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Geological and Geochemical Investigations of Uranium Occurrences in the Arrastre Lake Area of the Medicine Bow Mountains, Wyoming

by

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Abstract

Metasedimentary rocks of Precambrian X age in and near the Snowy Range wilderness study area of southeastern Wyoming are lithologically and chronologically similar to those on the north shore of Lake Huron in Canada. The rocks in Canada contain major deposits of uranium in quartz-pebble conglomerates near the base of the metasedimentary sequence. Similar conglomerates in the Deep Lake Formation in the Medicine Bow Mountains of southeastern Wyoming are slightly radioactive and may contain deposits of uranium and other valuable heavy metals.

During the summer of 1976, a geological and geochemical pilot study was conducted in the vicinity of Arrastre Lake in the Medicine Bow Mountains to determine the most effective exploration methods for evaluating the uranium potential of the Snowy Range wilderness study area. The area around Arrastre Lake was selected because of the presence of a radioactive lens within a quartz-pebble conglomerate of the Deep Lake Formation. The results of the survey indicate possible uranium mineralization in the subsurface rocks of this formation.

The radon content of the dilute waters of the area is much higher than can be accounted for by the uranium content of the surface rocks. Two sources for the high content of the radon are possible. In either case, the high values of radon obtained in this study are a positive indication of uranium mineralization in the subsurface rocks.

The determination of the radon content of water samples is the recommended geochemical technique for uranium exploration in the area. The determination of uranium in water and in organic-rich bog material is also recommended.

GEOLOGY

by

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INTRODUCTION

Two of the most interesting and complete sequences of metasedimentary rocks of Precambrian X age in the Rocky Mountains are in the Sierra Madre and Medicine Bow Mountains of southeastern Wyoming (fig. 1). Rock types include feldspathic quartzites, quartzites, pebbly quartzites, phyllites, slates, diamictites, metadolomite, and subordinate metavolcanic rocks. Stratigraphic descriptions of these rocks are in Houston and others (1968) for the Medicine Bow Mountains and in Houston, Schuster, and Ebbett (1975) for the Sierra Madre. Virtually all geologists who have examined these rocks, beginning with Van Hise and Leith (1909) and continuing with Blackwelder (1935), Houston and others (1968), Young (1970) and Houston, Schuster and Ebbett (1975), have noted the strong lithologic resemblance of these metasedimentary rocks with those of Early Proterozoic age (Early Precambrian X) on the north shore of Lake Huron.

The age of the metasedimentary rocks is not accurately determined by geochronologic studies; however, the rocks are bracketed between about 2.5 b.y., the age of the rocks on which they were deposited, and about 1.7 b.y., a metamorphic event that affected the rocks (Hills and others, 1968; Hills and others, 1975; Divis, 1976). The age determinations are thus compatible with the geologic guess that these rocks are Precambrian X, but do not confirm an Early Precambrian X age.

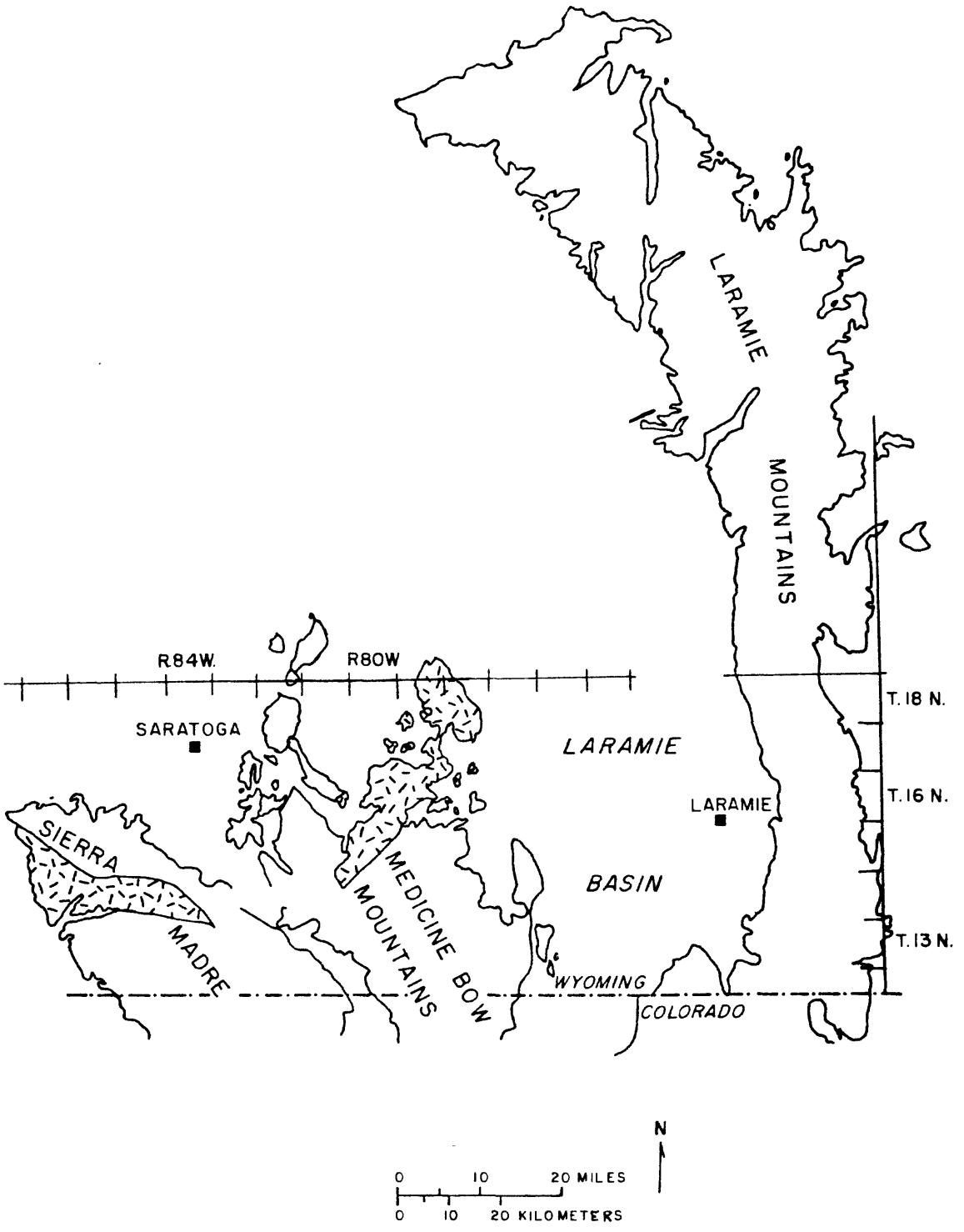


Figure 1.--Location of metasedimentary rocks (pattern) in the Sierra Madre and Medicine Bow Mountains, southeastern Wyoming.

From an economic viewpoint it is important to establish an exact age for these rocks, because sedimentary rocks older than about 2 b.y. are now believed to have been deposited in an atmosphere having a lower partial pressure of oxygen than that of today; under such atmospheric conditions placer deposits that contain uranium-bearing minerals could have formed (Cloud, 1968; Roscoe, 1973). Uranium-bearing minerals are present in placer deposits of major economic significance in the Blind River and Elliot Lake areas on the north shore of Lake Huron in Canada (Roscoe, 1969; Robertson, 1976). The placer deposits are in quartz-pebble conglomerates that occur near the base of the Early Precambrian X metasedimentary rocks of this area, and they contain the largest reserves of any single uranium district in North America. To several geologists familiar with these areas, the striking lithologic similarity between metasedimentary rocks at Blind River and the metasedimentary rocks of the Medicine Bow Mountains indicated that, despite uncertainties as to age, a careful study should be made of Medicine Bow rocks to determine whether or not Blind River type conglomerates were present. For example, in 1968, Houston and others (1968, p. 159) suggested that better sorted conglomerates of the Deep Lake Formation of the Medicine Bow Mountains should be examined as a possible source of gold and other heavy minerals, and in the early 1970's, Stewart Roscoe, formerly of the Canadian Geological Survey, who had done much of the detailed geologic study of the Blind River area in Canada, examined some conglomerates that were brought to his attention by one of the authors (Houston) and determined that they were slightly radioactive.

These early studies led to a recommendation that the metasedimentary rocks of the Deep Lake Formation of the Medicine Bow Mountains and rocks thought to be their equivalent in the Sierra Madre be investigated as possible sources of uranium and thorium. This recommendation was accepted and,with financial support from the U.S. Geological Survey, a study was undertaken in 1975 under the direction of Dr. Forrest K. Root of the Wyoming Geological Survey. Details of this investigation will be reported at a later date.

In the summer of 1976, the U.S. Geological Survey began a complementary mineral survey of the Snowy Range area of the central Medicine Bow Mountains. This proposed wilderness area is located in the center of the region that was recommended as a target for uranium exploration (fig. 2). It offered an opportunity to combine geologic, geophysical, and geochemical exploration methods in an effort to determine the presence or absence of mineral resources. This study is sponsored by the Energy Research and Development Administration. The following report contains preliminary results determined during the first summer of this wilderness investigation.

Geology of the Arrastre Lake Area

The area around Arrastre Lake has been extensively glaciated and the relatively subdued topography consists mainly of rounded hills. Elevation ranges from 2900 to 3200 m. Lakes, streams, seeps, and springs are present throughout the area. Except for bogs and meadows, the area is covered mainly by spruce and fir. Arrastre Lake is located within the outcrop area of the Deep Lake Formation and is about five kilometers west of the boundary of the Snowy Range wilderness area (fig. 2). Some of the best exposures and the most complete stratigraphic section of the Deep Lake

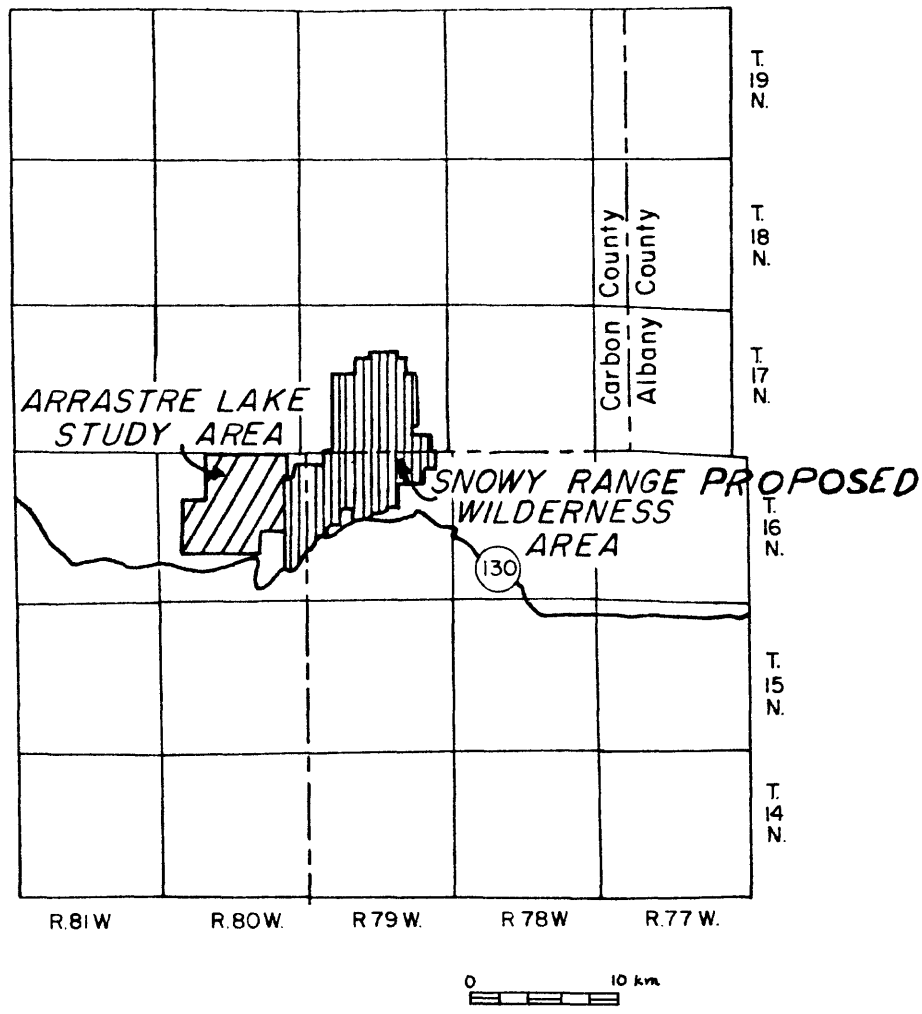


Figure 2.--Index map showing location of the Snowy Range proposed wilderness area and the Arrastre Lake study area, Carbon and Albany Counties, Wyoming.

An anticline is exposed at Arrastre Lake that is cored by metavolcanic rocks interlayered with open-framework conglomerate, phyllite, and slate (fig. 3). These rocks are overlain by feldspathic quartzites that are conglomeratic at the base. These radioactive conglomerates are exposed in a layer that extends from SW 1/4 to NW 1/4 of Sec. 10, T. 16 N., R. 80 W., a distance of approximately 1.2 kilometers (fig. 3). The conglomerates are lenticular and are as much as 1.6 meters thick; however, inasmuch as coarse-grained arkosic sandstones interlayered with the conglomerate are also radioactive, the total thickness of radioactive beds is greater than 1.6 meters in places.

Table 1 is a comparison of conglomerates of the Blind River and Medicine Bow areas. Perhaps the most critical differences between these two conglomerates are that pyrite is not as abundant and the Th/U ratio is much higher in Medicine Bow conglomerates than in those at Blind River. These differences may result from a more thorough oxidation of Medicine Bow rocks.

Table 1. Comparison of Conglomerates

Blind River	Medicine Bow
Well-sorted, thick in some areas	Moderately well sorted, not thick in the known localities
Clasts mostly quartz and black chert, but greenstone clasts also present; lies above volcanic rocks in some areas, especially where values are high	Clasts mostly quartzite and black chert, but granitic clasts present; lies above volcanic rocks
Green to greenish-brown coloration	Green to greenish-brown, but oxidized to orange locally
Abundant pyrite in matrix	Pyrite present but not abundant; may be oxidized
Radioactive	Radioactive
Thucolite present	Thucolite not identified
Well-rounded clasts	Immature clasts, not well rounded

Formation are in this area. This is also one of the areas where radioactive conglomerates are present. The Arrastre Lake area was therefore chosen for a thorough evaluation in a pilot geologic and geochemical study, so that geologic and geochemical investigations could be conducted with confidence within the proposed wilderness area.

The Deep Lake Formation crops out in the northern Medicine Bow Mountains, where it underlies an area of approximately 460 square kilometers (Houston and others, 1968, pl. 1). It unconformably underlies the Headquarters Schist, which is the basal formation of the Libby Creek Group. Rocks of the Deep Lake Formation are least deformed in the central part of this area (including the Arrastre Lake locality) and become more highly deformed and metamorphosed to the northeast. Unfortunately, extensive ground moraine of Pleistocene age and thick mantle of sedimentary rocks of Tertiary age cover the Deep Lake Formation in parts of the central area (Houston and others, 1968, pl. 1).

The Deep Lake Formation, which exceeds 3,000 meters in thickness, is interpreted as consisting of a series of sedimentary cycles that are repeated two or more times. A cycle begins with the deposition of volcanic rocks, at least locally, and this episode is followed by deposition of graywacke shales and thick open-framework conglomerates (diamictites or polymictic conglomerates). These rocks are succeeded by locally conglomeratic, feldspathic quartzites that grade upward into a thick succession of less feldspathic, better sorted quartzite with local beds of quartz-pebble conglomerate. Radioactive conglomerate has been noted at the base of the feldspathic quartzite.

Table 1. Comparison of Conglomerates (continued)

Generally occurs as extensive lenses in quartzite or gritty subarkose	Discontinuous lenses occur in feldspathic quartzites
Found near the base of conglomerate-argillite-arenite sequences	Stratigraphic and structural reconstruction not complete, but found near the base of a conglomerate-arenite sequence that contains some argillite

In the area west of Arrastre Lake, rocks of Tertiary age lie unconformably on the Precambrian. In the few places where the unconformity can be observed, a soil horizon is developed on Precambrian rocks, suggesting an episode of weathering prior to deposition of rocks of Tertiary age. The Precambrian rocks appear oxidized in most of the area. The quartzites have an orange color that is probably caused by oxidation of pyrite; further evidence is the presence of cubic cavities that are apparently sites where pyrite has been removed and the fact that dense, fresh samples of quartzite contain pyrite. The pyrite is widely disseminated and not abundant; some grains appear rounded when examined with a hand lens and others are euhedral. If rounded pyrite is present in the quartzite, it suggests an atmosphere favorable for transportation of pyrite at the time of deposition and supports the hypothesis of an Early Precambrian X age for the rocks.

In any event, this evidence of oxidation suggested that geochemical exploration methods should be devised that detect the presence of uranium where extensive surface alteration has occurred, and the following report discusses the results of this exploration geochemistry study.

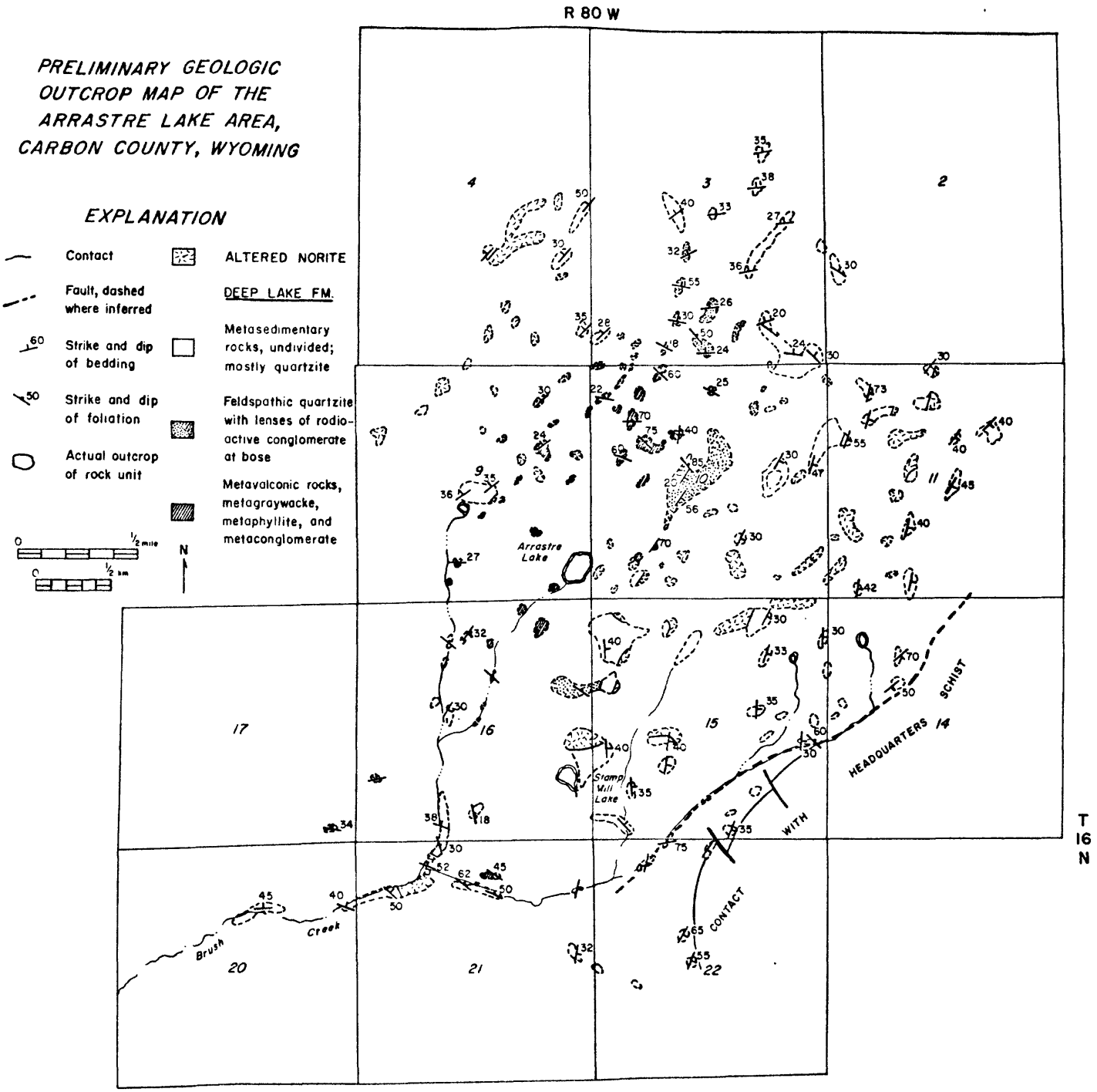


Figure 3.--Preliminary geologic map of the Arrastre Lake area.

Geochemical Orientation Survey

by

William R. Miller, Delmont M. Hopkins, and Walter H. Ficklin

Area

The area around Arrastre Lake was selected for study because of the presence of a slightly radioactive conglomerate of the Deep Lake Formation. The geology of the Medicine Bow Mountains is described in Houston and others (1968) and in this report. Arrastre Lake is located approximately in the core of an anticline formed by the Deep Lake Formation.

Methods

The purpose of the mineral survey was to determine if the area had potential for uranium deposits and what geochemical methods would be the most effective for locating favorable areas. Water samples collected from lakes, streams, seeps, and springs (fig. 4) were analyzed for calcium, magnesium, sodium, potassium, bicarbonate, fluoride, chloride, sulfate, silica, copper, zinc, uranium, radium, radon, and specific conductance. Temperature and pH were determined at the sample site. The methods of collection and chemical analyses for all the species except uranium, radium, and radon are described in Miller and Ficklin (1976). The results of the charge balance are all within 20 percent and half are within 5 percent. For fluorometric determination of uranium, 500-ml samples of water were collected separately and acidified with nitric acid to pH 2. In the laboratory, the uranium was extracted using Amberlite IRC-50 ion exchange resin. The resin was then burned off and the residue treated according to the method of Centanni and others (1956), except that a Na_2CO_3-K_2CO_3-NaF flux was used in place of the suggested flux.

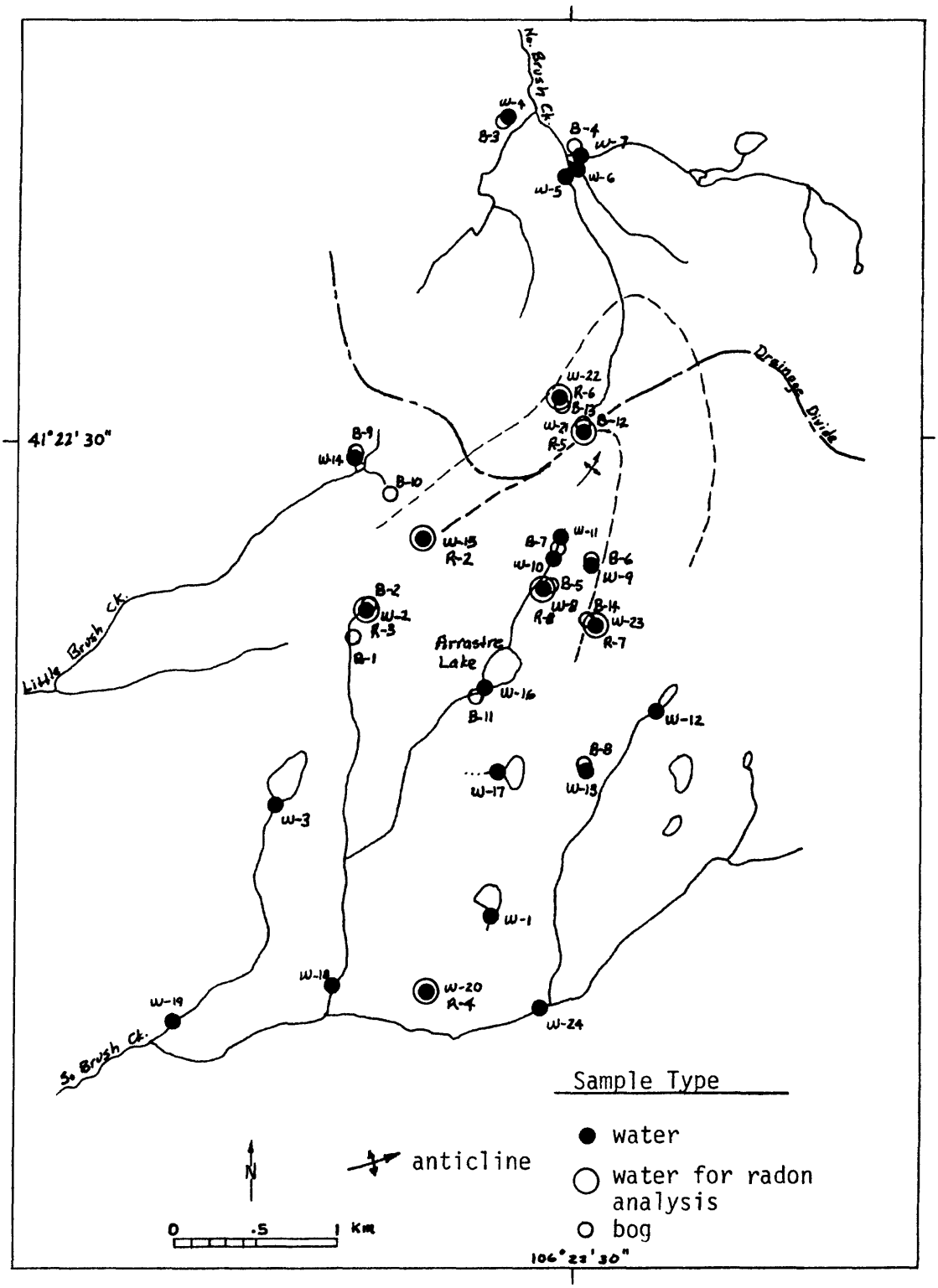


Figure 4.--Sample locality map for water and bog material. Dashed line is the location of the quartz-pebble conglomerate.

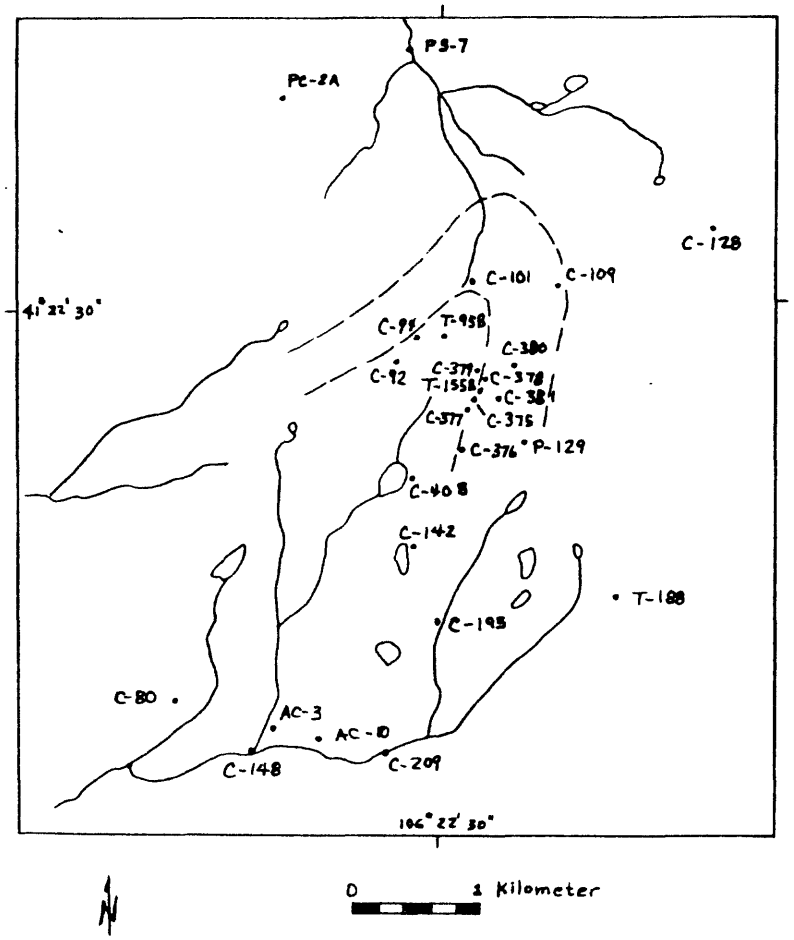


Figure 5.--Sample locality map for rock samples. Dashed line is the location of the quartz-pebble conglomerate.

For determination of radon gas in water, 50-ml samples of water were collected and stored in glass containers. Within several days, radon-222 was determined by the U.S. Geological Survey: water was degassed and the radon determined by alpha scintillation. The sample was then allowed to age and the radon was determined again so that radium could be calculated.

Uranium in bog material and in rocks (figs. 4 and 5) was determined fluorometrically according to the method of Centanni and others (1956). The bog material was oven-dried and then ashed overnight at 550°C. Thorium in the rocks was determined colorimetrically according to the method of Stanton (1971). Organic-rich lake sediments, soils, stream sediments, and conifer cones and needles were also collected, but each of these sample types had shortcomings. Consequently, they were not analyzed and will not be discussed.

Uranium in Surface Rocks

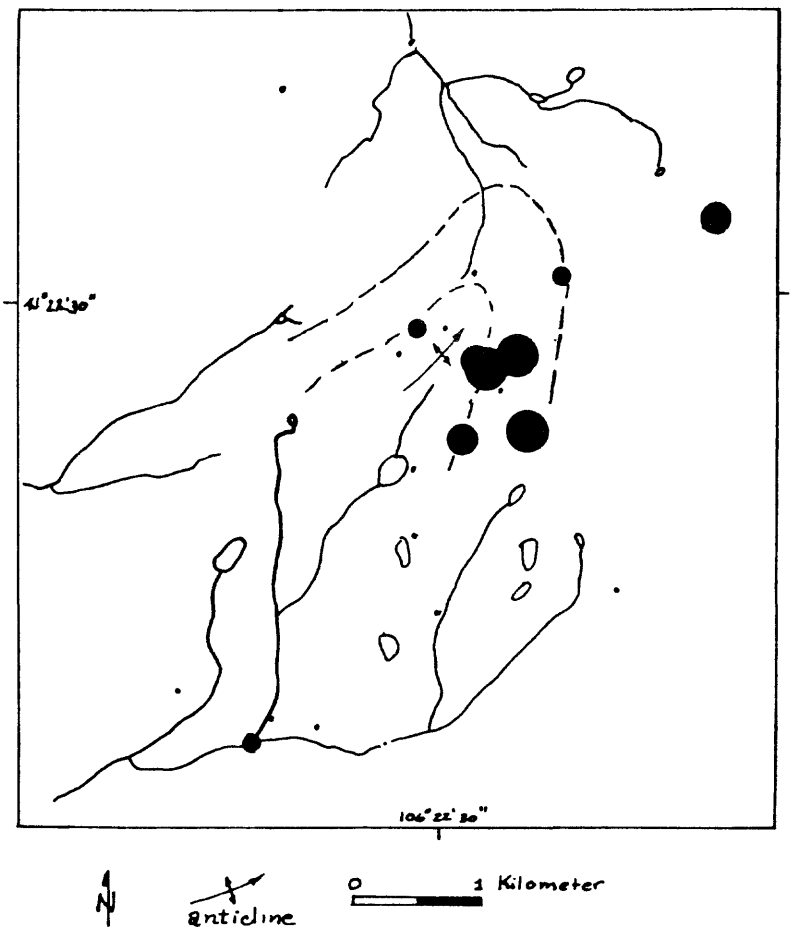
The uranium content of the surface rocks in the study area is not unusually high (table 2a). Uranium in the presence of oxygen is readily oxidized to the hexavalent state, which is readily soluble in water. Unlike uranium, radium does not easily form soluble compounds except in the presence of concentrated-chloride waters. Therefore, the uranium content of the surface rocks originally may have been higher. The surface rocks appear to be leached, and the equivalent uranium (eU) content is higher than can be accounted for by a scan of the uranium, thorium, and potassium. A comparison of the eU with uranium and thorium is shown on table 2b. The excess eU may be due to residual radium, which may still be present in the surface rocks. The highest values of uranium occur in the conglomerate associated with the Deep Lake Formation, which crops out northeast of Arrastre Lake (fig. 6).

Table 2a.--Uranium content of rocks in the study area

Sample No.	Uranium (ppm)	Sample No.	Uranium (ppm)
AC-3	0.79	C-375	2.9
C-59	7.2	C-376	6.3
C-80	1.4	C-377	4.3
C-90B	1.2	C-378	4.3
C-92	2.8	C-379	7.3
C-94	3.8	C-380	8.4
C-101	1.2	C-381	1.8
C-109	3.4	P-129	31.2
C-128	5.8	PC-2A	.52
C-148	3.0	PS-7	1.1
C-192	.72	T-95B	1.2
C-195	.51	T-155B	1.4
C-209	.79		

Table 2b.--Comparison of fluorometric uranium and thorium content of rocks with equivalent uranium (eU).

Sample No.	U-Fluorometric (ppm)	Th (ppm)	eU (ppm)
C-375	2.9	38	180
C-376	6.3	26	160
C-377	4.3	<20	60
C-378	8.4	<20	160
C-379	7.3	26	180
C-380	8.4	<20	100



Uranium-ppm

- >8.0
- 5.0-8.0
- 3.0-4.9
- < 3.0

Figure 6.--Distribution of the uranium content in rocks. Dashed line is the location of the quartz-pebble conglomerate.

Geochemistry of Waters

Chemical analyses of waters collected from streams, lakes, springs, and seeps are shown in table 3. The waters of the area are primarily calcium bicarbonate waters, but are extremely dilute. The small amounts of dissolved solids in the waters indicate either extremely short contact time of the waters with the rocks of the area, or that the rocks have been leached of the more reactive minerals. Because the waters are extremely dilute with respect to the total dissolved solids, the uranium content is not unusually low. The highest content occurs north of Arrastre Lake (fig. 7). Because much of the water in contact with the radioactive conglomerate of the Deep Lake Formation drains toward Arrastre Lake, the higher concentration of uranium around the lake is probably derived from this information.

The amount of radon gas dissolved in the water was determined on seven water samples (table 4). Radon, a daughter product of uranium-238, is a positive indication of uranium. Its short half life (3.8 days) does not allow long migration in water. The radon content of the waters near Arrastre Lake is extremely high, particularly for dilute waters. The equivalent amount of uranium-238 needed to produce the amount of radon-222 in the waters is shown in table 4. This amount greatly exceeds the uranium content of the surface rocks. In addition, table 4 shows the amount of radon-222 in the water samples that could have been derived from uranium-238 and radium-226 accompanying the radon in the water. In all cases, the amount of radon-222 in the water samples far exceeds these amounts.

Table 3.--Chemical analyses of waters collected from streams, lakes, springs, and seep.

Sample No.	Temp. (°C)	pH	Specific Conductance	Calcium	Magnesium	Sodium	Potassium	SiO_2	Bicarbonate	Sulfate	Fluoride	Copper	Zinc	Uranium	Radon 222
W-1	19	6.95	13.7	1.2	0.3	0.67	0.09	2.6	4.2	0.6	0.02	1.0	1.6	0.27	---
W-2 (R-3)	12	6.05	28.1	3.1	.7	1.00	.20	5.4	15.0	.5	.02	1.5	3.9	.50	800
W-3	19	6.85	11.1	0.6	.3	.53	.09	2.2	3.6	1.5	.03	2.0	2.1	.13	---
W-4	10	6.95	23.3	2.0	.6	1.00	.11	6.2	13.2	1.6	.02	2.0	1.2	.12	---
W-5	10	7.00	24.0	3.0	.5	.73	.12	4.4	12.0	.8	.02	2.0	1.3	.14	---
W-6	11	6.65	12.0	1.2	.4	.53	.09	2.9	3.6	1.0	.04	<1.0	1.2	.25	---
W-7	12	7.00	17.9	2.0	.4	.50	.05	3.8	9.5	.5	.02	1.0	.8	.40	---
W-8 (R-8)	17	7.35	82.7	9.1	.6	1.27	.79	9.0	49.7	.6	.02	3.0	3.5	.38	2600
W-9	24	6.65	13.4	1.3	.3	.43	.07	2.2	5.7	1.0	.04	<1.0	3.6	.34	---
W-10	19	7.00	16.8	1.9	.4	.50	.09	3.2	9.0	1.0	.02	<1.0	5.5	.42	---
W-11	17	6.75	29.5	3.8	.6	.59	.23	4.1	15.6	1.0	.06	2.0	4.4	.23	---
W-12	13	7.10	24.8	2.4	.6	.93	.14	7.0	10.8	.6	<.01	2.0	.9	.30	---
W-13	12	7.45	77.4	17.	.9	.90	.23	6.5	47.5	.6	.01	1.0	1.1	.18	---
W-14	12	7.05	39.1	5.0	.6	1.23	.25	9.2	22.0	.8	.02	<1.0	7.8	.10	---
W-15 (R-2)	3	5.65	14.5	1.2	.4	.70	.21	6.2	6.0	.5	.01	<1.0	4.0	.20	380
W-16	18	7.05	27.2	3.3	.6	.53	.20	3.5	15.0	.5	.01	1.5	1.8	.12	---
W-17	19	7.65	28.5	3.1	.6	.70	.23	2.3	14.4	.5	<.01	3.0	1.1	.20	---
W-18	14	7.25	30.8	3.1	.7	.80	.29	5.0	16.5	.5	.01	1.5	12.8	.18	---
W-19	13	7.25	25.9	2.6	.7	.90	.16	7.1	12.0	.4	<.01	2.5	2.2	.28	---
W-20 (R-4)	8	7.40	16.9	1.3	.5	.60	.13	7.2	7.9	.3	<.01	2.0	1.7	.14	<10
W-21 (R-5)	7	6.15	31.0	3.7	.5	.60	.30	5.3	16.5	.3	.02	3.0	1.7	.14	160
W-22 (R-6)	21	6.25	9.2	1.2	.3	.26	.04	1.7	2.9	.8	.02	3.0	10.0	.19	<10
W-23 (R-7)	3	5.80	20.3	2.0	.6	.87	.25	8.3	10.2	.5	.02	2.0	2.2	.32	1500
W-24	14	7.35	26.6	2.9	.6	.80	.16	5.6	13.2	.4	.03	3.0	2.4	.42	---

Note: Units for chemical species are mg/l except for copper and uranium which are µg/l. Units for specific conductance are µmho/l and for radon pc/l.
Chloride concentrations are all <0.05 mg/l.
(--- not analyzed)

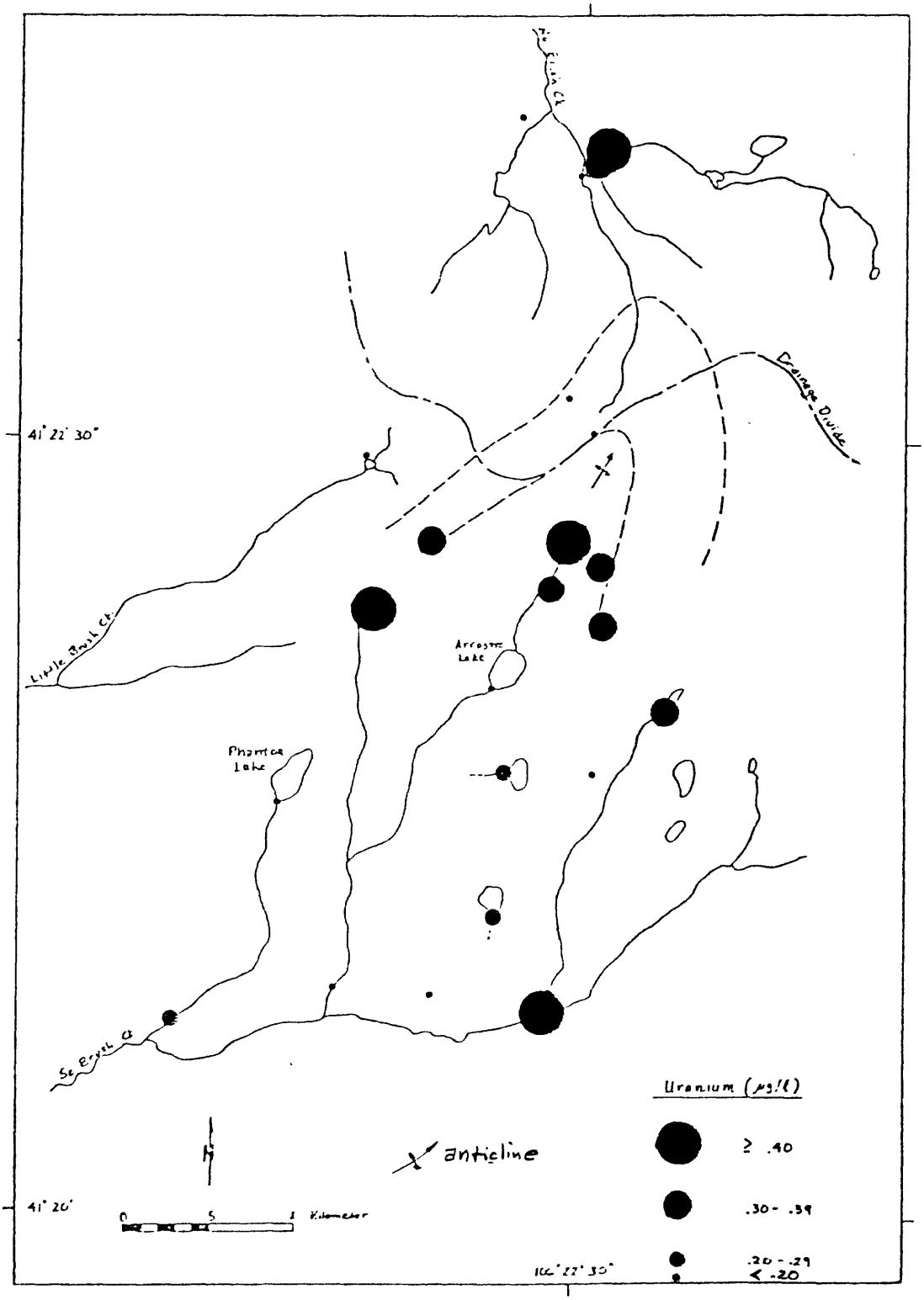


Figure 7.--Distribution of the uranium content of water. Dashed line is the location of the quartz-pebble conglomerate.

Table 4.--Summary of uranium, radon, and radium in the waters

Sample No.	U (mg/l)	Rn 222 (pc/l)	Ra 226 (pc/l)	$eRn^{1}_{(u)}$	$eRn^{2}_{(Ra)}$	eU^{3}
R-2	0.20	380	2.6	0.07	2.5	1.1
R-3	.50	800	1.5	.17	1.5	2.3
R-4	.14	10	---	.05	---	.03
R-5	.14	160	1.0	.05	1.0	.5
R-6	.19	710	.7	.07	.7	2.1
R-7	.32	1500	13.	.11	12.7	4.4
R-8	.38	2600	11.	.13	10.7	7.5

[1] $eRn_{(u)}$ is the amount of radon-222 that would be in equilibrium with the dissolved uranium in the water.

[2] $eRn_{(Ra)}$ is the amount of radon-222 that would be in equilibrium with the dissolved radium-226 in the water.

[3] eU is the amount of uranium-238, in mg, that each liter of water must come in contact with in order to generate the amount of radon-222 that is present in the water.

(--- not analyzed)

Two sources of the radon gas are possible. Radon gas can be generated by the normal decay of uranium-238 in the subsurface and can then migrate upward in the ground water, or residual radium may still be present in the surface rocks. If radium is present, its normal decay will generate radon. If it is assumed that the subsurface rocks have not been leached of uranium, then,in either situation, the high values for radon are a positive indication of a higher uranium content in the subsurface rocks. The highest values for radon occur around Arrastre Lake (fig. 6), where six of the seven samples were taken.

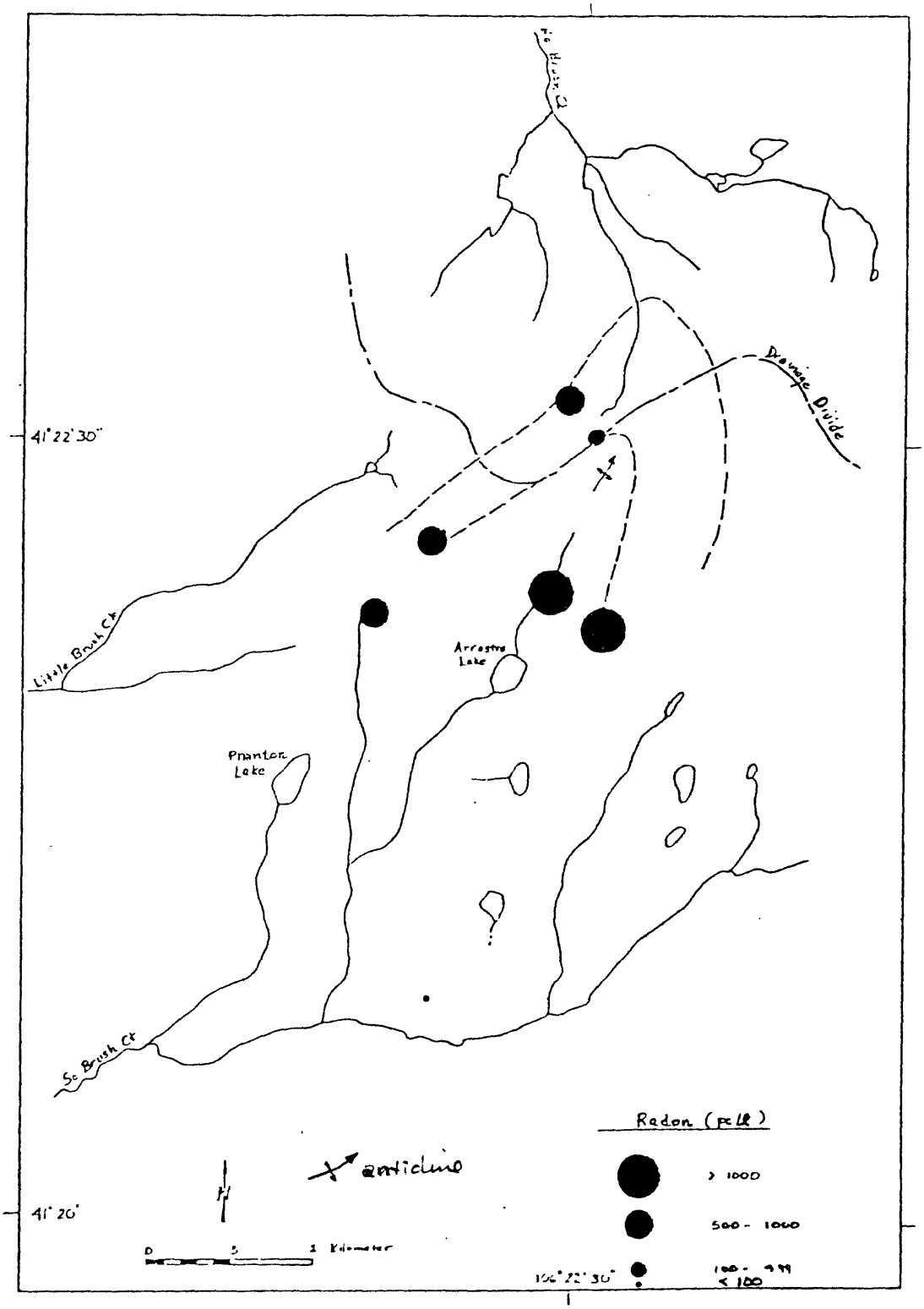


Figure 8.--Distribution of radon-222 content in water. Dashed line is the location of the quartz-pebble conglomerate.

Bog Material

Because organic material strongly adsorbs uranium from natural waters and because bogs are found throughout the area, organic-rich bog material was sampled. The size of the bogs vary, but most are less than 30 m in diameter. The thickness of the organic-rich material is not known, but it is probably several meters. The samples were collected near the center of each bog, approximately 5-15 cm below the surface. The bog material probably acquires uranium by adsorption from the natural waters that come in contact with the organic-rich material. Waters draining the bogs are extremely dilute. The uranium content of the bogs is two orders of magnitude greater than that of the waters (tables 3 and 5).

The areas of highest uranium content in bog material are shown in fig. 9. Highest uranium concentration is near Arrastre Lake and corresponds to the highest values in the water samples.

Table 5.--Uranium and inorganic content of bog material.

Sample No.	Percent Inorganic	U-ash (ppm)
B-1	52.3	2.9
B-2	54.5	4.3
B-3	88.5	2.1
B-4	61.0	3.6
B-5	45.7	3.0
B-6	43.9	5.5
B-7	31.5	3.3
B-8	84.0	5.2
B-9	56.0	2.8
B-10	41.7	3.0
B-11	31.5	3.0
B-12	50.9	3.0
B-13	55.7	3.0
B-14	49.8	3.3

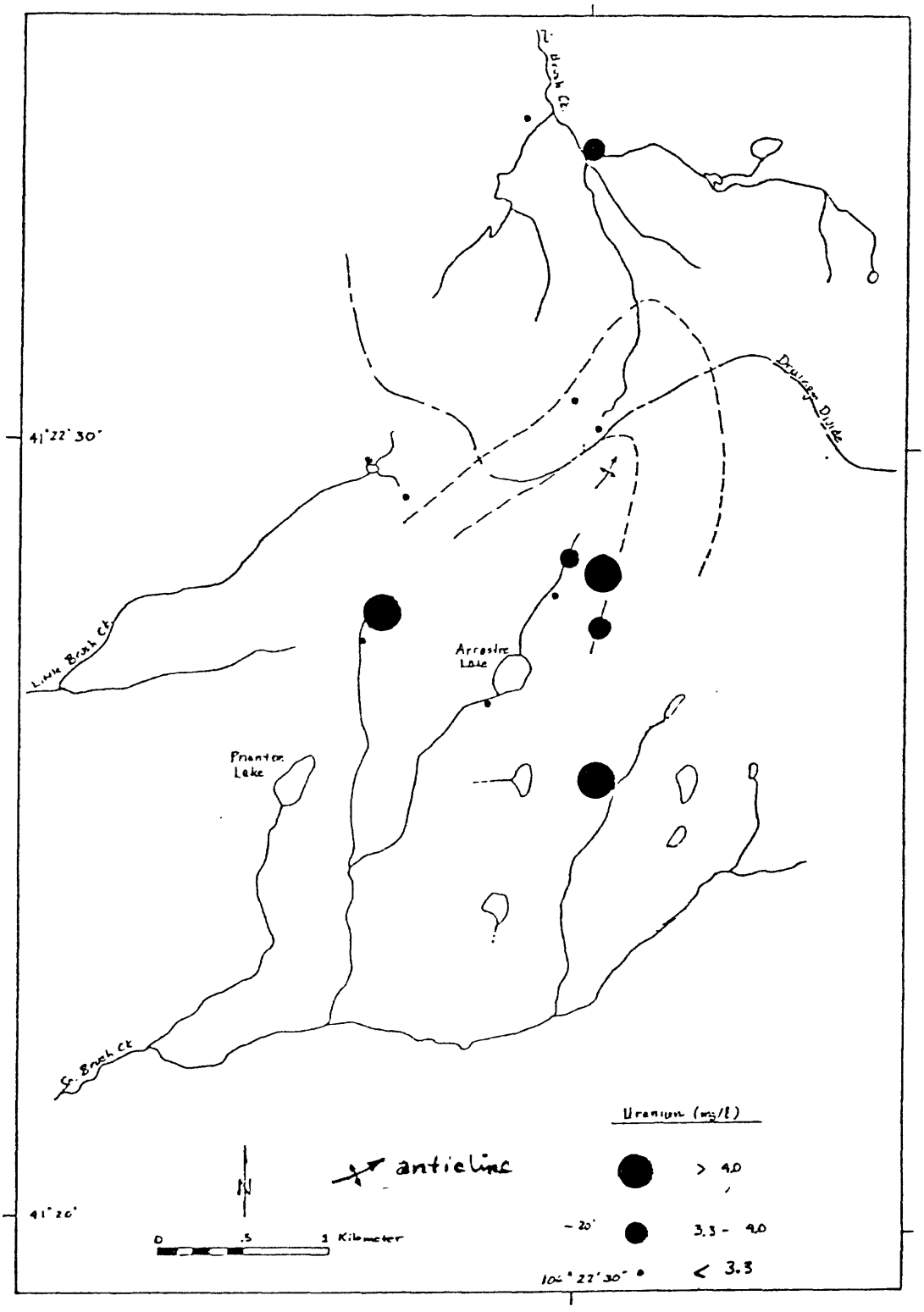


Figure 9.--Distribution of the uranium content of organic-rich bog material. Dashed line is the location of the quartz-pebble conglomerate.

Conclusion

A comparison of radon and the uranium contents of bog material and water is shown in table 6. The largest contrast or range is shown by dissolved radon in water. The range of the uranium content of bog material is small, but uranium is concentrated two orders of magnitude greater in bog material than in water.

The uranium contents of the water and bog material can be used in a qualitative manner to indicate the most favorable areas for uranium mineralization. The high values for radon, although based on a few samples, are a positive indication of uranium mineralization. The limited amount of data suggests that the subsurface rocks of the quartz-pebble conglomerate of the Deep Lake Formation, which crops out north and northwest of Arrastre Lake, may contain economic concentrations of uranium. More samples are needed in order to define the most favorable areas.

Radon in waters is the recommended sampling technique for geochemical exploration of uranium in the general area. Also recommended is uranium in waters and in organic-rich bog material.

Table 6.--Comparison of uranium content of rocks, water, and bog material with radon-222 in water.

Element	$\bar{x}$	Range or Contrast
U in rocks (ppm)	4.29	.51- 31.2
U in water (µg/l)	.25	.1 - .5
U in bog material-ash (ppm)	3.43	2.8 - 5.5
Radon 222 (pc/l)	880.	10. -2600.

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