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SOIL GAS RADON POTENTIAL OF THE UPPER PENINSULA OF MICHIGAN: HOUGHTON AND MARQUETTE COUNTIES

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ABSTRACT

Approximately 117 soil gas and 45 indoor radon measurements were made in the Houghton and Marquette Counties of Michigan, as part of the United States Geological Survey's (USGS) program to evaluate radon hazards in formerly glaciated terrain. Soil gas samples were taken using standard USGS procedures. Indoor radon samples were taken, using a standard charcoal canister, and sent to a commercial laboratory for measurement. Average readings from soils over four different formations in Houghton County were in the range 4.07 to 9.25 kBq l^{-1}. Average measurements from Marquette County were in the range 48.1 kBq l^{-1} to 259 kBq l^{-1}, and the highest soil gas reading was 274 kBq l^{-1} over the Bell Creek Gneiss. The highest indoor radon reading was 2.96 kBq l^{-1} in the city of Hancock. Through the study of soils, the soil's radon content, and the bedrock geology, the area's radon potential was evaluated. Houghton County has a low radon potential, while the Republic area of Marquette County has a high radon potential.

INTRODUCTION

Soils in formerly glaciated terrain are often high in radon activity. The USGS initiated a program during the summers of 1992 and 1993 to measure the soil gas radon in Houghton and Marquette Counties of Michigan (Fig. 1). The town of Republic in Marquette County was already known to have high levels of indoor radon, so special attention was directed to measuring soil radon in this area. One goal of this investigation was to provide data that may link the high indoor radon measurements with the bedrock geology. Data are not sufficient at the present to conclusively correlate indoor radon readings with bedrock geology, but our data do show that soil gas radon near Republic is approximately 10 to 20 times higher than samples measured during the same time in Houghton County. The geology of these two areas differs extensively.

The geology of Houghton County consists of The Portage Lake Lava Series, mostly basalt with a few intercalated rhyolite flows, Freda Sandstone, Jacobsville Sandstone, Copper Harbor Conglomerate, and Nonesuch Shale. The iron--rich soils are mainly glacial tills, gravely sands, silty sands, sandy silts, and sandy and silty loams. The soils contain mainly quartz, feldspar, volcanic and plutonic clasts, and trace amounts of magnetite.

The town of Republic lies above the Republic Syncline over gneissic bedrock overlain by the stratified rocks of the Marquette Supergroup. The Compeau Creek Gneiss and The Bell Creek Gneiss make up the bedrock. The gneiss are granitic, mafic, a migmatite, and an amphibolite. The Marquette Supergroup consists of The Siamo Slate; Ajibik Quartzite; Negaunee Iron Formation--including a hematite-rich oxide facies, a magnetite-rich oxide facies, and an iron silicate-rich iron formation; Goodrich Quartzite; basal conglomerate to the Goodrich; Greenwood Iron Formation--banded silicate-magnetite iron formation; metadiabase; and a slate. During the Penokean Orogeny, the area underwent faulting and fracturing and has been metamorphosed twice (Cannon 1975). The soils in Republic are mainly sands, silty sands, sandy silts, and clayey silts and sands, many though to be glacial outwash.

MATERIALS AND METHODS

Soil gas samples were taken using standard USGS procedures. The samples were taken by using a stainless steel probe driven 75 cm underground. A 20 cc syringe was inserted into a cap used to stop leakage, and then the gas was pulled from the soil. The time each sample was taken, syringe number, and sample location was recorded.

The soil at the top of each sample site and at the tip of the probe was studied to determine its type and mineralogy. Each sample was tested using a Pylon AB-5 portable radiation monitor measure radon activity. Each sample was put into a cell and read in two minute intervals for ten minutes. The readings were averaged, and the previously measured background radiation of the cell was subtracted from the average. The resulting number was multiplied by 7.9, to give the mean soil gas radon in picocuries per liter.

RESULTS

Soil Radon

Sixty-one samples were taken in Houghton County during the summer of 1992; fifty-six were taken in the Republic area during the summers of 1992 and 1993 (Fig. 2). These data are reported in Tables 1 and 2. The samples from Houghton County gave low soil gas radon levels with only a few exceptions. The highest levels (samples 28 and 31) occurred over the Jacobsville Sandstone and the Portage Lake Volcanics. A low of zero occurred over The Freda Sandstone (sample 48). Averages for soils developed over each formation in the areas are given in Tables 3 and 4.

Table 3. Average radon contents in soils developed on the five formations in Houghton County, Michigan. Measurements were taken in the summer of 1992.

Formation	Bq l^{-1}
Jacobsville Sandstone	7992
Freda Sandstone	5809
Nonesuch Shale	6216
Copper Harbor Conglomerate	9139
Portage Lake Volcanics	4070

Table 4. Average radon contents in soils developed on different bedrock types in Marquette County, Michigan. Measurements were taken in the summer of 1992 and 1993.

Formation/Rock Type	kBq l^{-1}
Bell Creek Gneiss[a]	48.7
Compeau Creek Gneiss	55.3
Metadiabase	56.1
Goodrich Quartzite	112.8
Siamo Slate	97.1
Ajibik Quartzite	97.1

[a] excluding the extreme numbers

Indoor Radon

In addition to the soil radon measurements, approximately 37 measurements of indoor radon were measured by charcoal canister in the spring of 1993. The results are shown in Table 5. In general, the indoor radon readings in the Houghton and Hancock area are low, except for one anomalous high reading of 2989.6 Bq l^{-1}, which was measured in a basement of a house in Hancock. (This reading was confirmed by alpha track measurements, and abatement procedures have begun.) The cause of this high reading is not known, and a more detailed investigation of the neighborhood is underway. Possible causes include:

1. building materials,
2. soil composition,
3. or bedrock geology.

The high readings in the Houghton area, ranging from 240 to 395 Bq l^{-1}, were taken in the basements of older buildings on the campus of Michigan Technological University. These readings closely resemble earlier measurements made by the university safety officer (according to Donald Daavettila of Michigan Technological University). These buildings are constructed of Jacobsville sandstone, a red facies with mottled bleached zones. The

centers of the bleached zones often contain concentrations of black opaque material, which is likely heavy metal (or possibly organic material). Further investigation of this sandstone is underway.

DISCUSSION

In 1992, the soils sampled in Houghton County contained low concentrations of radon, on the order of 3.7 kBq l^{-1} to 7.4 kBq l^{-1}. In contrast, the soils of Republic contained significantly higher concentrations of soil gas radon, in the range 37 kBq l^{-1} to 111 kBq l^{-1}. As a result of these findings, additional measurements were made near Republic in the summer of 1993.

The highest readings in Houghton were average amounts of radon for most soils. The Jacobsville may have a moderately high potential for radon, because a radioactive vein of calcite has been found to cut the sandstone (Johnson 1977). The Nonesuch Shale is a black shale in some localities that has a high organic content. It has not been systematically investigated, but this area may have hazard potential greater than indicated in the data reported here. Our data demonstrates that the radon hazard potential is low in Houghton County. The mains controls are:

1. the low concentrations of radioactive elements and
2. the extreme wetness of the area.

On the other hand, rocks in the Republic area have high concentrations of radioactive elements. The Goodrich Quartzite contains monazite. A gamma ray spectrographic assay for a granite near Republic yielded 102.4 ppm $eThO_2$, 14.7 ppm eU_3O_8, and 5.22% eK, and a migmatite near Republic has a radioactivity 5 to 8 times the average of surrounding rocks. These are only a few examples of the radioactive occurrences found near Republic. Worn pebbles of apatite and thin beds (1 cm thick) of apatite are present in the basal conglomerate of the Ajibik Quartzite. A sample of the Ajibik showed 15.5 ppm $eThO_2$, 12.4 ppm eU_3O_8, and 3.6% eK (Johnson 1977). The high radioelement content, the presence of phosphatic minerals, and the fact that many soils derive from glacial outwash give Republic a high radon potential, as indicated by the high average readings in Table 2.

CONCLUSIONS

The connection between high indoor radon readings and bedrock geology has not yet been definitively established. However, our data show that, like the soil gas readings, the indoor radon samples taken from the Houghton and Hancock area are low in most cases. This subject is currently under further investigation.

The lithologies present in Houghton County do not pose a threat for a widespread radon problem, because they have a low radioelement content. The area's numerous wetlands also act as a buffer against high soil gas and indoor radon concentrations. Due to the above factors, Houghton County is considered to have a low radon potential.

The bedrock in the Republic area has a high radioelement content and contains phosphate in areas. The radon is able to move freely through the glacial soils and faults and fractures caused by the area's episodes of metamorphism. These factors combined give republic a high radon potential.

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Republic SW Quadrangle (7.5 Minute Series Topographic Map). Reston: U.S. Geological Survey: 1975.

Table 1. Soil gas radon and geology for Houghton County

Sample	Radon(Bq/l)	Geology
1	4921	Portage Lake Volcanics
2	6068	Portage Lake Volcanics
3	5772	Portage Lake Volcanics
4	3589	Portage Lake Volcanics
5	4218	Jacobsville Sandstone
6	5032	Jacobsville Sandstone
7	7807	Nonesuch Shale
8	5661	Freda Sandstone
9	3885	Freda Sandstone
10	10545	Freda Sandstone
11	8621	Rhyolite
12	2109	Portage Lake Volcanics
13	5994	Nonesuch Shale
14	7178	Copper Harbor Conglomerate
15	8769	Copper Harbor Conglomerate
16	15503	Freda Sandstone
17	11174	Copper Harbor Conglomerate
18	4810	Nonesuch Shale
19	6734	Freda Sandstone
20	3441	Freda Sandstone
21	6179	Copper Harbor Conglomerate
22	12321	Copper Harbor Conglomerate
23	3219	Basalt stamp sand
24	4551	Basalt stamp sand
25	1332	Basalt stamp sand
26	2553	Portage Lake Volcanics
27	1924	Portage Lake Volcanics
28	86617	Jacobsville Sandstone
29	5217	Portage Lake Volcanics
30	2849	Portage Lake Volcanics
31	44770	Portage Lake Volcanics
32	2775	Portage Lake Volcanics
33	2183	Portage Lake Volcanics
34	2109	Freda Sandstone
35	5846	Jacobsville Sandstone
36	6438	Jacobsville Sandstone
37	7437	Jacobsville Sandstone
38	7474	Portage Lake Volcanics
39	3848	Portage Lake Volcanics
40	14356	Jacobsville Sandstone
41	8103	Jacobsville Sandstone
42	6586	Jacobsville Sandstone
43	814	Jacobsville Sandstone
44	37481	Portage Lake Volcanics
45	6475	Portage Lake Volcanics
46	4884	Freda Sandstone
47	5920	Freda Sandstone
48	0	Freda Sandstone
49	6734	Jacobsville Sandstone
50	6956	Jacobsville Sandstone
51	16820	Jacobsville Sandstone
52	6623	Freda Sandstone
53	2627	Freda Sandstone
54	35557	Freda Sandstone
55	6734	Freda Sandstone
56	11359	Freda Sandstone
57	3552	Freda Sandstone
58	2442	Freda Sandstone
59	3108	Freda Sandstone
60	3441	Freda Sandstone
61	5661	Freda Sandstone

Table 2. Soil gas radon and geology for Marquette County

Sample	Radon(Bq/l)	Geology
1	63122	metadiabase
2	18352	Bell Creek Gneiss
3	15799	Bell Creek Gneiss
4	131905	Goodrich Quartzite
5	60051	Bell Creek Gneiss
6	31746	Bell Creek Gneiss
7	55352	Bell Creek Gneiss
8	32745	Bell Creek Gneiss
9	31524	Goodrich Quartzite
10	102564	Goodrich Quartzite
11	97051	Bell Creek Gneiss
12	36371	metadiabase
13	95053	Bell Creek Gneiss
14	10397	Bell Creek Gneiss
15	27713	metadiabase
16	39738	Bell Creek Gneiss
17	38184	Bell Creek Gneiss
18	12173	Bell Creek Gneiss
19	65786	Bell Creek Gneiss
20	39997	metadiabase
21	24087	Bell Creek Gneiss
22	25974	Bell Creek Gneiss
23	11470	Bell Creek Gneiss
24	11470	Bell Creek Gneiss
25	69264	Bell Creek Gneiss
26	48470	Bell Creek Gneiss
27	273541	Bell Creek Granitic Gneiss
28	93721	Bell Creek Granitic Gneiss
29	29711	Bell Creek Granitic Gneiss
30	55241	Compeau Creek Granitic Gneiss
31	69116	Bell Creel Granitic Gneiss
32	40626	Bell Creek Granitic Gneiss
33	18019	Bell Creek Granitic Gneiss
34	88615	Bell Creek Granitic Gneiss
35	41958	Bell Creek Granitic Gneiss
36	28823	Bell Creek Granitic Gneiss
37	5032	Bell Creek Granitic Gneiss
38	70707	Bell Creek Granitic Gneiss
39	6771	Bell Creek Granitic Gneiss
40	159359	Siamo Slate and Ajibik Quartzite
41	65083	Compeau Creek Granitic Gneiss
42	37185	Bell Creek Granitic Gneiss
43	22274	Bell Creek Granitic Gneiss
44	45658	Compeau Creek Granitic Gneiss
45	55278	Compeau Creek Granitic Gneiss
46	185259	Goodrich Quartzite
47	50431	Bell Creek Granitic Gneiss
48	24420	Bell Creek Granitic Gneiss
49	64713	Bell Creek Granitic Gneiss
50	79698	Bell Creek Granitic Gneiss
51	64898	Bell Creek Granitic Gneiss
52	99197	Bell Creek Granitic Gneiss
53	19018	Bell Creek Granitic Gneiss
54	64935	Bell Creek Granitic Gneiss
55	63492	Siamo Slate and Ajibik Quartzite
56	68265	Siamo Slate and Ajibik Quartzite

Table 5. Indoor radon measurements taken from the Houghton and Hancock area.

City	Serial Number	Bq l^{-1}
Houghton	395271	0.0
Houghton	395232	0.0
Hancock	395274	0.0
Hancock	395223	0.0
Houghton	395252	0.0
Elo	395214	0.0
Houghton	395262	3.7
Hancock	395253	3.7
Houghton	395275	7.4
Chassell	395228	11.1
Houghton	395225	11.1
Pelkie	395219	14.8
Hancock	395249	14.8
Houghton	395215	14.8
Mohawk	395222	18.5
Ripley	395264	18.5
Hancock	395227	22.2
Hancock	395242	22.2
Houghton	395268	29.6
Hancock	395265	37.0
Hancock	395231	40.7
Houghton	392217	51.8
Chassell	395267	51.8
Hancock	395272	55.5
Chassell	395260	55.5
Paavola	395220	66.6
Hancock	395261	70.3
Houghton	395246	88.8
Houghton	395278	96.2
Houghton	395257	114.7
Chassell	395254	162.8
Hancock	395221	170.2
Houghton	395263	240.5
Houghton	395226	381.1
Houghton	395251	388.5
Houghton	395216	395.9
Hancock	395269	2989.6

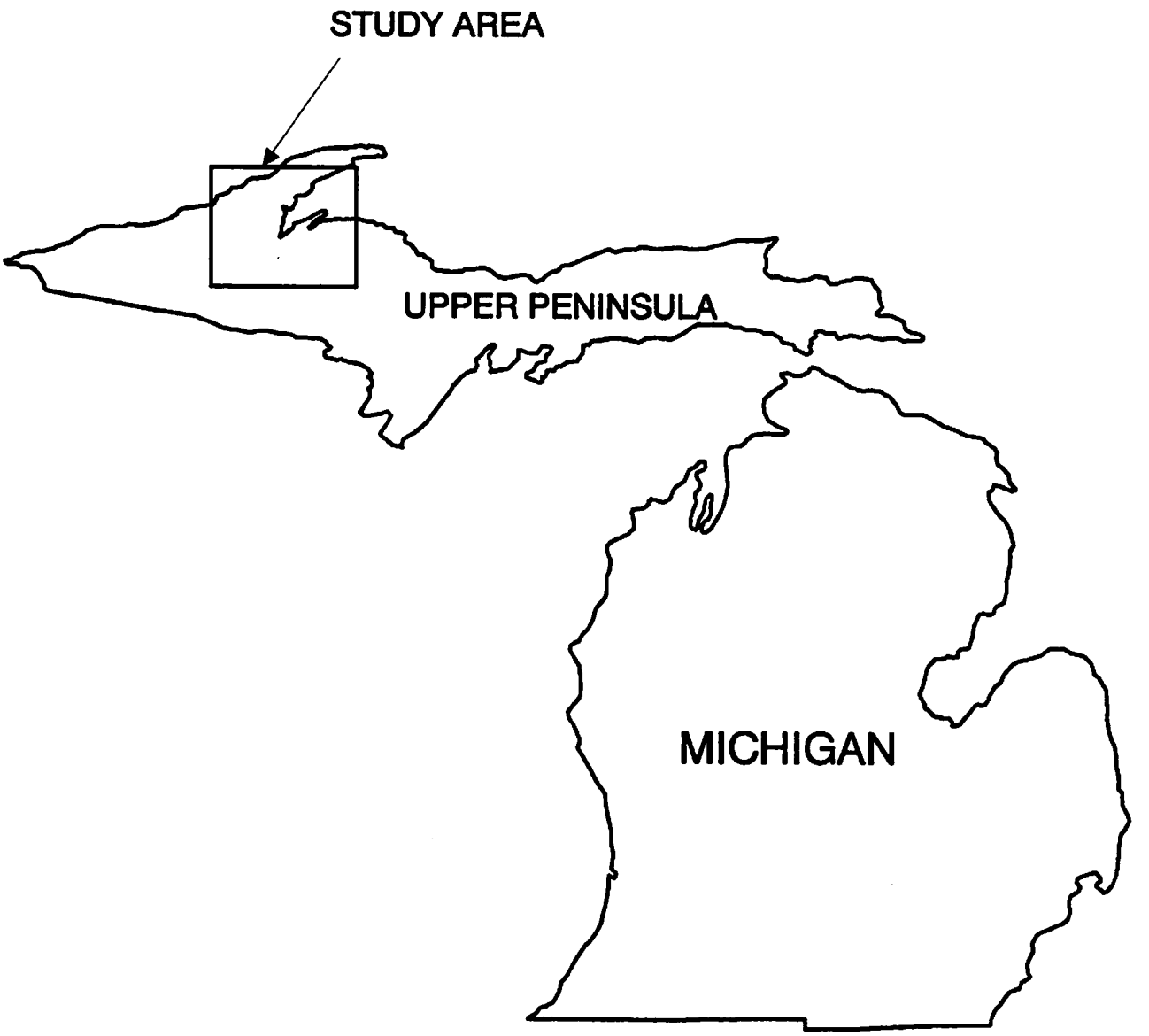

Figure 1. Map showing the area studied: Houghton and Marquette Counties, located in the upper peninsula of Michigan.

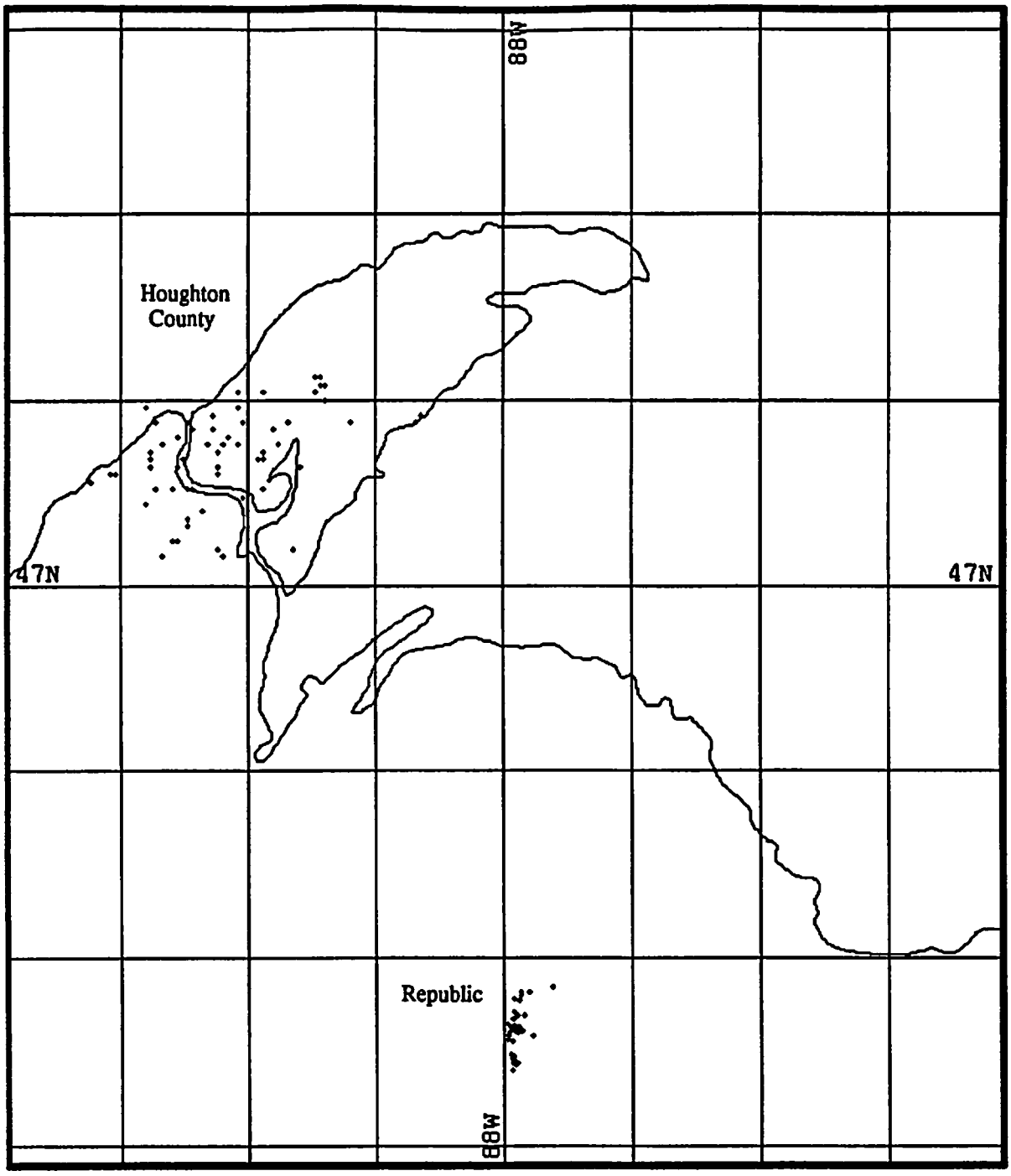

Figure 2. Map showing an enlargement of the study area: Houghton county and the town of Republic (Marquette County). The points mark the places from which soil radon samples were taken.