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Some controls on trace-element concentrations, especially uranium, in selected peat deposits of Vermont and New Hampshire

by

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SOME CONTROLS ON TRACE-ELEMENT CONCENTRATIONS, ESPECIALLY URANIUM, IN SELECTED PEAT DEPOSITS OF VERMONT AND NEW HAMPSHIRE

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ABSTRACT

Thirty eight deposits of Holocene peat sampled in the Vermont-New Hampshire area of the Glen Falls 1:250,000 sheet illustrate the ability of some deposits to accumulate anomalous amounts of certain elements, including Ni, Co, Cu, V, Sr, La, Nd, Eu, Th, and U. The amount of each element in a given deposit depends on the presence of available sources in the underlying bedrock, and the efficiency of groundwater transport from sources to peat-forming marsh or swamp. The presence of fracture zones and solution channels, such as in karst, facilitate transport.

Uranium is the most anomalous element, and in 76 samples ranges in concentration from 1 to 467 ppm (parts per million) with a mean of 48 ppm. Deposits having the greatest anomalies are located just south of Fern Lake, Vermont, in a swamp containing an estimated 40,000 tons of commercial quality dry peat, and in a marsh east of Lake Sunapee near New London, New Hampshire, where the peat resource is also estimated at 40,000 tons. This report relates the positions in the deposits where the various amounts of uranium occur, to ancient ecological environments or ecosystems which may influence or control uranium anomalies.

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The uranium contents of the peat deposit near Fern Lake are similar to the lowest ore-grade portions of the Flodelle Creek, Washington, deposit the only surficial uranium mine in the United States. Like the Washington State deposit, the deposits in Vermont and New Hampshire are relatively non-radioactive because of post-glacial ages <10,000 yrs., for which daughter products such as radium and thorium have not yet formed in appreciable amounts. Agricultural users of peat should be alerted to the uranium content of these samples.

INTRODUCTION

Thirty-eight deposits of Holocene organic materials (peat) in Vermont and New Hampshire were studied during mineral-resource assessment of the area covered by the Glen Falls 1:250,000 quadrangle. Core sites of these deposits are shown in Figure 1. For purpose of discussion they are divided into groups A-E. The entire area lies within the glaciated Appalachians. Deposits in Group A are located west of the Green Mountains in Vermont, overlying Lower Paleozoic sedimentary and metasedimentary rocks, chiefly dolomite and quartzite. Deposits in Group B are west of the Green Mountains overlying Middle and Lower Paleozoic rocks and Precambrian granitic rocks and quartzite. Deposits in Group C overlie Devonian and older phyllite, schist, gneiss, and granite on either side of the Connecticut River in Vermont and New Hampshire. Deposits in Group D are in New Hampshire overlying Devonian two-mica granite and quartz monzonite. The remaining deposits, in Group E in New Hampshire, overlie granite, gneiss, and various metasedimentary rocks.

The purpose of this report is to examine relationships between ash and trace-element contents and the geological settings of the organic deposits, together with the ecological environments that existed during deposition. Controls on trace-element concentrations, especially uranium, may thus be deduced.

METHODS AND RESULTS

Uninterrupted cores were taken with a Macaulay peat auger from the surface to the base of each deposit to determine stratigraphy and to collect samples for laboratory analysis. The valuable assistance in the field of Joan Esterle, graduate student from the University of Kentucky, is greatly appreciated. In the laboratory, ash content on a dry basis was determined for each sample and later used for emission spectrographic analyses by Z. A. Brown, C. Skeen, W. Crandell, and A. F. Dorrzapf at the U.S.G.S. laboratories in Reston, Virginia. Uranium and thorium data were obtained from the unashed fractions of the samples by D. M. McKown and R. B. Vaughn using the delayed neutron activation method in the U.S.G.S. radiochemistry laboratory in Denver, Colorado. Statistics for the entire data set are shown in Table 1. Anomalous concentrations of elements are considered to be at or above a threshold of two standard deviations above the mean. Among the elements occurring in some peat deposits as anomalies are Ni, Co, Cu, V, Sr, La, Nd, Eu, Th, and U. Of these the most noteworthy is U. In 76 samples, U ranges in concentration from 1.0 to 467.0 ppm with a mean of 48.28 ppm.

Anomalous elements are shown in Table 2 arranged according to core site group locations. U and Fe tend to be anomalous only in core site groups A and D; Ca and Mo tend to be anomalous only in groups A and C; Ga only in D and E; and V in only core site groups C and D. These trends tend to reflect: (1) types of bedrock, fracture zones, and solution channels through which ground water circulates; and (2) the interaction

of organic and inorganic constituents of the ecological environment composing the core stratigraphy within the deposits (see Fig. 2). Groups D in New Hampshire and A in Vermont are discussed in more detail because these are the principal localities of uranium anomalies in the peat deposits. Focus will be on two deposits. One is at core site 30 at Messer Pond near New London, New Hampshire, under a marsh with heath resting on glacial drift overlying two- mica granite of Devonian age. The other deposit is at core site 1, along Route 53 south of Fern Lake, Brandon Township, Rutland County, Vermont, in a largely hardwood swamp in karst topography over glaciated Cambrian dolomite. The uranium (U_3O_8) in these deposits of post-glacial age (< 10,000 years old) is not yet in secular equilibrium with daughter products such as radium and thorium. The deposits, therefore, are relatively non-radioactive. However, given time and stability, the parent uranium and associated daughters will intergrow in the direction of equilibrium, making the deposits more radioactive.

MESSER POND (NEW HAMPSHIRE) AREA

The New Hampshire deposit contains an estimated 40,000 tons of air-dried moss and reed-sedge peat with ash contents of less than 25 percent, which is the ash cutoff for commercial quality peat. Samples from a core in this deposit reveal a uranium content of 217 ppm in the commercial quality peat, with values reaching 291 ppm in the underlying ~~clay~~yey peat. Figure 2 shows the core with locations of samples in respect to core stratigraphy; thus sample material can be interpreted in terms of environments of deposition, and trends in ash and uranium contents from surface to the base of the deposit.

The bedrock substrate in this area is known informally as the Sunapee granite of Early Devonian age (about 385 Ma; J. B. Lyons, orally commun., 1984). The granite was emplaced as a north-northeast-trending, post-kinematic instrusive sheet (Fig. 3). This sheet, not penetratively deformed, is less than 1 km thick in present erosional context and probably is about one-half its original volume. The Sunapee is an evolved two-mica granite. To the west, it passes either into semi-pelite metamorphosed to the upper amphibolite faces (undivided Silurian and Devonian on the map), or into the Bethlehem granite of the Mt. Clough Pluton. To the east, the Sunapee granite is in contact with the Kinsman granite of the Cardigan Pluton. The Sunapee granite is younger than all its enclosing rocks (Chapman, 1952).

A regional study of the distribution of uranium in the Lower Devonian rocks of New Hamsphire was made by Lyons (1964). Secondary uranyl-phosphate uranium minerals occur within the Sunapee granite in an upland road cut on Interstate Highway I-89, near the town of New London (Boudette, 1977). This occurrence is about a mile from the Messer pond marsh (see map, Fig. 4). Bothner (1978) mapped the setting of the I-89 uranium occurrence in detail and established its spatial context within the Sunapee granite. The results of the analyses for uranium and thorium in the Sunapee granite are given in Table 3.

The U.S. Department of Energy (1982a) supported a reconnaissance study of the uranium content of water and modern sediments as part of the National Uranium Resource Evaluation Program (NURE). This work established that ground water at Messer Pond contain 29 ppb (parts per billion) uranium, and 24 ppb at nearby Clark Pond. The pond waters range in concentration from 0.64 to 1.0 ppb U. Another NURE Report (1982b) on the Glen Falls Quadrangle

(New York, Vermont, and New Hampshire) includes detailed descriptions of uranium occurrences.

During the 10-year-period after road-cutting for construction of I-89, the secondary uranium minerals were mostly leached away by solution and the movement of vadose ground water. It is likely that the process of leaching was enhanced by acid rain and snow, and reinforced by the saline spray from road salting operations. This rapid mobility of uranium led the authors to suspect that Holocene peat deposits below the water table would be ideal sinks for the uranium transported in ground water. This conclusion prompted the study of the deposits at the four core sites in Group D. Core 30 at Messer Pond was studied in the greatest detail. The core shown in Figure 2 has a total depth of 25 feet. Commercial quality peat accumulated to a depth of 5 feet in a marsh on which a heath developed. The commercial quality peat, with ash contents less than 25 percent, rests on clayey peat with ash contents of 25 to 50 percent. This clayey peat marks the base of the marsh and the top of the pond ecological environments. The clayey peat in turn rests on peaty clay to a depth of 24 feet with ash contents exceeding 50 percent. This is the base of the ancient Holocene pond deposit which rests on glaciofluvial clay and sand that overlies glacial drift resting on the Sunapee two-mica granite.

Uranium content peaks at 217 ppm in the center of the marsh materials and again at 291 ppm in the center of the buried pond materials. Trends in the ash and uranium curves at site 30 are consistent with those in cores from nearby sites 27 and 29 in marshes and heaths that overlie two-mica granite and quartz monzonite.

A ^{13}C NMR spectra (Fig. 5) obtained by Patrick Hatcher (U.S.G.S.) from the four samples in the upper 8 1/2 feet of core 30 are correlated with environments of deposition and uranium contents shown in Figure 2. Carbohydrates in the organic material decrease with depth, whereas paraffinic contents increase with depth; both are related to the aromatic contents as diagenesis progresses. Uranium contents peak above the base of the marsh where the paraffinic and carbohydrate peaks approach the same elevation. A relation between the ecological environments of organic accumulation and the diagenesis within these environments appears to exist. Mann and Fyfe (1984) report on an experimental study of algal uptake of U, Ba, V, Co, and Ni from dilute solutions reveals uptakes of uranium and barium to be 1000 to 10,000 ppm by dry weight. The uptake was by two species of fresh water green algae. These plants are common in marsh and pond environments where peat accumulates. Berthelin and Munier-Lamy (1983) describe microbial mobilization and preconcentration of uranium from various rock materials by fungi. Such processes that may be involved in uranium preconcentration and recovery appear to depend on the plant cell energistic processes. These processes are influenced by environmental factors such as reported by Bethelin, Guencot, and Munier-Lamy (1985). Their experience indicates that uranium solubilization depends not only on rock or mineral characteristics but also, especially, on the humus formation (induced by vegetation type) and associated microbial activity. Also, uranium adsorption and insolubilization is more effective on ferric oxides and microbial components than on clays and non-transformed plant materials. Gueniot, Guillet and Souchier (1982) observe uranium fixation on the surface of iron oxihydroxides in placic horizons of hydromorphic soils. Note that anomalous amounts of Fe and U occur together in both core site groups A and D.

FERNVILLE (VERMONT) AREA

The Fernville, Vermont, peat lies in a swamp in karst topography (Fig. 6). It contains an estimated 40,000 tons of air-dried reed-sedge peat. The stratigraphy is as follows: 0-3 ft = muck; 2-3 ft = reed sedge peat with ash content 22.5 percent and uranium content 467 ppm; 3-5 ft = gray clay; and at 5 ft = sand

Marsh and swamp vegetation has always predominated here at Core Site 1. The ancient pond environment that existed in the New Hampshire deposit is absent, however. Ground water containing uranium enters the Vermont peat deposit and is captured by organic matter as: (1) a part of life processes, and (2) after plant death during diagenesis. Decay or diagenesis is more severe in the muck than in the reed-sedge peat where plant remains are still recognizable.

The area around Fern Lake is underlain by the lower portions of the Paleozoic carbonate bank as described by Rodgers (1968). The following unit descriptions are summarized from Cady (1945). The Cheshire Quartzite is largely a pure, massive, white quartzite about 400 feet thick. The lower portion of the unit is somewhat argillaceous and less massive. The upper portion, which is about 50 feet thick, comprises interbedded vitreous orthoquartzite and minor dolomite which grade into the overlying Dunham Dolomite. The Dunham Dolomite, which can exceed 1700 feet in thickness, is primarily a siliceous, buff-weathering, massive dolomite containing irregularly distributed, well-rounded sand grains. The upper portion of the Dunham which contains numerous quartzite beds grades into the overlying Monkton quartzite.

The "Brandon residual-formation" unconformably overlies the Dunham Dolomite and Cheshire Quartzite in a zone extending from the southern end of Lake Dunmore to about one mile south of Forest Dale. Clark (1891) indicated that the unit occurs over a large area extending from Vermont to Georgia. The "Brandon residual-formation" was described by Burt (1931, p. 115) as "a series of unconsolidated deposits consisting of kaolin, ocher, quartz, sand, iron and manganese ores, and lignite." Berry (1919) ~~suggests an Eocene age for the Brandon, while Barghoorn and Spackman (1949) indicate that it~~ cannot be older than late Miocene. ~~The~~ aggregation of materials suggest a swamp environment of deposition that existed either during the Tertiary or in Precambrian time. Dale (1904) suggests that most of the original source material for the unit was Precambrian detritus derived from the Green Mountains.

Cady (1945) shows the Lake Dunmore Thrust near the Ferndale swamp area. Also, a regional system of high-angle faults is described by Stanley (1980) in this area. Fracture systems associated with these faults influence circulation of uranium-bearing groundwater which feeds the Ferndale swamp. The uranium in the system could have several sources. The Precambrian lithologies of the Green Mountains are known to host disseminated uranium concentrations as well as uranite-bearing veins (Grouch and Zarinski, 1976). The known occurrences are southeast of the Fernville area, but the Precambrian terrane east of Fernville has not been evaluated for uranium potential. Uranium deposits near Jamica, Vermont, (College Hill and Pinnacle Bedrock) occur in Precambrian gneiss and schist, and stratabound uranium-bearing zones in Precambrian quartzofeld spathic schist and gneiss are associated with Precambrain granite (augen gneiss) and tourmaline quartzite

(J. F. Slack pers. comm., 1986). The Chesire Quartzite, elsewhere in Vermont and other New England states, is also known to contain anomalous amounts of uranium (G. I. Grauch, pers. commun., 1985). Lignites and other sediments of the ancient swamps implied by the occurrence of "Brandon formation" may have received uranium in much the same manner that the peat of the Ferndale swamp is receiving today. Thus, the "Brandon," as well as the Precambrian and Paleozoic rocks, could contribute uranium to the groundwater moving through and into the karst containing the Ferndale swamp.

The uranium contents of the peat deposit near Fern Lake are similar to the lowest ore-grade portions of the Flodelle Creek, Washington, deposit. The peat deposit at Flodell Creek is the only surficial uranium mine currently operating in the United States. Future work in the Fernville area might define define a systematic distribution of highly urananiferous peat, and a possible resource potential for uranium.

DISCUSSION

Uranium is commonly associated with peat, and laboratory studies of the mechanism of uranium fixation indicate that adsorption, ion exchange, and reduction all play a role (Nakashima et al., 1984). Otton and Zielinski (1984) studied a Holocene deposit of clayey peat and peaty clay (ash contents 40 percent) together with clay, silt, and sand containing a slight amount of organic material in a swamp in northeastern Washington state. The swamp was fed by uraniferous waters. This deposit was laid down in marshes and swamps subject to flooding which added silt throughout Holocene time. The authors suggest that the fixation of uranium by organic matter is largely controlled by processes of adsorption and ion exchange, rather than by reduction to relatively insoluble U^{+4}.

The Fernville, Vermont, deposit is simpler, ecologically speaking, than the Washington deposit in that it has not been subject to flooding. It developed simply by growth and decay of vegetation and should more readily lend itself to organic and geochemical studies of the roles that plants, both living and dead, play on movement and fixation of uranium within a peat deposit. That ecological environments affect the movement and fixation of uranium is indicated by the peaks on the uranium curves in the Messer Pond, New Hampshire, (Fig. 2) deposit. The curve in the ancient marsh was repeated in the ancient pond deposit. A need for further studies of the role plants play in both ecosystems is indicated. Also, the presence of unusual amounts of uranium in certain deposits that are potential peat resources should be studied to alert members of the peat industry to investigate trace-element contents of the commodity.

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_____ 1982b, Glen Falls Quadrangle, New York, Vermont, and New Hampshire: U.S. Department of Energy, National Uranium Res. Eval. Program (NURE), Rept. (PGJ/F-025 (82), 31 p.

Table 1. --Ash and element statistics. Ash is reported on dry basis. Elements are reported (in ppm) on whole dry sample basis

		Minimum	Maximum	Mean	Deviation	Number of valid samples
ASH		1.74	97.92	45.84	27.31	
BA	PPM	18.70	607.62	153.09	126.41	139
FE	%	0.02	5.73	.95	1.03	139
MG	%	0.02	2.58	.32	0.37	139
CA	%	0.08	42.72	2.11	5.35	139
TI	%	0.00	0.69	.11	0.12	139
MN	PPM	13.39	2349.16	218.66	308.21	139
AG	PPM	0.006	0.98	.11	0.12	139
B	PPM	0.84	86.00	19.34	20.10	139
NI	PPM	0.45	147.13	17.23	21.23	139
BE	PPM	0.01	4.31	.83	0.86	89
CO	PPM	0.11	51.44	5.01	7.01	139
CR	PPM	0.26	82.26	14.00	16.44	139
CU	PPM	0.59	131.43	19.17	21.04	139
LA	PPM	0.03	206.38	39.06	38.50	139
MO	PPM	0.09	39.47	4.11	4.67	139
NB	PPM	0.08	20.57	3.94	3.74	71
V	PPM	0.59	112.18	20.61	20.47	139
PB	PPM	0.29	35.55	7.19	6.82	120
SC	PPM	0.13	18.69	4.62	3.90	139
SR	PPM	9.43	405.49	93.18	86.50	137
CE	PPM	0.80	254.94	39.41	42.81	96
Y	PPM	0.28	72.84	16.16	14.59	139
ZN	PPM	0.40	273.23	55.63	46.97	132
ZR	PPM	1.24	233.70	42.73	42.59	137
YB	PPM	0.02	8.34	1.93	1.69	139
GA	PPM	0.03	16.87	3.49	3.78	124
NI	PPM	1.30	267.14	57.00	58.25	97
EU	PPM	0.2	10.61	1.49	1.55	68
TH	PPM	2.24	99.20	16.51	12.00	15
U	PPM	1.00	467.00	48.28	55.24	79

Table 2. --Anomalous elements* arranged according to core site group locations

Element	Core Site Group A	B	C	D	E
BA					
FE	X			X	
MG	X		X	X	X
CA	X		X		
TI				X	
MN	X			X	
AG	X			X	X
B		X		X	X
NI			X		X
BE			X	X	X
CO			X		X
CR			X	X	X
CU	X	X	X		
LA	X		X	X	X
MO	X		X		
NB		X	X	X	X
V			X	X	
PB	X		X	X	X
SC			X	X	X
SR	X		X	X	
CE			X	X	X
Y	X		X	X	X
ZN			X		X
ZR	X			X	X
YB	X		X	X	X
GA				X	X
ND					X
EU	X		X	X	X
TH	X			X	X
U	X			X	

* Anomalous elements are those with concentrations at least two standard deviations above the mean.

Table 3. --Thorium and uranium distribution in the Sunapee granite. Analyses by instrumental neutron activation methods (INNA).

Sample No.	Latitude	Longitude	Th	U	Th/U
S-1*	43° 24' 53' N	72° 01° 23"W	7.2	25.4	.28
S-2*	43-24-52	72-01-23	4.9	2.2	2.22
MK-107*	43-23-32	71-58-48	4.2	3.4	1.24
MK-1*	43-21-33	71-59-48	8.1	8.1	1.45
MK-108*	43-23-51	71-57-47	1.5	1.5	1.88
SU-U1a†	43-24-50	72-01-50	8.6	18.7	.46
Su-U1b†	"	"	8.2	13.3	.62
Su-U1b†	"	"	9.4	31.8	.30

* Analyses by P. A. Baedecker, U.S. Geological Survey, Reston, VA

† Analysis by D. M. McKown, H. T. Millard, Jr., M. Scheider, U.S. Geological Survey, Denver, CO

Figure 1. Location of Core sites in Vermont and New Hampshire. Sites are grouped A through E.

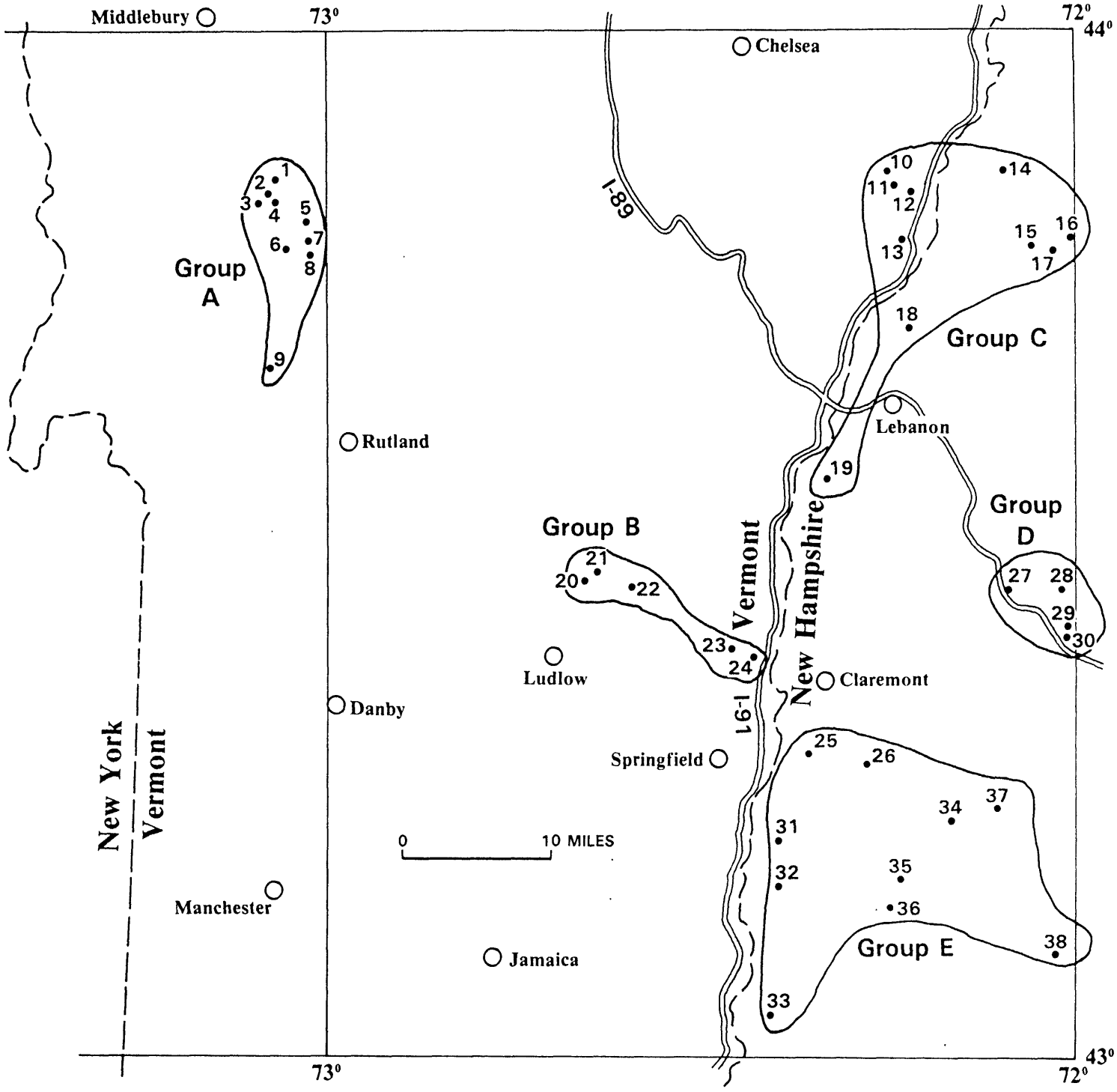

Middlebury
73°
72°
44°
Chelsea
I-89
Group A
Group B
Group C
Group D
Group E
Rutland
Lebanon
Ludlow
Claremont
Danby
Springfield
Manchester
Jamaica
New York
Vermont
Vermont
New Hampshire
I-91
0
10 MILES
43°
73°
72°

Figure 2. Core 30 showing relationships of types of materials to enrviornments during deposition and to ash and uranium contents; the uranium distribution curve is also shown from the surface to the base of the deposit.

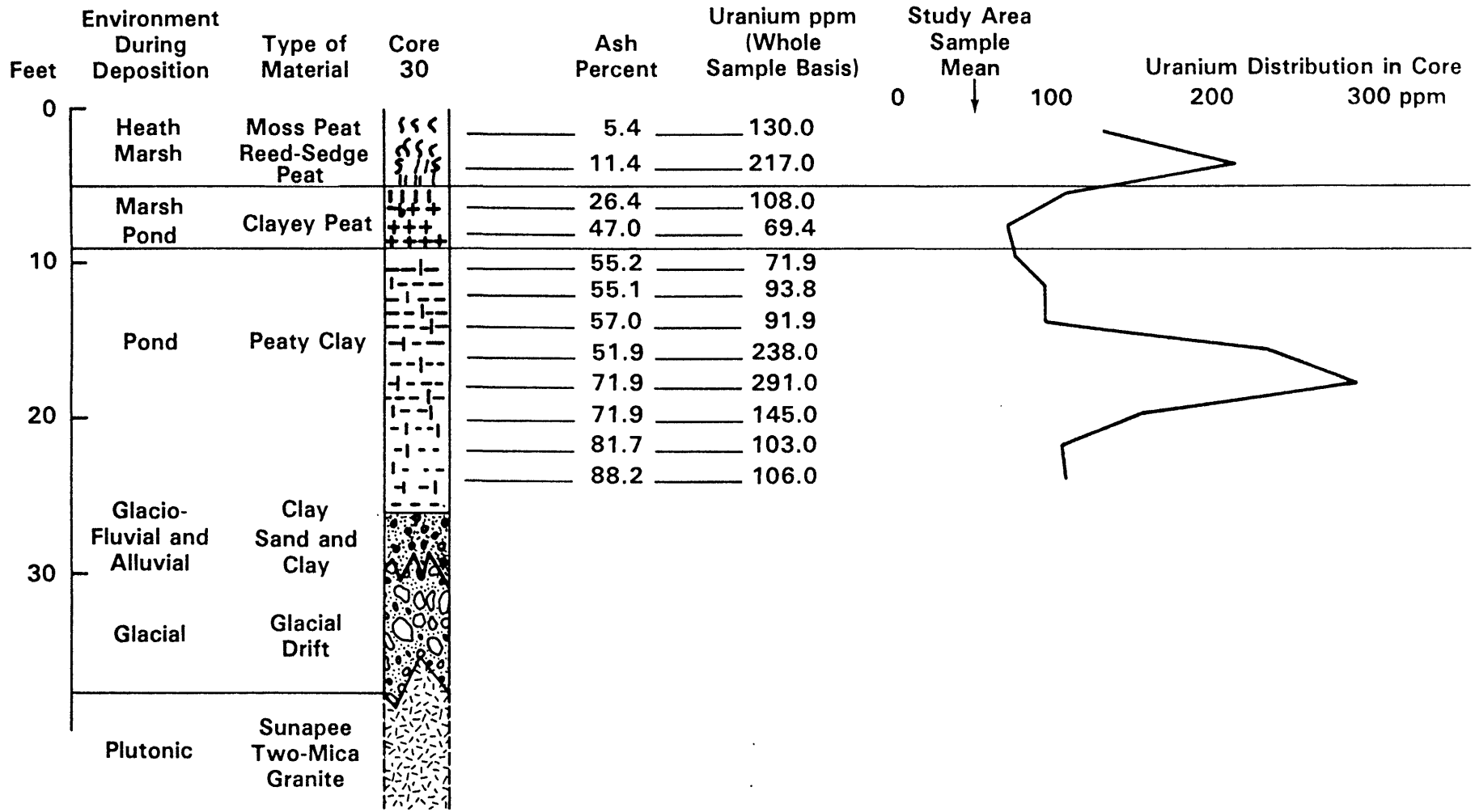
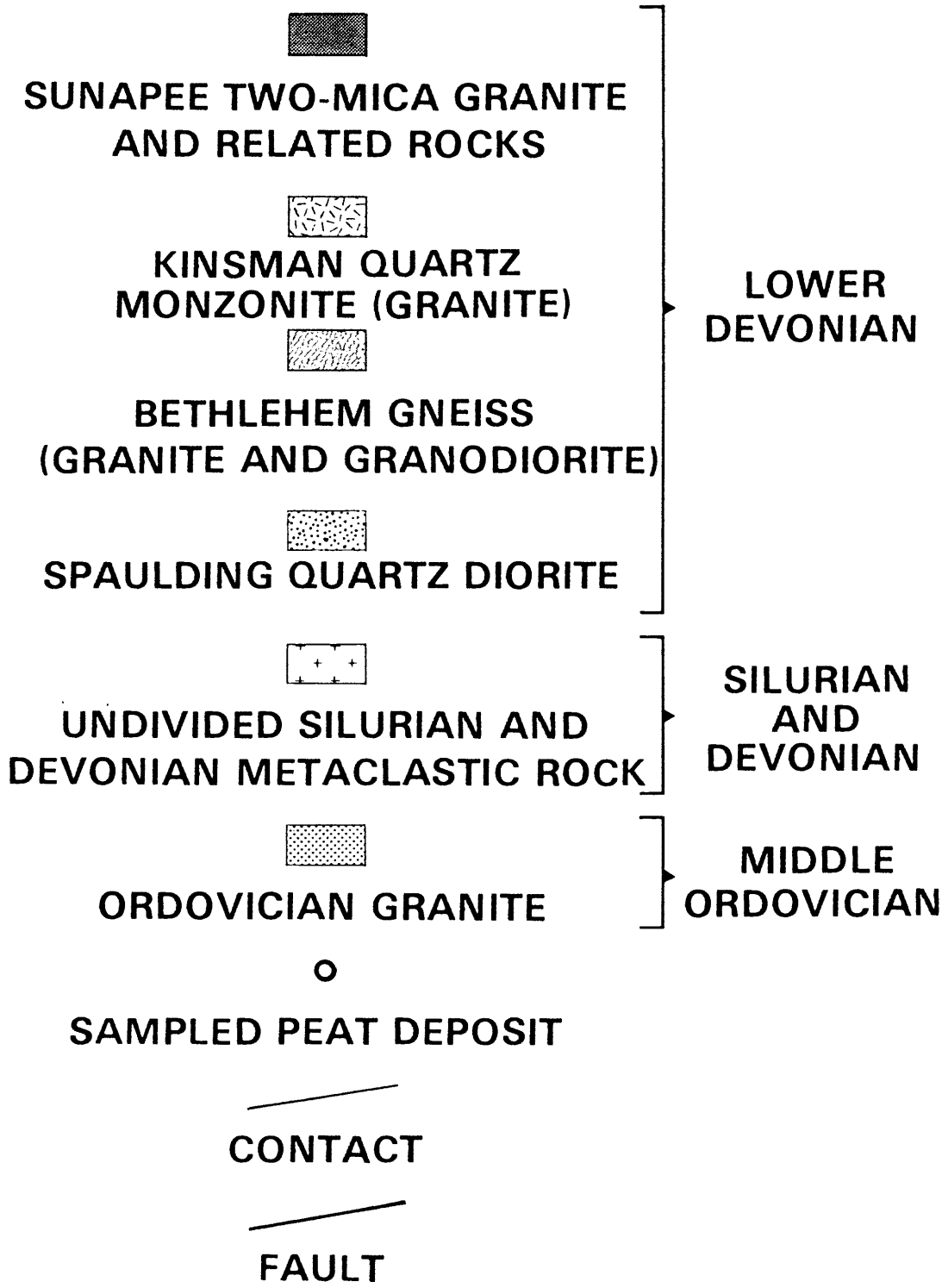
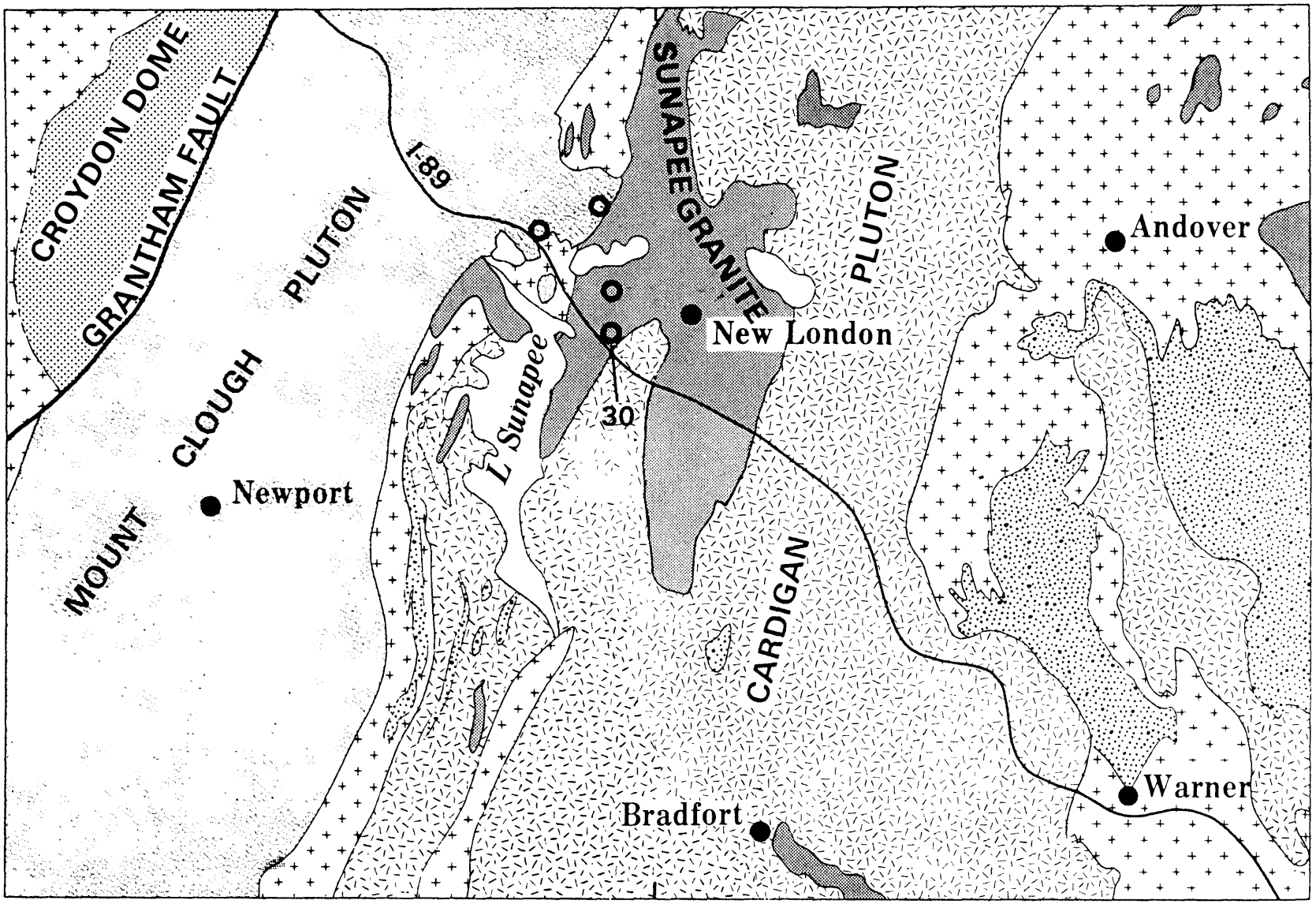

Feet
Environment During Deposition
Type of Material
Core 30
Ash Percent
Uranium ppm (Whole Sample Basis)
Study Area Sample Mean
Uranium Distribution in Core
0
100
200
300 ppm
0
10
20
30
Heath Marsh
Moss Peat
Reed-Sedge Peat
5.4
130.0
11.4
217.0
Marsh Pond
Clayey Peat
26.4
108.0
47.0
69.4
Pond
Peaty Clay
55.2
71.9
55.1
93.8
57.0
91.9
51.9
238.0
71.9
291.0
71.9
145.0
81.7
103.0
88.2
106.0
Glacio-Fluvial and Alluvial
Clay Sand and Clay
Glacial
Glacial Drift
Plutonic
Sunapee Two-Mica Granite

Figure 3. Bedrock geologic substrate of peat deposits at New London, New Hampshire (Geology after Lyons and others, unpublished slate map of New Hampshire).


SUNAPEE TWO-MICA GRANITE AND RELATED ROCKS
KINSMAN QUARTZ MONZONITE (GRANITE)
BETHLEHEM GNEISS (GRANITE AND GRANODIORITE)
SPAULDING QUARTZ DIORITE
LOWER DEVONIAN
UNDIVIDED SILURIAN AND DEVONIAN METACLASTIC ROCK
SILURIAN AND DEVONIAN
ORDOVICIAN GRANITE
MIDDLE ORDOVICIAN
SAMPLED PEAT DEPOSIT
CONTACT
FAULT



GEOLOGY AFTER LYONS AND OTHERS, UNPUBLISHED STATE MAP OF NEW HAMPSHIRE

Figure 4. Map of Messer Pond area showing location of Core 30 in relation to road cut with uranium occurrence.

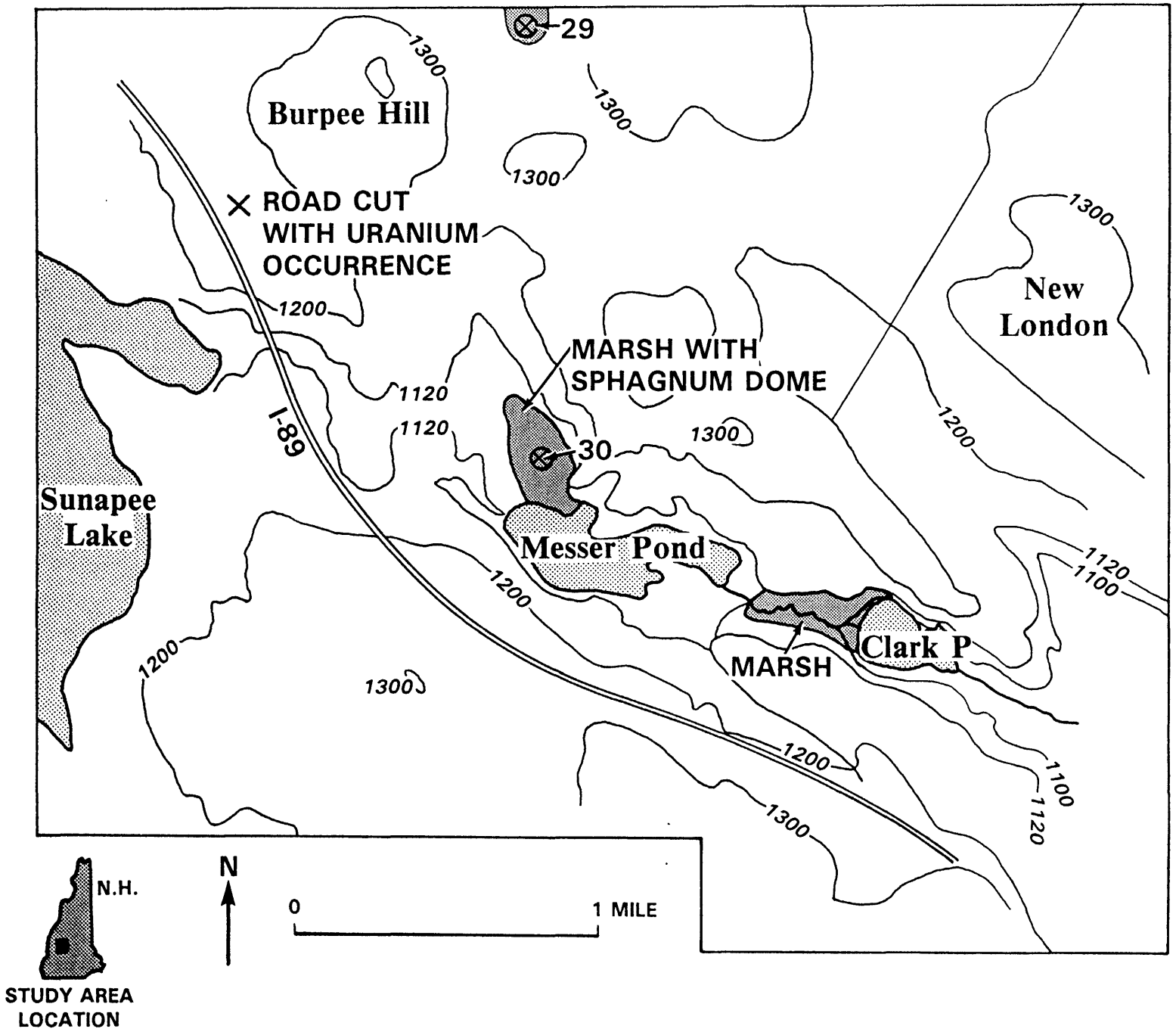
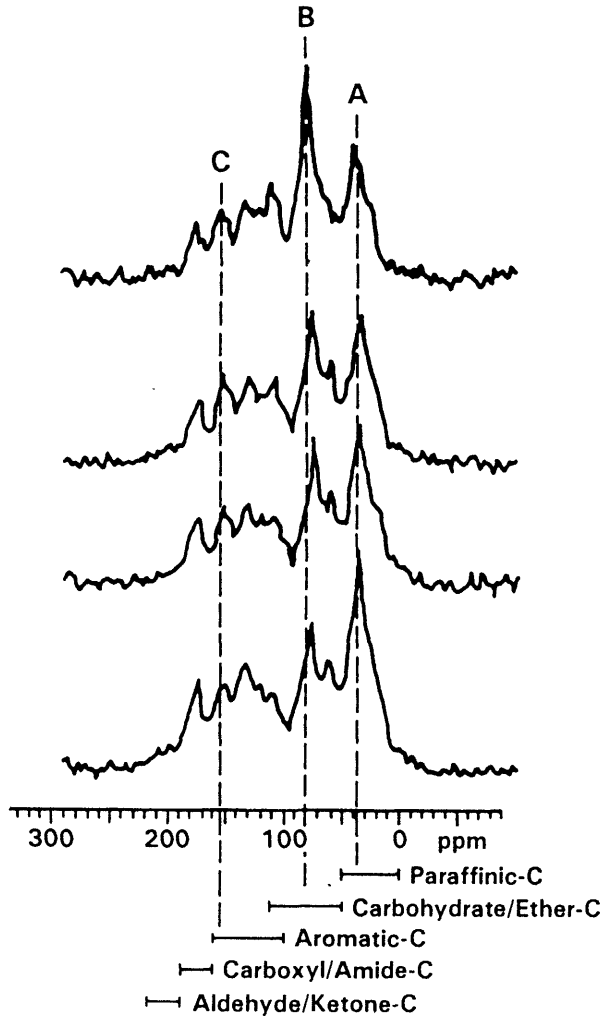

29
Burpee Hill
1300
1300
1300
ROAD CUT
WITH URANIUM
OCCURRENCE
1200
1120
1120
MARSH WITH
SPHAGNUM DOME
30
1300
1200
New
London
I-89
Sunapee
Lake
Messer Pond
1200
1120
1100
1200
1300
MARSH
Clark P
1200
1100
1120
1300
N.H.
STUDY AREA
LOCATION
N
0
1 MILE

Figure 5. NMR spectra in the upper 8.5 feet of Core 30, Messer Pond marsh (Analysis by Patrick Hatcher).

CORE 30

^{13}C NMR SPECTRA



Description	Depth (ft)	B/C	A/C	U(ppm)
Heath	1 – 2.5	3.0	1.8	130.0
Marsh	3 – 4.5	1.8	1.7	217.0
Marsh	5 – 6.5	1.9	2.2	108.0
Pond	7 – 8.5	1.7	2.7	69.4

Figure 6. Bedrock geologic map showing locations of core sites 1-4 in peat deposits in swamps.

LEGEND

---- APPROXIMATE LOCATION OF CONTACT

APPROXIMATE LOCATION OF DUNMORE LAKE THRUST FAULT. UPPER PLATE TO THE EAST.

MINE OR PROSPECT

$\mathbf{\epsilon_w}$ WINOOSKI DOLOMITE

$\mathbf{\epsilon_m}$ MONKTON QUARTZITE

$\mathbf{\epsilon_{dh}}$ DUNHAM DOLOMITE

$\mathbf{\epsilon_c}$ CHESHIRE QUARTZITE

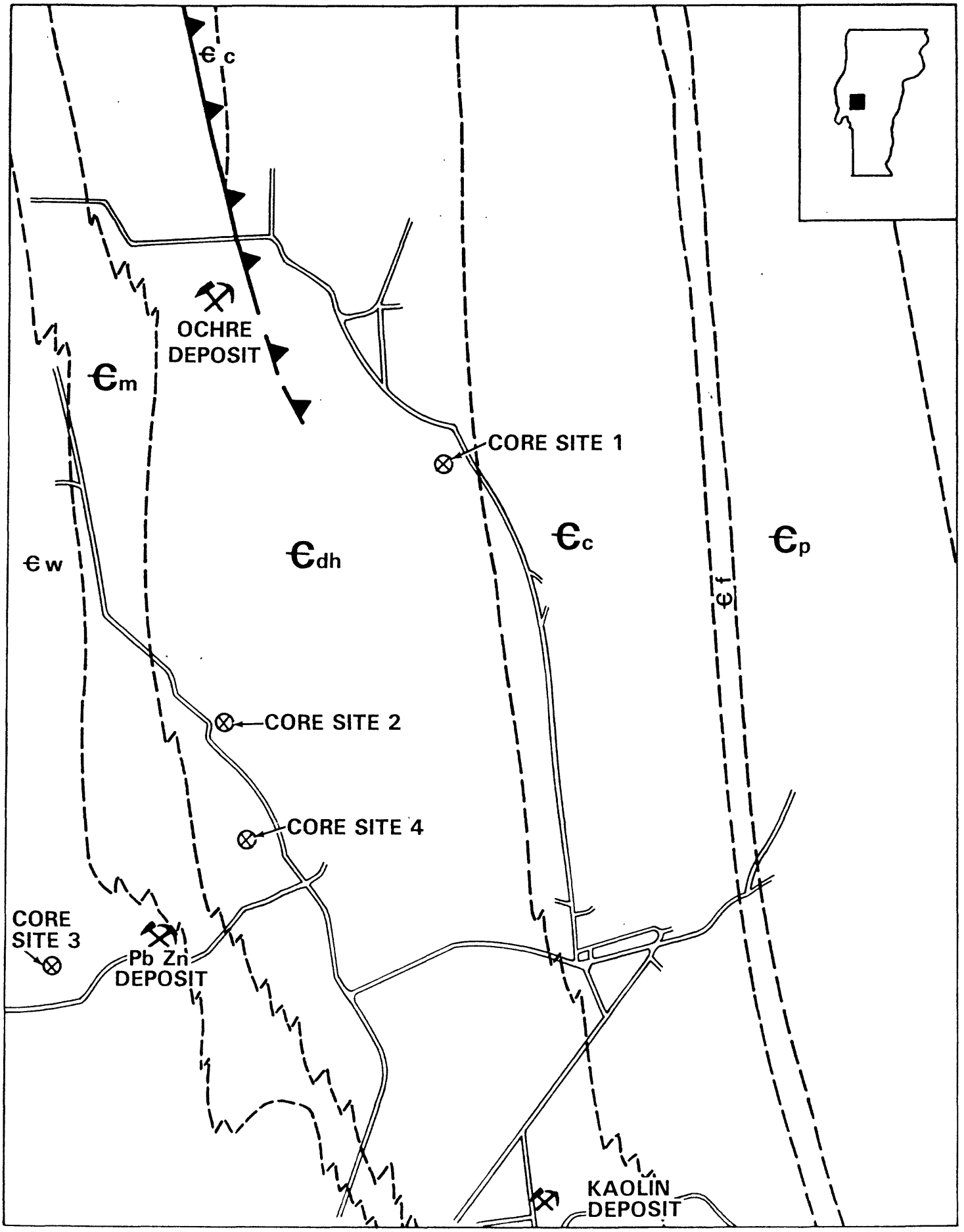
$\mathbf{\epsilon_f}$ FORESTDALE MARBLE

$\mathbf{\epsilon_p}$ PINNACLE FORMATION

BASE MAP: BRANDON QUADRANGLE, VERMONT: U.S. GEOLOGICAL SURVEY 7 1/2-MINUTE SERIES, SCALE 1:24000

GEOLOGY MODIFIED FROM CADY, 1945 AND DOLL AND OTHERS, 1961.

NOTE: SURFICIAL DEPOSITS ARE NOT SHOWN ON THE MAP.


€c
OCHRE DEPOSIT
€m
CORE SITE 1
€w
€dh
€c
€p
€f
CORE SITE 2
CORE SITE 4
CORE SITE 3
Pb Zn DEPOSIT
KAOLIN DEPOSIT