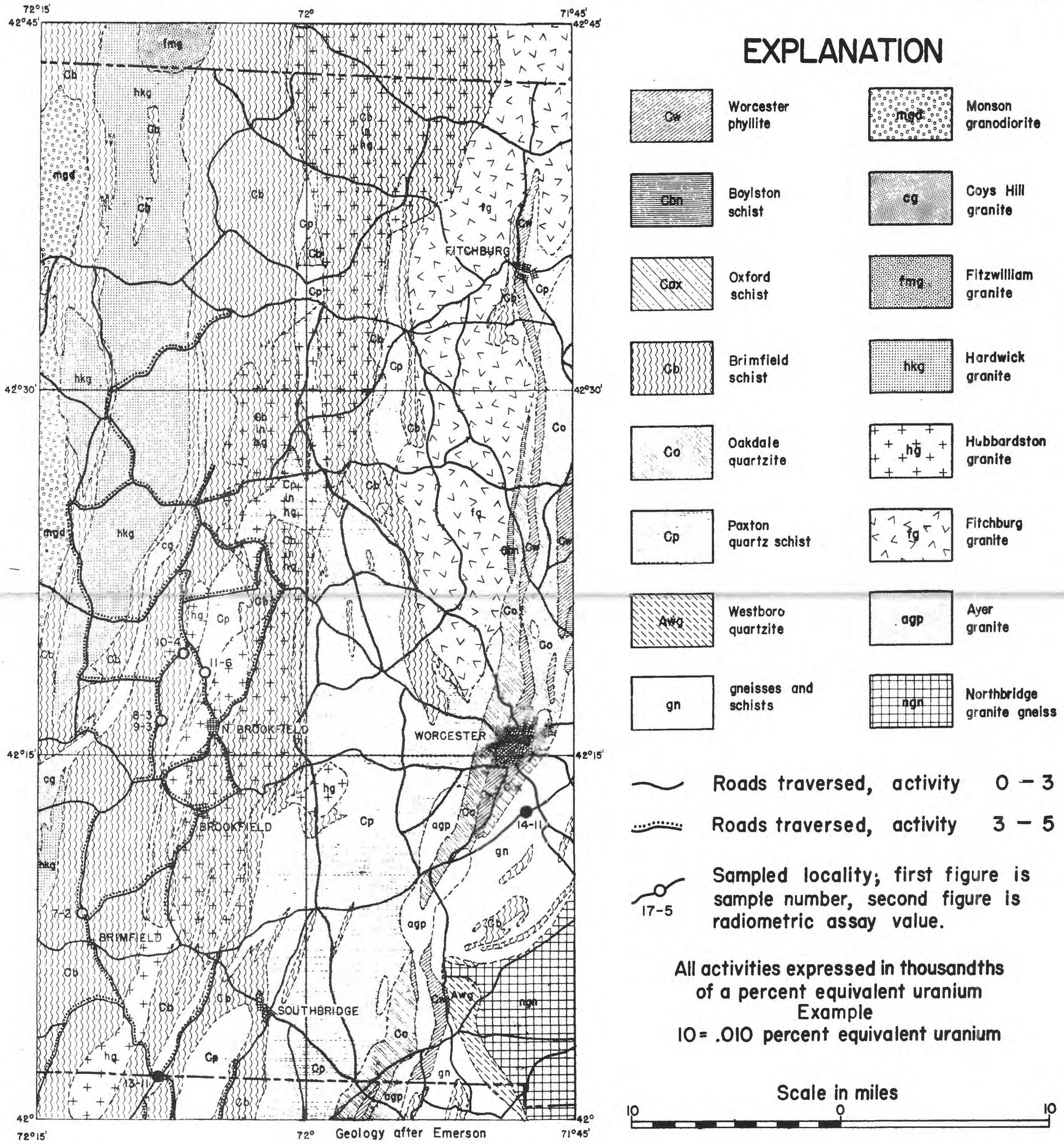


FIGURE 2. GEOLOGY AND RADIOACTIVITY OF CENTRAL MASSACHUSETTS