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National Uranium Resource Evaluation

**ALBANY QUADRANGLE
MASSACHUSETTS, NEW YORK, CONNECTICUT,
VERMONT, AND NEW HAMPSHIRE**

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Bendix Field Engineering Corporation
Grand Junction, Colorado

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Issue Date
September 1982

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
Grand Junction Area Office, Colorado

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NATIONAL URANIUM RESOURCE EVALUATION:
ALBANY QUADRANGLE,
MASSACHUSETTS, NEW YORK, CONNECTICUT,
VERMONT, AND NEW HAMPSHIRE

MASTER

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This is the final version of the subject-quadrangle evaluation report to be placed on open file. This report has not been edited. In some instances, reductions in the size of favorable areas on Plate 1 are not reflected in the text.

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ABSTRACT

The Albany 1° x 2° Quadrangle, Massachusetts, New York, Connecticut, Vermont, and New Hampshire, was evaluated to a depth of 1500 m for uranium favorability using National Uranium Resource Evaluation criteria. Areas of favorable geology and aeroradioactivity anomalies were examined and sampled. Most Triassic and Jurassic sediments in the Connecticut Basin, in the central part of the quadrangle, were found to be favorable for sandstone uranium deposits. Some Precambrian units in the southern Green Mountains of Vermont were found favorable for uranium deposits in veins in metamorphic rocks.

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INTRODUCTION

PURPOSE

The Albany Quadrangle, an area of 18,330 km², is between latitudes 42°N. and 43°N. and longitudes 72°W. to 74°W. (Fig. 1). It includes about half the state of Massachusetts, a large portion of New York, and small portions of Vermont, New Hampshire, and Connecticut.

The quadrangle was evaluated to a depth of 1500 m to identify geologic environments and delineate areas that exhibit characteristics favorable for the occurrence of uranium deposits. Favorable environments, as determined by surface and subsurface investigation, are those that could contain uranium deposits of at least 100 tons uranium oxide with an average grade not less than 100 ppm uranium oxide. Selection of a favorable environment is based on the similarity of its geologic characteristics to those found in close association with known uranium deposits (recognition criteria) as described in Mickle and Mathews (eds., 1978). The study was conducted by Bendix Field Engineering Corporation (BFEC) for the National Uranium Resource Evaluation (NURE) program, managed by the Grand Junction Area Office of the U.S. Department of Energy (DOE).

SCOPE

Review of literature and preliminary reconnaissance in the Albany Quadrangle was done as part of a study of the Connecticut Basin in the Albany and Hartford Quadrangles from March to November 1976, resulting in a preliminary report (Truesdell and Zollinger, 1977b). Study of the Albany Quadrangle as a quadrangle project began with preparatory work from September 1977 to April 1978, interrupted by several weeks of other work, for a total of 7 man-months. Most of the field work was done from April to November 1978 (17 man-months). Data analysis and folio preparation were done from October 1978 to February 1979, when work was stopped for another project. Folio preparation resumed in March 1980 and was completed in May 1980. Folio preparation and data analysis time was 6 man-months, for a total of 30 man-months for the project.

PROCEDURES

Rock units were chosen for field investigation on the basis of favorable geology and anomalies from the U.S. Geological Survey aeroradioactivity map (Popenoe, 1964). Anomalies on the Texas Instruments aeroradioactivity map (1976) were also examined, but only one of these could be verified on the ground. No Hydrogeochemical and Stream Sediment Reconnaissance (HSSR; Koller, 1979) survey information was available until a year after the conclusion of field work.

The areas emphasized in field work were the Connecticut Basin in the central part of the quadrangle, in which nearly every outcrop was visited; the Cambrian Dalton Formation in western Massachusetts; Precambrian orthogneisses in the Berkshire and Green Mountains (Fig. 2); Silurian quartzites in the

Figure 1. Location of Albany Quadrangle

* Favorable for uranium deposition

U - Unconformity

Figure 2. Generalized stratigraphic column

central part of the quadrangle; the area of high radioactivity in the southeast part of the quadrangle (discussed in Unfavorable--Pegmatitic); and all granites.

Radioactivity was measured with Mount Sopris SC-131-A and SC-132 scintillometers, and the scintillometers were used during traverses on foot and by car. Grab samples for geochemical analysis were taken of all outcrops that showed anomalous radioactivity and of many other outcrops for background information, for a total of some 350 samples.

GEOLOGIC SETTING

The Albany Quadrangle spans the northern Appalachians from unmetamorphosed cratonic cover rocks in the west to high-grade metamorphic rocks of the orogenic core in the east (Fig. 2). The quadrangle contains more than 100 stratigraphic and intrusive rocks units. The geologic/geographic provinces (Fig. 3) are described below, from west to east.

Catskill Mountains

Only a small portion of the Catskill Mountains Province is present in the Albany Quadrangle. It consists of Middle Devonian flat-lying shale and sandstone, underlain by Lower Devonian limestone.

Hudson Valley

The Hudson Valley area, between the Catskill and the Taconic Mountains, is underlain by black shales of Cambrian-Ordovician age and small amounts of red shale, green shale, and limestone. The rocks have undergone folding and thrusting, but little metamorphism.

Taconic Mountains and Berkshire Valley

Rocks in this province along the New York-Massachusetts and New York-Vermont border are similar to those in the Hudson Valley, except that they are metamorphosed to slates and phyllites. Relief is greater, the hills rising to 700 to 800 m. Most rocks are allochthonous, having been thrust into the area from some distance to the east. Between the Taconics and the Berkshires/Green Mountains is a valley underlain by Cambrian-Ordovician limestone and dolomite.

Berkshire Mountains and Green Mountains

The Precambrian schists and gneisses of the Berkshires and Green Mountains rise abruptly on the eastern side of the Berkshire Valley. Elevations in the Berkshires are about the same as in the Taconics, whereas those in the Green Mountains are higher, up to 1000 m. The western side of the Precambrian is overlain unconformably by Cambrian shallow-water sandstones. The Precambrian and Cambrian rocks have been overthrust from the east and now form a stack of imbricate slices (Pl. 7). The Precambrian in

Figure 3. Geologic and geographic provinces of the Albany Quadrangle .

Vermont is not continuous with the Precambrian in Massachusetts, and it has been suggested (Mukasa and others, 1980) that they are separated by a major thrust, the Green Mountains representing a higher structural level.

Eastern Berkshires

East of the Precambrian core of the Berkshire Mountains is a thick sequence of marine sediments and volcanics ranging in age from Early Cambrian to Early Devonian. Metamorphism is of medium grade and increases to the east. The rocks in the western part of are a series of thrust slices, like the adjacent rocks in the Berkshires. In the eastern part of the province, the strata are in complex folds. A few intrusive bodies are present.

Connecticut Valley

The lowlands of the Connecticut River Valley are underlain by red shale, sandstone, and conglomerate and diabase flows of Triassic and Jurassic age that fill a graben in the Paleozoic crystalline rocks.

Bronson Hill Anticlinorium and Merrimack Synclinorium

The Albany Quadrangle east of the Connecticut Valley is an undulating plateau averaging about 300 m high. The rocks in this area occupy the core of the Appalachian orogen and are highly metamorphosed and folded into large alpine-type nappes. The western portion, the Bronson Hill anticlinorium, consists of a sequence of Middle Ordovician to Lower Devonian schists underlain by domes of pre-Middle Ordovician gneiss. The Merrimack synclinorium has similar rocks, but the Silurian section is much thicker, and domes are not present. Syntectonic Devonian plutonic rocks are common in both areas.

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

Two areas in the Albany Quadrangle are favorable for uranium deposits (Pl. 1). The Connecticut Basin has favorable geology for sandstone uranium deposits. The Precambrian of the Green Mountains of Vermont contains concentrations of uranium over a large area, the richest of which contains 0.3% uranium oxide.

There are several rock units in the Albany Quadrangle that are intermediate in uranium content; although they do not have enough uranium to be classified as favorable, they have radioactivity of a few times background and deserve some discussion. These are the Dalton Formation in western Massachusetts, the Warwick Dome in north-central Massachusetts, an area of gneiss and pegmatite in the southeastern part of the quadrangle, and the two-mica granites in southwestern New Hampshire. These units are discussed under Environments Unfavorable for Uranium Deposits.

SANDSTONES

The New Haven-Sugarloaf Arkose, Shuttle Meadow Formation, Portland Arkose, and portions of the East Berlin Formation, all in the Connecticut Basin, are favorable for sandstone uranium occurrences of the Wyoming type, Subclass 241, of Austin and D'Andrea (1978). They have the following favorable characteristics:

- Basin between crystalline highlands in a mobile belt
- Feldspathic and arkosic sandstones
- Stacked sequences of braided alluvial-plain sediments
- Sediments ranging from pebble conglomerate to shale

Favorability characteristics exhibited to a limited degree are the presence of carbonaceous material, bleaching of red sediments, and the presence of uranium minerals.

The Connecticut Basin is one of the Triassic grabens of the eastern United States. It is filled with red arkoses, shales, and basalts of Late Triassic to Early Jurassic age (Cornet and Traverse, 1975; Peterson and Pipiringos, 1979, p. 33). The basin is roughly triangular (Fig. 3), 70 km long north to south, and about 30 km wide at the southern base. The favorable environment has an area of 1233 km². The eastern side of the graben is a normal fault with approximately 5000 m displacement (Ahmad, 1975; Chung, 1968), and the sediments are more than 1500 m thick in most of the basin (Fig. 4). The western side appears to be an unconformity in the northern part of the Albany Quadrangle and a steeply dipping fault in the south.

The basin is filled with a sequence of arkoses, siltstones, and shales deposited in alluvial fans and plains in a semi-arid climate (Hubert and others, 1978). Basalts were extruded into the basin near the middle of the sequence (Fig. 5). Concurrently, because of erosional lowering of the highlands and (or) the extrusion of the volcanics, gradients within the basin decreased, and siltstones and shales were deposited, some in lakes, forming parts of the Shuttle Meadow and East Berlin Formations. Rejuvenated uplift of the crystalline highlands along the eastern boundary fault followed, and the youngest sediments in the basin are sandstones, conglomerates, and arkoses similar to those in the lower part of the section. The arkoses are typically 50% quartz, 5% potassium feldspar, and 40% plagioclase.

At about latitude 42°20'W., a ridge of basement is exposed beneath the Mesozoic sediments on the eastern side of the basin. The Connecticut Basin south of this ridge is called the Hartford Basin, and the area north of it is the Deerfield Basin. The lower sequence of arkoses is called the New Haven Arkose in the south and the Sugarloaf Arkose in the north, although the two are contiguous.

The New Haven-Sugarloaf Arkose, Shuttle Meadow Formation, Portland Arkose, and coarser portions of the East Berlin Formation are included in the favorable environment because they consist largely of arkoses deposited in an

Figure 4. Schematic cross-section of the Connecticut Basin

Figure 5. Stratigraphy in the Connecticut Basin

alluvial plain. The Mount Toby Conglomerate, Turners Falls Sandstone, and shale beds of the East Berlin Formation were excluded because their content of alluvial-plain arkoses is small. On the map, it was not possible to differentiate the shale beds of the East Berlin Formation and the basalts from the arkoses, which surround and underlie them.

Evidence of uranium enrichment and associated bleaching of the red beds is limited in the Albany Quadrangle. There are some minor areas of bleaching with and without uranium enrichment. Small outcrops at Southwick, Massachusetts, are partially bleached and contain 5 and 11 ppm uranium oxide (MHG 015, 016) and well above background. At Westfield, Massachusetts, arkose about 500 m stratigraphically above the unconformity with crystalline basement is bleached and is a little less radioactive than is typical. Uranium may have been leached and moved down along the unconformity. Minor bleaching was observed at Southampton, Massachusetts, 3 km south of the Loudville lead occurrence (locations shown in Occurrence Report 5). One area of arkose shows bleaching and copper mineralization. At another place nearby, bleached areas along joints have twice the radioactivity of the surrounding red rocks.

A critical locality for the study of uranium favorability in the Connecticut Basin is the Old Newgate Prison Mine, just south of the Albany Quadrangle. This mine, opened in 1707, is 4 km south of the Albany Quadrangle and 7 km west-northwest of Bradley International Airport. It is a copper mine containing uranium, of which the richest sample analyzed was 682 ppm uranium oxide. Uraninite and coffinite are the primary uranium minerals, with lesser amounts of uranophane and tyuyamunite (Schnabel and Eric, 1964; this report). The red sandstones and shales at the mine and for some distance around are bleached gray (Occurrence Report 12).

There is a close relationship between bleaching and uranium mineralization, and it can be seen more clearly in a road cut on Route 66 in Meriden, Connecticut, 45 km south of Newgate. Here, there is a circular bleached area about 4 m in diameter cutting across bedding in red sandstone. The red sandstones have normal background radioactivity, but the bleached sandstones are 5 to 20 times more radioactive.

Petrographic studies at Newgate (J. F. Hubert, pers. comm.) show that there was an early stage of hematite deposition, when hematite coated the grains, and a later stage, when hematite stained the matrix. This later hematite was reduced and dissolved by the late copper-bearing solutions. Geochemical analyses indicate that the bleached sandstone has about two-thirds the iron content of the red sandstones (MHS 041 and 042, 275 and 276).

Deposits of the size of Newgate (or Meriden) have not been found in the Connecticut Basin sediments of the Albany Quadrangle, although some minor areas of bleaching and enrichment have been found, as discussed above. The rocks are easily eroded, and the basin is rather densely populated, so outcrop is limited. The critical question is whether the deposit at Newgate is unique or whether it could be expected to occur at other places within the basin, at depth or under surficial cover.

Two studies were made of the Newgate Mine deposit (Perrin, 1973; Potisat, 1978), and they have different conclusions. Potisat believed that the ground water was enriched in uranium from the arkoses or the crystalline highlands

and the uranium was precipitated by reducing copper-bearing fluids from depth, related to the basalts. Perrin believed the deposit resembles the "red-bed" copper-uranium deposits, where both copper and uranium are carried in the ground water and precipitated where they encounter reducing conditions in the sediments. Perrin believed that, at Newgate, disseminated copper from solutions associated with the basalt was deposited soon after sedimentation and concentrated by later ground-water solutions, which also brought in the uranium.

Neither study suggests that the conditions at Newgate are unique and could not be found elsewhere in the Connecticut Basin. The copper-bearing fluids suggested by Potisat could have come from any of the basalt flows and dikes in the valley. The copper deposits need not be next to the flows, and are not so at the large copper mine at Bristol, Connecticut. Perrin's, and to some extent Potisat's, theory depends on proper stratigraphic and ground-water conditions, which are probably not unique to Newgate.

Not enough is known about Newgate or the Connecticut Valley sediments to say what these conditions are or how commonly they might occur. Organic material, an important favorability characteristic, is found in microscopic sizes at Newgate, where it forms 1% or more of the arkose (Perrin, 1973, p. 16, 70). Organic material is not found in arkoses elsewhere in the Connecticut Basin, but it could be missed if it is microscopic. Spores and root impressions provide evidence that plants grew in the area. It may be that much of the plant material was oxidized rather than preserved, as reduction and associated bleaching of the red beds is rare. Organic material was preserved in the shaly lake sediments in the Shuttle Meadow and East Berlin Formations. A swamp may have formed at Newgate when extrusions of the Talcott Basalt interrupted drainage.

Cornet and Traverse (1975, p. 3) postulated an erosional hiatus at the stratigraphic level of the Newgate deposit. Weathering of this erosional surface may have altered the chemistry so as to make it favorable for uranium deposition.

The Newgate Mine is at the stratigraphic level of the Talcott Basalt, near the northern limit of the Talcott, and at a place where it is absent (Fig. 5 and Occurrence Report 12). However, a chemical relationship between the Talcott Basalt and the deposit has not been demonstrated. Chemical analyses of the Talcott Basalt (MHG 040, 043) show that neither is it different from other basalt flows and dikes in the Connecticut Basin (MHG 031, 044, 045, 047, 057, 150, 151, 160, 161), nor are the basalts enriched in the elements concentrated in the sediments at the Newgate Mine (MAC 677 through 686, MHG 039, 041, 042, 271 through 277).

At present, it is reasonable to assume that the conditions at Newgate could be duplicated anywhere within the arkoses of the basin. It may be that the only favorable arkoses are near the reducing sediments of the lake beds or the permeability restrictions of the basalt flows. Either could have an important influence on uranium deposition, but the model for Subclass 241 gives no basis for preferring such stratigraphic situations over a simple alluvial-plain sequence.

The sediments of the Connecticut Basin must have originally extended some distance west of their present limits, above an unconformity with the crystalline rocks, which is now exposed. An unconformity of sandstones above crystalline basement is often the site of deposition of uranium or other minerals, especially if there are fractures in the basement (Langford, 1977). However, no indications of radioactivity were found by aerial survey, HSSR, or ground investigation. The possibility still exists that uranium is present at depth, either in fractures in the basement or along the unconformity.

Land in the Connecticut Basin is used primarily for residence and farming, and parts of it are urban. Land ownership is almost entirely private. Access is good throughout.

VEINS IN METAMORPHIC ROCKS

Members of the 1-b.y.-old Mount Holly Complex in the core of the Green Mountains of Vermont form an area favorable for the occurrence of vein deposits in metamorphic rocks (Class 720 of Mathews, 1978b). These members meet the following favorability criteria:

- Tectonic setting is a remobilized shield
- Metamorphic rocks are of varied lithology and high metamorphic grade
- Uranium and associated minerals are uraninite, uranothorite, and thorite and lesser amounts of uranophane, coffinite, thorianite, monazite, allanite, molybdenite, pyrite, galena, and possibly bastnaesite

Favorability criteria that have not been found are hematitization and other alteration (except perhaps in MHG 179), brecciated textures, and retrograde metamorphism. Some of these might be found in a more detailed study.

This area contains the most uranium-rich rocks in the Albany Quadrangle (up to 0.3% uranium oxide), and it forms a large area (111 km²) over which rocks with anomalous concentrations (>20 ppm uranium oxide) are found (Pl. 8 and 9). The favorable units range from 0 to more than 1500 m in depth but are more than 1500 m deep in most of the area (Pl. 8).

It may be that the uranium mineralization in the Mount Holly Complex is in a form not described in the favorability criteria. It is put in Class 720 because of the occurrence at City Stream, which appears to be a metamorphosed vein; the broad area of radioactive rock, which is a good source area for veins; and the petrographic and gamma-spectrographic evidence for uranium mobility. These features will be discussed below after a general description of the rocks.

The Mount Holly Complex in the Albany Quadrangle was described by Skehan (1961). It consists of seven units, four of which are rather widespread and massive: plagioclase gneiss, microcline gneiss, Stamford Gneiss, and Wilmington Gneiss (Fig. 6). The widespread plagioclase gneiss is overlain with apparent unconformity by a quartzite, a lime-silicate unit, and another plagioclase gneiss.

AGE	FORMATION	LITHOLOGY	DESCRIPTION
CAMBRIAN	Ec - Cheshire Quartzite		Ec - Quartzite
	Eh - Hoosac Formation		Eh - Sulfidic and graphitic schist
	Tyson Formation		Quartzite and conglomerate
LATER PRECAMBRIAN	Heartwellville Schist		Graphitic mica schist
	Readsboro Schist		Rusty-weathering garnet schist
EARLIER PRECAMBRIAN	Plagioclase gneiss *		Quartz-plagioclase gneiss
	Lime-silicates *		Lime-silicate and quartzose white gneiss
	Quartzite *		Quartzite, conglomerate, and conglomeratic gneiss
	epCw - Wilmington Gneiss		epCw - Microcline augen gneiss
	epCsgg - Stamford Granite Gneiss		epCsgg - Granite gneiss with microcline augen
	epCpg - Plagioclase gneiss *		epCpg - Blue and white quartz-plagioclase gneiss
	epCmg - Microcline gneiss		epCmg - Banded and porphyritic microcline gneiss

* Favorable for uranium deposition

U-Unconformity

Figure 6. Inferred stratigraphy in the Mount Holly Complex and associated units.

The favorable area was defined by the distribution of the four units of Skehan, which appear to include the radioactive rocks; these four units are the plagioclase gneiss and the three apparently overlying units: quartzite, lime-silicate rock, and the other plagioclase gneiss (Fig. 6). The northernmost extent of these units was excluded because the radioactivity appears to diminish to the north.

These relatively early Precambrian rocks are succeeded by a later Precambrian group, which has basal conglomerate and is succeeded in turn by Cambrian and later rocks that have another basal conglomerate, the Tyson Formation.

In the field, the authors had difficulty matching the rocks in outcrop with their descriptions on Skehan's map. The western part of the favorable area was found to be banded plagioclase gneiss; the southeastern part, sulfidic schist and gneiss that have uranium values up to 96 ppm uranium oxide; and the northeastern part, nonsulfidic, quartzose gneisses. It was determined from the numerous quartzites and high thorium-to-uranium ratios that this northeastern area includes some ancient placer deposits. The authors suspect that some of the rocks in this area are equivalent to the Dalton Formation in the Berkshires (see Unfavorable--Placer) and that they lie unconformably on the other favorable rocks. This is despite the fact that these rocks are shown as being older than the Tyson Formation, which is supposed to be the Dalton equivalent. Future mapping may show that the rocks should be subdivided differently and that the favorable area is not restricted to the units as currently mapped, but there is not enough information at present to justify changing the map boundaries.

The occurrences in City Stream (MHG 181, etc., of Pl. 9) in the western part of the favorable area are in and near a 1-m-wide band consisting of blue quartz with garnet and minor sulfides. This quartz-garnet band, parallel to foliation, is inferred to be a metamorphosed quartz-chlorite vein. It does not appear to be a thin sandstone bed in a metasedimentary sequence, and the thorium-to-uranium ratio is close to 1:1, so it is not a placer occurrence. This quartz-garnet rock has the highest known concentration of uranium in the Albany Quadrangle (MHG 183, 184, 326, and 327 of Table 1). The surrounding plagioclase gneiss has a uranium content of 5 to 10 ppm in the vicinity of City Stream.

The extent of radioactive quartz-garnet rock at City Stream is not known. About 30 m is exposed in the stream, which is surrounded by high till-covered banks. A few blue quartzite and garnet boulders were found 0.7 km west of the stream outcrop. In Dunville Hollow, 2 km to the southwest, is a large boulder that has a uranium content of 400 ppm (MHG 179), but it is a gneiss consisting of quartz and altered feldspar rather than quartz and garnet.

A puzzling feature of uranium occurrences in this area is their presence in different rock types. Two possibilities arise, both of which require more mapping to establish their validity. One is that there is an association between the different units that is not now apparent. The other is that the mineralization is related to unknown structures. Recent studies in the region indicate more thrust faults than shown on Skehan's map, as well as variable ages of late metamorphism within the Precambrian (Harwood and Zietz, 1974; Mukasa and others, 1980).

TABLE 1. URANIUM AND THORIUM IN SOME ROCKS IN
THE MOUNT HOLLY COMPLEX FAVORABLE AREA

	MAC 818	MAC 819	MHG 183	MHG 184	MHG 282	MHG 289	MHG 317	MHG 318	MHG 326	MHG 327
U ₃ O ₈ (ppm)	24	60	3217	836	17	38	96	27	1500	1000
eU	12	59			14	4	85	24	1190	718
eTh	121	583			278	16	1360	71	504	836

Uranium mobility in the favorable area is shown by the wide variation in thorium-to-uranium ratios and chemical uranium-to-equivalent uranium ratios (Table 1). Some of the high thorium-to-uranium ratios are believed to be from placer deposits, but others are not. Samples MHG 317 and 318 (Table 1) from the southeast part of the favorable area were taken only 30 m apart from a long road cut of sulfidic schists, yet they have very different uranium and thorium contents and ratios. Sample MHG 289 has much less equivalent than chemical uranium. These samples imply relatively modern solution and deposition of uranium in the area, a condition favoring the formation of vein deposits. There is also petrographic evidence of mobility of uranium and other minerals. In samples MHG 182 and 326 (App. D), uraninite fills fractures and replaces pyrite. In MHG 184, 317, and 318, pyrite encloses thorite. In MHG 179 and 315, uraninite is enclosed by thorite.

In summary, a part of the Precambrian Mount Holly Complex contains uranium at concentrations well above background and appears favorable for the occurrence of veins. The uranium occurs in different rock types, which may not correspond to the different rock types shown on current maps. The sequence may include an unconformity between overlying quartzites and underlying schists and gneisses, and the unconformity may have had some control on the uranium occurrences.

Areas favorable for uranium occurrences are also found in the Mount Holly Complex in the Glens Falls Quadrangle immediately north of the Albany Quadrangle (McHone and Wagener, 1980). Although some of these occurrences are in veins and quartzites, the rocks are quite different, and the occurrences probably have no direct association with the occurrences in Albany. They do emphasize the existence of uranium occurrences in the Mount Holly Complex and the need for a study of the entire complex.

Most of the favorable area lies within the Green Mountains National Forest, and part of it has been proposed as a RARE area. A small part of the favorable area, mostly in the east, is privately owned. The area is heavily wooded, and vehicle access is limited to one east-west paved road and a few gravel roads.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

PLACER

The Dalton Formation of the Berkshire Mountains meets many criteria for placer uranium deposits (Class 110, Jones, 1978), but is insufficiently enriched in uranium to meet the tonnage criterion. It is a metamorphosed placer of Eocambrian age. Some units within the Mount Holly Complex in the Green Mountains also appear to be placers, as previously mentioned. The Dalton Formation meets the following favorability criteria:

- Stratiform beds derived from crystalline rocks of granitic composition
- Quartzite and conglomerate with resistate heavy minerals

- Uranium-bearing minerals are heavy resistate minerals with minor amounts of uranium, monazite, xenotime, and thorite (e.g., MAC 816, App. D)

The Dalton Formation unconformably overlies Precambrian schists and gneisses on the west slope of the Berkshires (Occurrence Reports 2 and 3). It consists of metamorphosed interbedded shale, sandstone, and conglomerate. The Dalton Formation is a quartz-pebble conglomerate of probable Precambrian age, but it is late rather than early Proterozoic and thus does not meet criteria for Class 120 of Jones (1978), quartz-pebble conglomerates. All conglomerate beds have radioactivity 3 to 7 times background, whereas the schists and quartzites are less than twice background. The radioactivity is caused mostly by thorium, in thorite and monazite. These heavy minerals were deposited with 1-cm quartz pebbles. Most of the conglomerate beds in the Dalton Formation were found in the Pittsfield East Quadrangle and north; the coarsest beds are in the North Adams Quadrangle.

Sandstones unconformably overlying crystalline rocks are often the site of uranium deposition. Such is not the case with the Dalton Formation, as radioactive minerals are not concentrated at the unconformity. Radioactivity depends on the presence of conglomerate, and the radioactivity of the conglomerate does not vary with its position in the section. The Dalton was deposited at a time when the earth had an oxidizing atmosphere, but land plants were nonexistent, so organic sources of reductants were limited.

The environment of deposition of the Dalton cannot be determined from its present setting. The presence in some outcrops of several percent feldspar and muscovite favors a fluvial (Subclass 111) environment, but the well-rounded pebbles and good sorting imply a beach (Subclass 112). It is overlain by the Cheshire Quartzite, a clean, massive quartzite, apparently a beach deposit. Probably the Dalton is a fluvial deposit transitional to the Cheshire.

There was probably no single source rock for the radioactive minerals in the Dalton Formation and equivalents. The conglomerates are all mature sediments with well-rounded quartz pebbles, and all the conglomerates are radioactive regardless of the adjacent Precambrian rocks.

MARINE BLACK SHALES

A thick sequence of marine shales and graywackes is found in the Hudson Valley, Taconic Mountains, and Eastern Berkshires Provinces (Fig. 3). All shales and graywackes are unfavorable for uranium occurrences of Class 130, marine black shales (Jones, 1978). The formations are:

Austerlitz Phyllite
 Rensselaer Graywacke
 Everett Schist
 Nassau Formation
 Germantown and Poultney Formations
 Elizaville Formation

Stuyvesant Falls Formation
 Mt. Merino and Indian River Formations
 Normanskill Formation
 Walloomsac Formation
 Austin Glen Graywacke
 Hoosac Formation
 Rowe Schist, Pinney Hollow, Stowe, and Ottaquechee Formations
 Moretown Formation
 Missisquoi Formation
 Goshen and Northfield Formations
 Waits River Formation
 Gile Mountain Formation

The Austerlitz through Missisquoi Formations were all deposited in the same Cambrian-Ordovician geosyncline of the Appalachian mobile belt. The Goshen through Gile Mountain Formations were deposited in a later, Early Devonian, syncline of the mobile belt. Some of the formations have undergone low- to medium-grade metamorphism. All the formations are predominantly deep-water shales, slates, and graywackes and lack most of the favorable characteristics, such as deposition in stable epicontinental seas and high organic content.

LIMESTONE

The limestones of the Albany Quadrangle do not meet favorability criteria for Class 230, limestones (Jones, 1978). The limestones are in two groups, those within each group being closely related. The Cambrian-Ordovician limestones, in the Taconics and Berkshire Valley, are:

- Balmville Limestone
- Stockbridge Group, Beekmantown Group, Bascom Formation, Clarendon Springs Formation, Winooski Dolomite, and Dunham Dolomite

The Lower Devonian limestones, in the western Hudson Valley Province, are:

- Onondaga Limestone
- Helderberg Limestone

Both limestone groups are clean, continental-shelf deposits. The Cambrian-Ordovician group is dolomitic. The limestones lack deposition in an enclosed basin, high organic content, and other aspects for limestone uranium deposits.

Uranium has been found in thin phosphates in the upper Clarendon Springs Formation in northern Vermont, but these phosphates are not known in the Albany Quadrangle.

CONTINENTAL SANDSTONE AND SHALE

Several unrelated continental sandstones are present in the quadrangle. Those in the Connecticut Basin that meet favorability criteria have been discussed above. The others do not meet favorability criteria for uranium deposits of Class 240, sandstone (Austin and D'Andrea, 1978).

The Hamilton Group in the Catskill Mountains consists of marine and nonmarine shale and sandstone. The extent of the nonmarine sediments in the Albany Quadrangle is limited, there are no radioactivity anomalies over them, and no anomalous radioactivity has been found in these rocks in quadrangles to the southwest of Albany.

The Monkton, Cheshire, and Clough Quartzites are clean quartzites. The Monkton has very limited extent in the Albany Quadrangle. The Cheshire and Clough were examined several times in the course of field work and found to have radioactivity about half that of background.

ORTHOMAGMATIC

There is a variety of intrusive igneous rocks in the quadrangle, mostly east of the Connecticut Valley in the Bronson Hill anticlinorium and Merrimack synclinorium. There are also a few bodies in the eastern Berkshires and two Precambrian orthogneisses in the Berkshires and Green Mountains (Pl. 7).

Several of the intrusive rocks are dioritic, too mafic to meet criteria for Class 310, orthomagmatic (Mathews, 1978a). The granitic rocks also do not meet criteria for favorability, as they are not peralkaline or postorogenic; a few exhibit greater radioactivity than do others and will be discussed here.

The Tyringham Gneiss of the Berkshires, a Precambrian granite gneiss, contains up to 11 ppm uranium oxide in places, apparently in allanite (Occurrence Report 4). Other parts of the Tyringham have normal radioactivity.

The Warwick, Vernon, and Keene Domes of the northern part of the Bronson Hill anticlinorium (Thompson and others, 1968) have cores of Pauchaug Gneiss, a massive feldspathic gneiss. For the most part, this gneiss has normal radioactivity (1 to 2 ppm uranium oxide), but the south end of the Warwick Dome, in which a deeper structural level may be exposed (Robinson, 1967b), has an area of about 2 km² where the uranium content is 5 to 15 ppm uranium oxide--one sample had 33 ppm (Occurrence Report 8). Combined with the thin tree cover in this area, these outcrops produce a strong aeroradioactivity anomaly.

The Coys Hill granite, Kinsman Quartz Monzonite, and granitic gneiss with garnet were examined in the field and found to be less than 2 times background. Some aeroradiometric highs over the Kinsman in New Hampshire were not found on the ground. Small bodies of unnamed late granite in the North Brookfield area of the Merrimack synclinorium, too small to show on the map, were 3 to 4 times background, perhaps due to the high potassium feldspar content (Occurrence Report 10).

The Hardwick and Spaulding Quartz Diorites form large igneous bodies in Massachusetts and New Hampshire. Allanite is common in these diorites, and there are aeroradiometric anomalies over parts of them. Only one anomalous area was found on the ground, however, in a body of Hardwick west of the main body near Athol, Massachusetts. This area has radioactivity several times background in one place (but only 4 ppm uranium oxide; Occurrence Report 9).

Two-mica granites are found only in the New Hampshire part of the Albany Quadrangle. These granites are of interest because uranium is associated with two-mica granite in some parts of the world, and because of the secondary uranium minerals in the joints of a two-mica granite at Lake Sunapee, New Hampshire, 45 km north of the Albany Quadrangle. These granites in New Hampshire, both in the Albany Quadrangle and at Lake Sunapee, are sometimes called Concord-type granites, after one such body at Concord, New Hampshire. Except for a few pegmatites (Occurrence Reports 6 and 7), nothing over 3 times background was found in these granites in the Albany Quadrangle. The pegmatites are too few and have insufficient tonnage to be favorable for pegmatitic occurrences (Class 320 of Mathews, 1978a). The two-mica granites are not postorogenic or peralkaline, and thus do not meet favorability criteria.

PEGMATITIC

Some uranium concentrations are found in pegmatites in a broadly radioactive area in the southeast part of the Albany Quadrangle. None of these pegmatites meet the favorability criteria for pegmatites (Class 320 of Mathews, 1978a). They are not complex pegmatites associated with granite bodies, and retrograde metamorphism and alteration are not present. They also lack sufficient concentration of uranium to meet the tonnage criterion, typically having several parts per million uranium oxide, except MHG 004, which has 107 ppm. Some pegmatites in New Hampshire have been discussed under Orthomagmatic.

The broad radioactive high in the southeast corner of the Albany Quadrangle appears on both the Popenoe (1964) aeroradioactivity map and the stream-sediment map of the HSSR report, and a high background was found during ground traverses. The high does not appear on the Texas Instruments aeroradioactivity map. The area contains a variety of high-grade metamorphic rocks, predominantly sulfidic schist (Partridge Formation); fine-grained, quartz-plagioclase-biotite gneiss (Paxton Formation); and quartz diorite (Hardwick Quartz Diorite). There is no particular unit that appears to be the source of radioactivity; the only aspect that the rocks have in common is their high metamorphic grade. The high radioactivity is so pervasive that some gravel pits in this area are twice as radioactive as typical bed rock elsewhere in the quadrangle.

Within this area of high background, there are concentrations of uranium and thorium, usually in simple pegmatites and migmatites (Occurrence Report 11, App. C). There are several small sills of migmatitic granodiorite and numerous quartz-feldspar pegmatites in this part of the quadrangle. These igneous rocks are probably the result of partial melting of the surrounding rocks during the high-grade metamorphism and acquired a disproportionate amount of uranium and thorium.

VOLCANOGENIC

The volcanic rocks in the quadrangle are all basic, and thus lack an essential characteristic for favorability for uranium deposits in volcanic rocks (Class 500 of Pilcher, 1978). These rocks are the basalt flows and dikes in the Connecticut Valley and some Ordovician basic volcanics, now metamorphosed to amphibolites.

METAMORPHIC SCHISTS AND GNEISSES

There is no classification for uranium deposits in these rocks, except Class 720, veins in metamorphic rocks. However, there are some radioactive areas. There are two groups of metamorphic rocks: the Precambrian rocks in the Berkshires and Green Mountains (a portion of the Mount Holly Complex in the Green Mountains is favorable and has been discussed) and most of the rocks in the Bronson Hill anticlinorium and Merrimack synclinorium (Fig. 2) in the eastern part of the quadrangle. Anomalous rocks in the Bronson Hill anticlinorium and Merrimack synclinorium are discussed under Orthomagmatic and Pegmatitic. Moderately metamorphosed rocks in the eastern Berkshires are discussed under Marine Shales and Volcanogenic.

The Precambrian schists, gneisses, and amphibolites of the Berkshires yielded few aeroradioactivity anomalies; in the field, they did not show anomalous radioactivity, with the exception of the "Hinsdale" Gneiss (discussed below) and the Tyringham Gneiss (discussed under Orthomagmatic). Precambrian gneisses on East Mountain, southeast of Great Barrington, Massachusetts, have radioactivity about half that of the typical crystalline rock in the quadrangle.

Precambrian gneisses in the Windsor, Massachusetts, 7 1/2 minute quadrangle, formerly called the Hinsdale Gneiss, have 5 to 10 ppm uranium oxide in several places and are more radioactive than that in a few spots (Occurrence Report 1). The most radioactive samples analyzed include 30 ppm uranium oxide in gneiss and 80 ppm in a small pegmatite. These radioactive rocks are found in several places in the gneiss but are of limited extent. No pattern was found to their occurrence. There is a broad similarity between the "Hinsdale" Gneiss and the favorable Mount Holly Complex in Vermont, but, although not far from each other, they are believed to be separated by a major thrust and to represent different structural levels (Harwood and Zietz, 1974; Mukasa, 1980).

INTERPRETATION OF AERORADIOMETRIC DATA

Two aeroradiometric surveys are available for the Albany Quadrangle. One by the U.S. Geological Survey (Popenoe, 1964) measured total count on a 1-mi (1.5-km) flight spacing, and one by Texas Instruments (1976) measured radiation from potassium, uranium, and thorium on a 10-km (6-mi) spacing. The U.S. Geological Survey map was useful because of its close spacing, although many anomalies on the map were caused by elevation changes rather than greater radioactivity. Only one of the preferred anomalies of the Texas Instruments survey could be correlated with radioactive rocks on the ground.

Two particular areas were detected by these surveys: the south end of the Warwick Dome (see Unfavorable--Orthomagmatic), and the southeast part of the quadrangle (see Unfavorable--Pegmatitic). Other anomalies were apparently caused by the Dalton Formation (see Unfavorable--Placer), elevation changes, areas of thin tree cover, and areas of urbanization.

INTERPRETATION OF HYDROGEOCHEMICAL AND STREAM-SEDIMENT DATA

Two main areas stand out on the HSSR maps. One is an area of high background in the southeast corner of the quadrangle, an area that was previously identified in an earlier aeroradioactivity study (Popenoe, 1964). The HSSR anomaly is due to a high content of uranium in stream sediments. This area is discussed under Unfavorable--Pegmatitic. The other area is one of high thorium-to-uranium ratios in stream sediments over the northern Taconic Mountains (Fig. 3). The cause of this anomaly is not known. The area was not found to be anomalous in the field or in either aeroradioactivity study. Also, the rocks in the area of the anomaly are the same gray slates that are found west and south of the anomaly.

The favorable Mount Holly Complex shows as a weak anomaly for uranium on the stream-sediment map.

RECOMMENDATIONS TO IMPROVE EVALUATION

The authors believe that unfavorable environments in the Albany Quadrangle have been sufficiently investigated and that further work would not change their classification. The two favorable areas, however, should be targeted for further investigation.

The Newgate Mine is a key element in classifying the Connecticut Basin as favorable, and further work in the Connecticut Basin should start with a thorough investigation of the Newgate Mine area to determine why there is an occurrence there. Two studies have already been made of the area but were insufficient to establish whether such an occurrence is unique in the Connecticut Basin. New work, therefore, should build on these studies with a carefully planned drilling program to determine depth of mineralization, changes in mineralization below the water table, and any features that might explain this occurrence.

Drilling of the western contact of the Connecticut Basin (at Westfield, for instance) could yield valuable information about chemical variations at the unconformity below the water table, and might indicate whether mineralization could be expected at the unconformity.

The first step to understanding the distribution in the Mount Holly Complex of Vermont is detailed mapping of the favorable area to determine if uranium is confined to certain subdivisions, structures, or other features. The thorium-to-uranium ratio is a feature that must be measured in this study. If a relationship between geology and uranium is found, it could be relevant to uranium investigations in the Precambrian throughout the Appalachians.

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Plate I. AREAS FAVORABLE FOR URANIUM DEPOSITS

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

EXPLANATION

	URANIUM OCCURRENCES			
	CLASSIFICATION			
	Sedimentary	Plutonic	Volcanic	Other
Minor prospect or mineral occurrence	□	△	○	☆
Prospect or mine, production unknown	■	▲	●	★
Significant prospect or mine reporting minor production	◻	◼	◌	✱
Mine having production over 200,000 pounds U ₃ O ₈	■	▲	●	★
Not visited	□Y	△Y	○Y	☆Y
Not found	□X	△X	○X	☆X
Mining District	-----			

Plate 2. URANIUM OCCURRENCES

Plate 3. INTERPRETATION OF AERIAL RADIOMETRIC DATA

ALBANY, N. Y. / CONN. / MASS. / N. H. / VT.

Plate 4. INTERPRETATION OF DATA FROM HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE

April 1980
Plate 5.

Plate 6. DRAINAGE

Plate 7a. GEOLOGIC MAP OF THE ALBANY QUADRANGLE

AGE	NEW YORK	BERKSHIRES AND GREEN MOUNTAINS	EAST OF BERKSHIRES	CENTRAL MASSACHUSETTS
QUAT.	<div><div>Q</div><div>Thick Pleistocene and Recent cover</div></div>			
TRIASSIC - JURASSIC			<div><div>CONNECTICUT BASIN</div><div><div><div>JpcJp</div><div>Portland arkose : arkose with lake beds; Jpc- conglomerate and sandstone</div></div><div><div>Jm</div><div>Mt. Toby Conglomerate</div></div><div><div>Jbha</div><div>Hampden Basalt</div></div><div><div>Jbg</div><div>Granby Tuff and basalt</div></div><div><div>JecJe</div><div>East Berlin Formation: sandstone with lake beds; Jec- conglomerate and sandstone</div></div><div><div>JbdJbh</div><div>Holyoke Basalt; Jbd- Deerfield Basalt</div></div><div><div>Jt</div><div>Turners Falls sandstone</div></div><div><div>Jsm</div><div>Shuttle Meadow Formation: sandstone with lake beds</div></div><div><div>Jhv</div><div>Hitchcock Volcanics</div></div><div><div>JsJn</div><div>New Haven Arkose and Sugarloaf Formation: arkose, sandstone, and conglomerate with lake beds</div></div><div><div>RsRn</div></div></div></div>	
DEVONIAN	<div><div>MIDDLE</div><div><div><div>Dhpl</div><div>Hamilton Group, Plattskill Formation: shale and sandstone</div></div><div><div>Dhm</div><div>Undifferentiated lower Hamilton Group: shale and sandstone</div></div></div><div><div>LOWER</div><div><div><div>Dou</div><div>Onondaga Limestone</div></div><div><div>Dhg</div><div>Helderberg Limestone</div></div></div></div></div>		<div><div>Dw</div><div>Waits River Formation; brown-weathering quartzose and micaceous limestone</div><div><div>Dws</div><div>Standing Pond volcanics</div></div><div><div>Dgo</div><div>Goshen and Northfield Formations: mica schists and quartzite</div></div><div><div>Dgm</div><div>Gile Mt. Formation: quartz-muscovite schist</div></div></div>	<div><div>De</div><div>Erving Formation: biotite-plagioclase granulite and amphibolite</div><div><div>DI</div><div>Littleton Formation: well-bedded gray mica schist</div></div><div><div>DO</div><div>Undifferentiated schists in New Hampshire, mostly Littleton and Partridge Formations</div></div></div>
SILURIAN			<div><div>Sr</div><div>Russell Mt. and Shaw Mt. Formations: brown quartzose limestone, sulfidic thin-bedded calc-silicate, quartzite</div></div>	<div><div>Sf</div><div>Fitch Formation: gray and sulfidic calc-silicates</div><div><div>Sc</div><div>Clough Quartzite</div></div><div><div><div>SpsS</div><div>Sps</div><div>Spg</div><div>Spw</div></div><div>Sp</div><div>Paxton Schist: gray bedded biotite-quartz-plagioclase granulite and calc-silicate; Sps- biotite, granulite and calc-silicate; Spg- biotite granulite and sulfidic schist; Spg- gray mica schists; Spw- sulfidic magnesian schist</div></div></div>
UNCONFORMITY				
ORDOVICIAN	<div><div>UPPER</div><div><div><div>Oag</div><div>Austin Glen Formation: graywacke and shale</div></div></div><div><div>MIDDLE</div><div><div><div>Owl</div><div>Walloomsac Formation: slate and schist</div></div><div><div>On</div><div>Normanskill Formation: mudstone and sandstone</div></div><div><div>Omi</div><div>Mt. Merino and Indian River Formations: shale, slate and chert</div></div><div><div>Otm</div><div>Taconic Mélange</div></div></div><div><div>LOWER</div><div><div><div>Osf</div><div>Stuyvesant Falls Formation: shale, argillite and quartzite</div></div><div><div>Ole</div><div>Elizaville Formation: shale, argillite and quartzite</div></div></div></div></div></div>	<div><div>Owl</div><div>Walloomsac Formation: slate and schist</div><div><div>Obo</div><div>Bainville Limestone</div></div><div><div>UNCONFORMITY</div></div><div><div>OEst</div><div>Stockbridge Group, Beekmantown Group, Bascom Formation, Clarendon Springs Formation, Winooski Dolomite, Dunham Dolomite: dolomite and limestone.</div></div></div>	<div><div><div>Ohv</div><div>Ohb</div><div>Ohe</div><div>Ohe</div><div>Ohe</div></div><div>Oh</div><div>Hawley Formation: Ohv- metavolcanics (Barnard volcanics in Vermont); Ohb- carbonaceous schists; Ohe- gray mica schist; Ohe- gray bedded schists and granulite</div><div><div>Om</div><div>Moretown and Missisquoi Formations: pinstripe quartz-feldspar-mica-granulite</div></div><div><div>Ocr</div><div>Rowe schist, Pinney Hollow, Stowe and Ottaquechee Formations; quartz-muscovite-chlorite schist with some amphibolite and ultramafics</div></div></div>	<div><div><div>OpvOp</div><div>Partridge Formation: sulfidic schist and amphibolite; Opv- volcanics</div></div><div><div>Oa</div><div>Ammonoosuc Volcanics</div></div><div><div><div>pa</div><div>mo</div><div>pqq</div><div>gl</div></div><div>GNEISSES OF THE DOMES</div><div>Pauchaug Gneiss: massive feldspar gneiss Manson Gneiss: bedded feldspar gneiss and amphibolite Pelham Gneiss: bedded feldspar gneiss and quartzose gneiss Glastonbury gneiss: massive feldspar gneiss</div></div></div>
CAMBRIAN	<div><div><div>Eg</div><div>Germantown and Poulitney Formations: shale, conglomerate, limestone</div></div><div><div>En</div><div>Nassau Formation: shale and slate</div></div><div><div>Eev</div><div>Everett Schist</div></div><div><div>Er</div><div>Rensselaer Graywacke</div></div><div><div>Ea</div><div>Austerlitz Phyllite</div></div><div>(Some formations may be late Precambrian)</div></div>	<div><div><div>Em</div><div>Monkton quartzite, occurs within OEst in Vermont</div></div><div><div>Ec</div><div>Cheshire quartzite</div></div><div><div>Ecd</div><div>Dalton and Cheshire undifferentiated</div></div><div><div>Ed</div><div>Dalton and Tyson Formations: arkose, conglomerate, quartzose schist, may be late Precambrian</div></div><div><div>Ecr</div><div>Cavendish Formation, Readsboro Member: quartz-muscovite schist</div></div></div>	<div><div><div>ChaCh</div><div>Hoosac Formation: quartz-albite-biotite schist; Cha- amphibolite</div></div></div>	<div><div>AGE</div><div>INTRUSIVE ROCKS</div><div>These are found only in the eastern half of the Albany sheet</div><div><div>LOWER AND MIDDLE DEVONIAN</div><div><div><div>Dbt</div><div>Two-mica granites</div></div><div><div>Dd</div><div>Diorites</div></div><div><div><div>Dbg</div><div>Dbm</div><div>Dbt</div></div><div>Belchertown Intrusive Complex: Dbm- orthopyroxene diorite; Dbt- hornblende diorite</div></div><div><div>DpqDpg</div><div>Prescott Intrusive Complex: quartz diorite gneiss; Dpg- hornblende gabbro</div></div><div><div>Dwg</div><div>Williamsburg Granodiorite</div></div><div><div>Dhs</div><div>Hardwick and Spaulding Quartz Diorites</div></div><div><div>Dgg</div><div>Granitic gneiss with garnet</div></div><div><div>Dg</div><div>Miscellaneous granitic intrusives</div></div><div><div>Dck</div><div>Coys Hill Granite and Kinsman Quartz Monzonite</div></div></div><div><div>ORDOVICIAN</div><div><div><div>Od</div><div>Ou</div></div><div>Diorite Ultramafic Rocks</div></div></div></div></div>
PRECAMBRIAN		<div><div><div>pCs</div><div>Stamford Granitic Gneiss</div></div><div><div>pC</div><div>Mt. Holly complex in Vermont, undifferentiated Precambrian in Massachusetts</div></div><div><div>pCm</div><div>Marble and calc-silicate</div></div><div><div>pCa</div><div>Quartzite and quartzose schist</div></div><div><div>pCt</div><div>Tyringham Granitic Gneiss</div></div><div><div>pCbg</div><div>Biotite-quartz-plagioclase gneiss</div></div><div><div>pCag</div><div>Hornblende-garnet amphibolite gneiss</div></div><div><div>pCwg</div><div>Washington Gneiss: quartz-plagioclase gneiss, rusty biotite-muscovite-quartz gneiss, hornblende-garnet amphibolite</div></div></div>		

April 1980
Plate 7b

EXPLANATION

- C Cambrian undifferentiated, includes:
Hoosac Formation: rusty-weathering and graphitic schists.
Cheshire Quartzite: massive buff-weathering quartzite.
Mendon Formation: black phyllite.
- Ct Tyson Formation: quartzite and conglomerate.
- Unconformity
- pCh Heartwellville Schist: graphitic mica schist; may be Cambrian.
- pCr Readsboro Schist: rusty-weathering garnet schist; may be Cambrian; includes Sherman Marble Member (pCrs) and Searsburg Conglomerate (pCrsc).
- Major Unconformity
- epCg Plagioclase gneiss: blue and white quartz-plagioclase gneiss, closely associated with epCl and epCq.
- epCl Lime-silicates and white gneiss: fine to coarse lime-silicate and blue and white quartzose white gneiss.
- epCq Quartzite, conglomerate, and conglomeratic gneiss: massive buff to blue glassy quartzite, blue quartz conglomerate, and rounded to angular microcline conglomeratic gneiss.
- epCw Wilmington Gneiss: microcline augen gneiss; in Wilmington Dome.
- epCsgg Stamford Granite Gneiss: granite gneiss with microcline augen.
- epCpg Plagioclase gneiss: blue and white quartz-plagioclase gneiss.
- epCmg Microcline gneiss: banded and porphyritic microcline gneiss.

- Contact
- Thrust fault (Teeth on upper plate)
- Favorable area
- Thrust fault in cross-section
- Line of cross-section

Geology from Skehan, 1961; Doll, 1961; Harwood and Zietz, 1974

CROSS-SECTION A-A'
No vertical exaggeration

Plate 8. GEOLOGIC MAP AND SAMPLE LOCATIONS IN THE WOODFORD-SEARSBURG AREA

Plate 9. RESULTS OF DETAILED GEOCHEMICAL SAMPLES IN THE WOODFORD-SEARSBURG AREA-ROCK SAMPLES

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13. Ruedemann, 1942, scale 1:62,500.
14. Weaver, 1957, scale 1:62,500.
15. MacFadyen, 1956, scale 1:62,500.
16. Skehan, 1961, scale 1:62,500.
17. Hepburn, 1975, scale 1:140,000.
18. Moore, 1949, scale 1:62,500.
19. Fowler-Billings, 1949, scale 1:62,500.
20. Herz, 1961, scale 1:24,000.
21. Chidester and others, 1967, scale 1:24,000.
22. Hatch and Hartshorn, 1968, scale 1:24,000.
23. Segerstrom, 1956a, scale 1:31,680.
24. Balk, 1956b, scale 1:31,680.
25. Balk, 1956a, scale 1:31,680.
26. Robinson, 1977, scale 1:24,000.
27. Hadley, 1949, scale 1:31,680.
28. Robinson, 1967a, scale 1:72,000.
29. Herz, 1958, scale 1:31,680.
30. Norton, 1967, scale 1:24,000.
31. Norton, 1975, scale 1:250,000.
32. Osberg, Hatch, and Norton, 1971, scale 1:24,000.
33. Segerstrom, 1956b, scale 1:31,680.
34. Willard, 1952, scale 1:31,680.
35. Balk, 1956c, scale 1:31,680.
36. Cullen, 1975, scale 1:75,000.
37. Norton, 1974b, scale 1:24,000.
38. Hatch, 1969, scale 1:24,000.
39. Willard, 1956, scale 1:24,000.
40. Willard, 1951, scale 1:31,680.
41. Tucker, 1977, scale 1:24,000.
42. Ratcliffe, 1974a, scale 1:24,000.
43. Ratcliffe, 1974b, scale 1:24,000.
44. Ratcliffe and Harwood, 1975, scale 1:200,000.
45. Norton, 1974a, scale 1:24,000.
46. Hatch, Norton, and Clark, 1970, scale 1:24,000.
47. Balk, 1957, scale 1:31,680.
48. Robinson, 1967b, scale 1:62,500.
49. Guthrie and Robinson, 1967, scale 1:62,500.
50. Field, 1975, scale 1:48,000.
51. Field, in preparation, scale 1:24,000.
52. Zen, 1971, scale 1:24,000.
53. Ratcliffe, 1974c, scale 1:24,000.
54. Ratcliffe, 1975b, scale 1:24,000.
55. Ratcliffe, 1975a, scale 1:62,500.
56. Jackson, 1975, scale 1:24,000.
57. Stanley, 1975a, scale 1:62,500, or Stanley, 1975b, scale 1:80,000.
58. Clark, 1977, scale 1:24,000.
59. Larsen, 1972, scale 1:24,000.
60. Leo and others, 1974, scale 1:24,000.
61. Pomeroy, 1977, scale 1:24,000.
62. Pomeroy, 1975, scale 1:24,000.
63. Zen and Hartshorn, 1966, scale 1:24,000.
64. Ratcliffe and Burger, 1975, scale 1:24,000.
65. Harwood, 1975, scale 1:62,500.
66. Ratcliffe and Harwood, 1975, scale 1:200,000.
67. Schnabel, 1973, scale 1:24,000.
68. Schnabel, 1974, scale 1:24,000.
69. Colton and Hartshorn, 1966, scale 1:24,000.
70. Hartshorn and Koteff, 1967, scale 1:24,000.
71. Peper, 1977a, scale 1:24,000.
72. Peper, 1977b, scale 1:24,000.
73. Seiders, 1976, scale 1:24,000.
74. Peper, Pease, and Seiders, 1975, scale 1:125,000.
75. Hatch and Stanley, 1976, scale 1:24,000.

Plate 10. GEOLOGIC-MAP INDEX

A Areas Managed by National Park Service

A-1 Saratoga National Historical Park

C Forest Service RARE II Areas

C-1 Woodford

G Government Installations

G-1 Westover Air Force Base

L National Trails

L-1 Appalachian Trail

M State Withdrawals**New York**

M-1 Peabody Island State Park
M-2 John Boyd Thacher State Park
M-3 Bristol Beach State Park
M-4 Clermont State Park
M-5 Lake Taghkanic State Park
M-6 Taconic State Park
M-7 Cherry Plain State Park
M-8 Gratiot Lakes State Park

Connecticut

M-9 Mount Ripa State Park
M-10 Campbell State Park
M-11 Haystack Mountain State Park
M-12 Algonquin State Park
M-13 Tuxedo State Park
M-14 Shennecossett State Forest
M-15 Nipmuck State Forest
M-16 Bepow Hollow State Forest

Massachusetts

M-17 Foxburg State Forest
M-18 Tuxedo Trail State Park
M-19 Mount Greylock State Reservation
M-20 Putnam State Forest
M-21 Bates Memorial State Park
M-22 Beartown State Forest
M-23 October Mountain State Forest
M-24 Peru State Forest
M-25 East Mountain State Forest
M-26 Barns Falls State Forest
M-27 Mount Everett Reservation
M-28 Sandfield State Forest
M-29 Tolland State Forest
M-30 Granville State Forest
M-31 Otis State Forest
M-32 Chester State Forest
M-33 M. Gardner State Park
M-34 Daughters of the American Revolution State Forest
M-35 Conway State Forest
M-36 Deer Hill State Reservation
M-37 Hawley State Forest
M-38 Windsor State Forest
M-39 Savoy Mountain State Forest
M-40 W. Jackson State Forest
M-41 Middle State Forest
M-42 Fitch State Forest
M-43 H. D. Cook State Forest
M-44 Lyndon State Forest
M-45 South River State Forest
M-46 Mount Tom Reservation
M-47 Rudolph State Park
M-48 Ossipee State Park
M-49 Sawyer State Park
M-50 Cadyville Municipal Forest
M-51 Mount Sugarloaf State Reservation
M-52 Mount Toby State Forest
M-53 Montpelier State Forest
M-54 Northfield State Forest
M-55 Warwick State Forest
M-56 Mount Grace State Forest
M-57 E. W. Shipley State Forest
M-58 Wenden State Forest
M-59 Orange State Forest
M-60 New Salem State Forest
M-61 Shutesbury State Forest
M-62 Petersham State Forest
M-63 Brimfield State Forest
M-64 Wells State Park
M-65 Sylvan State Forest
M-66 Oxbow State Forest
M-67 Rutland State Forest
M-68 Hubbardston State Forest
M-69 Templeton State Forest
M-70 Winchendon State Forest

Vermont

M-71 Newell's Mill Pond Site
M-72 Woodford State Park
M-73 Howe Pond State Forest

M-74 Molly Stark State Park

M-75 Fort Dummer State Park

M-76 Dutton Pines State Park

New Hampshire

M-77 Wantastiquet Mountain State Forest
M-78 Pisgah Wilderness State Park
M-79 Pierce's Island State Park
M-80 Chesterfield Gorge Geologic Site
M-81 Hyland Hill
M-82 Otter Brook State Park
M-83 Ossipee Lake State Park
M-84 Rhododendron State Park
M-85 Grant State Forest
M-86 Monadnock Mountain State Park
M-87 Gay State Forest
M-88 Haven State Forest

New York Wildlife Areas

M-89 Capitol District Forest and Game Refuge

Vermont State Wildlife Areas

M-90 Waterfowl Management Area
M-91 Stamford Meadows Wildlife Management Area
M-92 Bennington State Fish Hatchery
M-93 Atherton Meadows Wildlife Management Area
M-94 Roaring Brook Wildlife Management Area
M-95 Forbush Wildlife Sanctuary

Historical Sites

M-96 Brigham Young Birthplace
M-97 Brigham Young Memorial
M-98 Bennington Battle Monument
M-99 Shaker Museum
M-100 William Cullen Bryant Homestead
M-101 Old Sturbridge Village
M-102 Hancock Shaker Village
M-103 Home of Oliver Wendell Holmes
M-104 Ashley House
M-105 Emily Dickinson's Birthplace

N Other Land Categories

N-1 Quabbin Reservoir Reservation
N-2 Pleasant Valley Reservoir

Vermont Town Forests

N-3 Stamford Town Forest
N-4 Pownal Municipal Forest
N-5 Bennington Town Forest
N-6 Bennington Municipal Forest
N-7 Woodford Municipal Forest
N-8 North Bennington Municipal Forest
N-9 Readboro Municipal Forest
N-10 Wilmington Town Forest
N-11 Putney Municipal Forest
N-12 Putney Central School Forest

Plate II. LAND STATUS MAP

Plate 12. CULTURE