UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

Uranium Potential of the Adirondack Region

by

C. J. Nutt

Open-File Report 80-1062

1980

Contents

Uranium potential of the Adirondack Region

by C. J. Nutt

ABSTRACT

There has been little recent exploration for uranium in the Precambrian granitic and metamorphic terrain of the Adirondack region, although uranium mineralization is known to occur in pegmatites and to be associated with magnetite ore. The Adirondack geologic setting is similar to the Precambrian Grenville Province of Canada, which contains uraniferous pegmatites, and to the New York-New Jersey Hudson Highlands, where ore-grade uranium concentrations are commonly associated with magnetite bodies. The uraniferous pegmatites of the Adirondack Lowlands are in the carbonate-dominated Grenville Complex which is host to the uraniferous pegmatites in Bancroft, Canada. Although Bancroft pegmatites have been successfully mined, the tonnage of individual pegmatites in the Adirondacks is too low to encourage future exploration. The uraninite associated with magnetite ore is primarily in accessory minerals, and is not concentrated in ore tonnages. Leucogranitic gneiss and unconformities are considered possible uraniferous environments, but no uranium enrichment has been identified in these settings. It is concluded, therefore, that there is little potential for large uranium deposits in the Adirondacks.

INTRODUCTION

The uranium occurrences of the Adirondacks have received little attention. Recent U.S. Geological Survey work on this subject has been limited to field checks of previously reported uranium occurrences (Grauch and Zarinski, 1976) and cursory field examination of favorable environments. This paper consolidates available information, places known occurrences into a geologic framework, identifies possible uranium environments, and evaluates the possibility of significant uranium concentrations. This evaluation is part of the U.S. Department of Energy World Class program, and is based on a search of the literature and reconnaissance examination of surface exposures. It should be noted that a few companies are currently active in the area, and that detailed geochemical and geophysical studies and drilling may modify the author's conclusions.

GEOLOGIC SETTING

The Adirondack region is an extension into New York State of the Grenville Province of the Canadian Shield (fig. 1). It consists of Precambrian intrusives and supracrustal rocks, which were subjected to amphibolite to granulite facies metamorphism during the Grenville orogeny, about 1000-1250 m.y. ago (Doig, 1977). The Adirondack area is divided into two sections, the highlands, which consist of mountainous terrain, and the lowlands, which consist of low-relief ridges and valleys on the northwestern edge of the Adirondack Mountains.

The highland rocks are granulite facies metamorphic and intrusive rocks. Anorthosite, gabbroic anorthosite, and charnockite form the core complex of the mountainous area and underlie the high peaks of the Adirondacks. Igneous rocks, high-grade gneisses, and subordinate metasedimentary rocks surround the core. Dating of charnockite gneiss associated with anorthosite indicates the age of the core complex is approximately 1130 m.y. (Silver, 1969).

The lowlands are underlain by the 1200-1700(?) m.y. Grenville Complex (Brown, 1980), which was metamorphosed in the lower to upper amphibolite facies during the Grenville orogeny (Wynne-Edwards, 1972). The major rock types are marble and calc-silicates, interlayered with paragneiss, amphibolite, and leucogranitic gneiss. Granites and gabbros intrude the metasedimentary rocks, but are much less important volumetrically than in the highlands. The Adirondack Lowlands are part of the Central Metasedimentary Belt of the Grenville Province (Wynne-Edwards, 1972).

The Adirondacks have been subjected to complex folding. In the lowlands a northeast structural trend dominates, but at least three major directions of deformation have been identified (Romey and others, 1980). In contrast to the ductile folding and plastic flow of rocks in the lowlands, the rocks in the highlands were cataclastically deformed as well as folded. The rigid core complex affected folding, causing the surrounding rocks to conform to the outline of the complex. Multiple fold sets are also recognized in the highlands. The highland-lowland boundary is a major structural feature, although its origin is uncertain. Suggestions include that it is a change in metamorphic grade along which subsequent shearing and displacement occurred (Engel and Engel, 1958) or that it is the axial surface of a large-scale nappe structure (Romey and others, 1980).

URANIUM EVALUATION

Few uranium occurrences are known in the Adirondacks; those reported by Grauch and Zarinski (1976) are shown on figure 1 and in table 1. The Adirondack rock types are, however, similar to those in the uraniferous terrains of the Grenville Province of Canada and in the Hudson Highlands

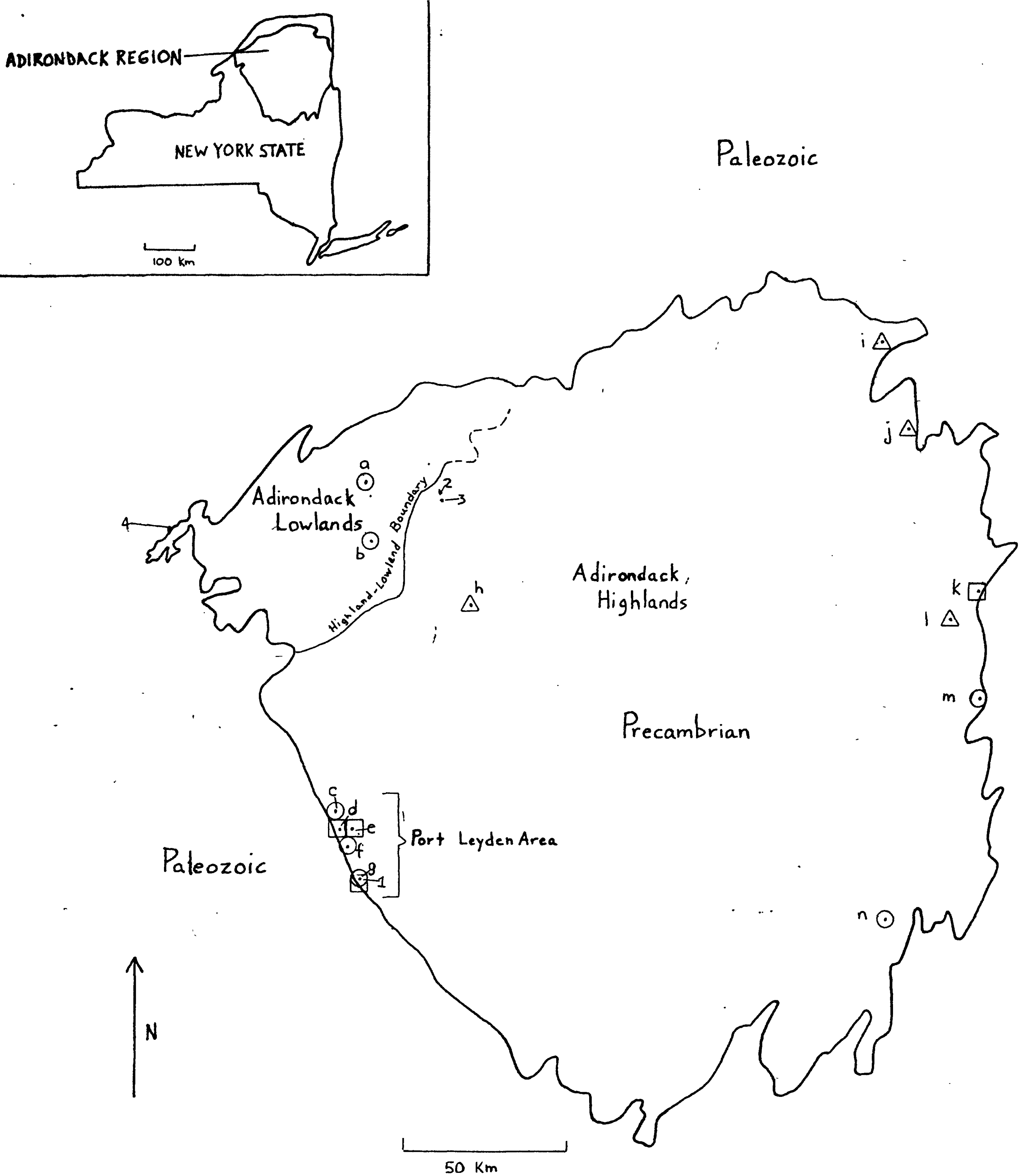

Figure 1.--Adirondack uranium occurrences and sample localities. Descriptions of the occurrences and localitites are given in tables 1 and 2. Uranium occurrences are shown as follows: ⊙ uraniferous pegmatites; △ magnetite-uranium associations, ⊡ uranium-rich segregations. Uranium occurrence localities are from Grauch and Zarinski (1976).

Table 1.--Uranium occurrences in the Adirondack region

[Description of Adirondack uranium occurrences shown on figure 1. Descriptions are from Grauch and Zarinski (1976). Leaders (---) indicate mineralogy is not reported in the literature]

Occurrence	Name	Mineralogy	Host	Comments	Location
a	McLear pegmatite	Uraninite	Precambrian pegmatite	The pegmatite intrudes marble of the Grenville Complex	St. Lawrence County. The locality is 6.4 km north 47 degrees 45 minutes east from Richville Station.
b	Talcville	Uraninite, allanite molybdenite, pyrite	Precambrian pegmatite	Pegmatite intrudes limestone of Grenville Complex. A grab sample contains 0.043% U and 0.02% Th.	St. Lawrence County. The inactive talc mine is 0.3 km northwest of Talcville bridge.
c	Stiles Farm No. 1	-------	Pegmatite	Maximum radioactivity is about 40 times background	Lewis County. Go north from Glenfield 0.8 km to Stiles Farm; take a right at railroad tracks then left for 340 m.
d	Plato No. 1	Uraninite, pyrite	Precambrian granitic gneiss	Uraninite and pyrite occur as irregular streaks and lenses. Maximum radioactivity is about 35 times background.	Lewis County. Go north from the ridge at Lyons Falls for 6.4 km to junction; take a right and proceed for 0.8 km. Prospect is located 1 km due south of the town of Greig.
e	Adirondack Uranium No. 1	Thorite, magnetite	Precambrian granite	Chemical analyses of "lenses of magnetite in injecting granite" show values ranging from 0.03 to 0.2% U_3O_8.	Lewis County. Go north from the bridge at Lyons Falls for 7.5 km; take a left at the junction and proceed 3.9 km; take left at the junction and proceed 0.5 km to a dirt road; take a right and go 200 m.

Table 1.--Uranium occurrences in the Adirondack region--continued

Occurrence	Name	Mineralogy	Host	Comments	Location
f	Shaneey No. 1	Thorite, uraninite	Precambrian hornblende pegmatite	Maximum radioactivity is about 60 times background.	Lewis County. Go north from the bridge at Lyons Falls for 2.4 km to a dirt road; take a left and proceed 0.4 km to mine workings.
g	Stenn-brickner Farm	Uraninite, pyrite, magnetite, sphalerite, fluorite	Precambrian gneiss, amphibolite, pegmatite	Maximum radioactivity is about 15 times background. Radioactivity is generally but not always associated with pegmatite. Uraninite is sometimes included in hornblende crystals.	Lewis County. South on Route 12 from blinker in Port Leyden for 3.1 km; 100 m east to the outcrop. USGS Bench mark K184 is located on the south end of the outcrop.
h	Benson mines	Torbernite, allanite, magnetite	Precambrian granite gneiss, pegmatite	Radioactivity is concentrated in the "disseminated garnet zone" and reaches a maximum of 0.019% eu. This may be Gableman's Star Lake occurrence.	St. Lawrence County. The mines are 3.2 km east of Star Lake on Route 3.
i	Ellis Ore Pits	Thorite, magnetite	Precambrian Lyon Mountain Granite Gneiss, feldspar-pyroxene rock	Maximum radioactivity is 0.12% eu.	Clinton County. The locality is 1.6 km northeast of Dannemora.

Table 1.--Uranium occurrences in the Adirondack region--continued

Occurrence	Name	Mineralogy	Host	Comments	Location
j	Rutgers Mine	Magnetite, apatite, zircon	Precambrian Lyon Mountain Granite-Gneiss, pink syenite gneiss, plagioclase syenite gneiss	Radioactivity is apparently associated with apatite and zircon. This is similar to the Mineville occurrence. Magnetite ore from the dumps shows 0.005 to 0.01% eu. Numerous schlieren of pyroxene skarn are associated with the gneisses.	Clinton County. The mine is about 8 km north of Ausable Forks.
k	Lodge Hill Road Cut	Pyrite	Granite gneiss	A siliciffied portion of the gneiss is radioactive (0.01% eu).	Essex County. The road cut is 3.2 km southwest of Westport
l	Mineville district	Magnetite, apatite	Syenite, gneiss	Most radioactivity is restricted to the "Old Bed" horizon which is rich in rare-earth-bearing apatite. An analysis of apatite shows 0.032% U, 0.15% Th and 11.14% REE.	Essex County. The locality is near the village of Mineville.
m	Lawrence Prospects	Magnetite	Pegmatite	Black radioactive grains occur in the pegmatite.	Essex County. The prospects are located on Sugar Hill about 2.4 km southwest of Crown Point.
n	Lake George	------	Precambrian pegmatite, granite	An assay of the pegmatite shows 0.013% U and 0.03% ThO_2. The granite contains 0.002% U and 0.001% ThO_2.	Warren County. The road cut is located 5.1 km north of the junction of Routes 9 and and 9N on Route 9.

(Grauch, 1978, Grauch and Zarinski, 1976) and all three Precambrian areas are part of the Grenville Orogenic Belt (Wynne-Edwards, 1972). Therefore, evaluation of the uranium potential of the Adirondacks will include comparison with known uraniferous environments in Canada and the Hudson Highlands. Possible rock types and structures with uranium enrichment are pegmatite, leucogranitic gneiss, magnetite ore, and unconformities.

Pegmatites

The predominant type of radioactive occurrence in the Adirondacks is uraniferous pegmatite (fig. 1). These pegmatites are in the same structural province as Canadian uraniferous pegmatites, which have been well documented. This paper will summarize the work on the Canadian pegmatites and the genetic models which have been developed, and then evaluate the Adirondack uraniferous pegmatites. The Canadian review is based primarily on work by Bateman (1955), Satterly (1956), Robinson (1960), Evans (1964), Wynne-Edwards (1972), Little and others (1972), Little (1974), Bright (1976), Gorden and Masson (1977,1978), Masson and Gorden (1979), Ruzicka (1979), and Allen (1980). Only specific details have been referenced in the summary of Canadian pegmatites.

Canadian Pegmatites

The Canadian uraniferous pegmatites are located in the Grenville Province of the Precambrian Shield, predominantly within the Central Metasedimentary Belt. The best known and most economically important are located near Bancroft, Ontario; these are part of a uraniferous pegmatite belt extending from Bancroft to about 100 km north of Mount Laurier, Quebec, (Allen, 1980). Other radioactive occurrences in what may be correlative metasedimentary rocks are clustered along the north shore of the Gulf of St. Lawrence.

Most pegmatites are within the Grenville Complex, which consists of metamorphic carbonates, calc-silicates, quartz-silicates, quartzites, paragneiss, and metavolcanic rocks (Wynne-Edwards, 1972). These rocks unconformably overlie the Archean(?) to middle Precambrian(?) gneissic basement (Wynne-Edwards, 1972; Lumbers, 1975). Granites and syenites intrude the Grenville Complex and are common in the vicinity of uraniferous pegmatites.

The pegmatites are heterogeneous, varying in composition from granite to syenite; the composition may be dependent on enclosing rock types (Allen, 1980). Uraniferous zoned and unzoned pegmatites occur in the region, but economic grades of uranium have been found only in red unzoned pegmatites. The red color is the result of extensive hematitization. The principal uranium minerals are uraninite and uranothorite, which have Pb-isotope dates of 950-1070 m.y. (Robinson, 1960). Recently determined Rb-Sr whole rock pegmatite ages are in the range 950-970 m.y. (Fowler and Doig, 1979).

Uranium mineralization is broadly stratigraphically controlled, but concentration is defined by structure and lithology (Masson and Gorden, 1979). In the Bancroft area, uraniferous pegmatites occur within a broad carbonate-rich sedimentary sequence in the middle of the Grenville stratigraphic section (Gorden and Masson, 1978). Small uraniferous metasomatic or stratabound occurrences and calcite-fluorite-apatite-rich veins also appear to be most common in this horizon. Within the pegmatites, uranium mineralization is erratically distributed, but it tends to be concentrated in shattered zones and along the margins of the pegmatites. Uranium is commonly associated with clots of ferromagnesian minerals.

Grenville Province pegmatites and associated occurrences contain two percent of Canada's total uranium resources (Ruzicka, 1979); however, this percentage may decrease as Canada develops its rich unconformity-type uranium deposits in Saskatchewan. In the Bancroft area, pegmatites are minable only where several occur together. In the Baie Johan Beetz area, along the north shore of the Gulf of St. Lawrence, the resources are in granite containing 100-200 ppm uranium (Ruzicka, 1979).

There are presently two major models for the origin of Canada's uraniferous pegmatites. These are as follows:

1. Igneous pegmatites - There is a spatial relationship between pegmatites and granitic intrusions, suggesting the pegmatites were derived from the intrusions. Recent work, however, indicates these granites are older than the pegmatites (Fowler and Doig, 1979). Fowler and Doig propose that the pegmatites are related to nearby younger, alkaline intrusions.

2. Anatectic pegmatites - Anatexis of uraniferous strata has been proposed as the mechanism of pegmatite formation (Bright, 1976; Gorden and Masson, 1977, 1978; Allen, 1980); this proposal is similar to the model for the Rössing, Namibia, deposit (Berning and others, 1976). The uranium source rock is envisioned as an extensive unit, which explains the occurrence of pegmatites throughout the province. Varying pegmatite compositions are the result of differing amounts of melting, compositional variations in source rocks, and assimilation of wall rocks. The anatexis theory can be used to relate the seemingly different uraniferous granite at Baie Johan Beetz and the Bancroft pegmatites. At Baie Johan Beetz, the uraniferous granite was derived from sediments by anatexis or autometamorphism, according to Mackie (1978) and Hauseux (1977); uranium in the sediments was remobilized into fold axes, but remained within the unit. In the Bancroft and Mekoos areas, anatectic pegmatites and uranium have risen from their source area during ultrametamorphism. Allen (1980) suggests that the uranium and pegmatites

originated in an arkosic unit overlying the unconformity separating Archean(?) from late Proterozoic rocks.

Many workers have noted that the uraniferous pegmatites have some replacement textures and that mineralization is in cataclastic zones and along pegmatite margins. Masson and Gorden (1979) have suggested that uranium concentration occurred during a hypogene deformational-hydrothermal event; uranium enriched fluids moved along tectonized zones in recrystallizing or recently crystallized pegmatites. This may explain the extensive hematitization of uraniferous pegmatites, the association of deformed pegmatites and uranium mineralization, and the fact that pegmatite ages are younger than the 1100-1200 m.y. age of granites and peak Grenville orogeny in Canada (Wynne-Edwards, 1972). The Mont Laurier pegmatites show few hydrothermal or alteration effects; this lack of hydrothermal effects correlates with low economic potential of the pegmatites. The idea of hydrothermal enrichment is compatible with either model, as the fluids could represent late stage anatectic or igneous activity.

Adirondack Pegmatites

Adirondack uraniferous pegmatites are in the Grenville Province, as are the Canadian pegmatites. Two are in marble of the Grenville Complex in the Adirondack Lowlands (fig. 1); they are, however, east of the Bancroft-Mont Laurier belt. The other pegmatites are in the Adirondack Highlands and are associated with granulite facies gneisses and intrusive rocks. The Port Leyden area contains a cluster of radioactive occurrences of pegmatites and uraniferous lenses and segregations (fig. 1), and is analogous to the Bancroft area with its concentration of pegmatites and scattered metasomatic or stratabound uranium occurrences.

By analogy with productive districts in Canada, the Adirondack Lowlands have the most potential for uraniferous pegmatites. The existence of two uraniferous pegmatites in the region supports this hypothesis; the scarcity of discovered radioactive pegmatites may only reflect the dense vegetation and the lack of intense exploration efforts. The lowlands consist of carbonate-rich metasediments, which are the eastern extension of the Canadian carbonates, and granitic intrusions. Hypothesized uraniferous strata underlying Canadian pegmatites could also be present in the Adirondacks. There are, however, important differences between the Canadian and Adirondack metasedimentary belts, including the lack of late alkaline intrusions in the Adirondacks and the absence of identified basement rocks in the region.

The general lack of uraniferous pegmatites in the Adirondack Highlands suggests an original scarcity of uraniferous strata or intrusions, a stratigraphically different position than the metasedimentary uraniferous sections, or escape of uranium from the rocks during the extreme metamorphism which affected the area. The few pegmatites that do occur are located along the margins of the Adirondacks. There are no uranium occurrences associated with the core complex. The Port Leyden area is enigmatic, in that it is uraniferous and is within the Adirondack Highlands. Small, spherical uraninite grains are common in sphene and apatite-rich rocks (table 2), and are generally associated with clinopyroxene and sphene; these relations are similar to the occurrence of uraninite in rocks of the Hudson highlands (Grauch, 1978; oral commun., 1980).

It is unlikely that Adirondack uraniferous pegmatites could be economically developed. The Canadian pegmatites are profitable only where they occur in swarms and can be mined concurrently. The known Adirondack uraniferous pegmatites are scattered, even in the uraniferous Port Leyden

Table 2.--Sample descriptions and U and Th analyses

[Sample localities are shown on figure 1. U and Th determined by delayed neutron activation analysis by H. T. Millard of the U.S. Geological Survey]

Sample Locality	Rock Type	U(ppm)	Th(ppm)
1	leucogranitic gneiss[1]	4.93	36.2
1	uraninite-sphene-clinopyroxene pegmatite[2]	1420	<330
1	uraninite-sphene-quartz-clinopyroxene-feldspar gneiss[3]	2380	<540
1	uraninite-apatite-sphene-biotite-feldspar-quartz gneiss[4]	1230	<300
2	leucogranitic gneiss[5]	9.08	69.4
2	tourmaline pegmatite[6]	2.15	266
3	leucogranitic gneiss[7]	1.84	16.0
4	leucogranitic gneiss[8]	3.66	28.7

[1]Representative sample of leucogranitic gneiss.

[2-4]Pegmatite and interlayered gneiss occur in an area approximately 3x5 meters. Radioactivity is discontinuous, and is commonly associated with K-spar-rich segregations along foliation.

[5]Representative tourmaline-rich leucogranitic gneiss from the complex of Boyd Pond.

[6]Tourmaline pegmatite in the leucogranitic gneiss.

[7]Representative leucogranitic gneiss from Lampsons Falls.

[8]Representative leucogranitic gneiss from Alexander Bay.

area. Considering the private land and park status of much of the Adirondack region, the fact that there are no nearby processing mills, and the low tonnage of pegmatites, it appears neither practical nor profitable to explore for uraniferous pegmatites.

Unconformity-type Deposits

There are no known unconformity-type uranium occurrences within the Grenville Province. There is, however, a regional unconformity separating Adirondack Precambrian rocks and the surrounding Paleozoic rocks, and there may be unconformities within the Precambrian section. Since Precambrian unconformity-type deposits contain important reserves in Canada and Australia, this paper will examine the possibility of such an occurrence in the Adirondacks, using the criteria of Kalliokoski and others (1978). Kalliokoski and others (1978) emphasize that unconformity-related deposits occur near regional unconformities separating an older metamorphic terrain and an overlying thick sandstone unit. The metamorphic rocks are Archean to middle Proterozoic gneisses and schists of marine origin. The overlying unmetamorphosed sandstone units are middle to late Proterozoic in age, and were deposited in a fluvial environment.

The Precambrian-Paleozoic unconformity is similar to uraniferous unconformities in that it is regional in extent and is the contact between a metamorphosed carbonate-bearing marine sequence and an overlying thick sandstone unit. There are also important differences; the overlying Potsdam Sandstone is Cambrian, not Proterozoic, and is of shallow marine origin, not continental fluvial (Selleck, 1980). These characteristics and the lack of known uranium anomalies associated with the unconformity indicate it is not a favorable uranium environment.

Recent work in the Adirondacks suggests there may be unconformities within the Precambrian metamorphic sequence (Walton and deWaard, 1963). The evidence for unconformities is equivocal, but metamorphism may have obscured the features and affected isotope dates. Any unconformity-type mineralization in the Adirondacks would have been metamorphosed and probably remobilized during the Grenville orogeny. The lack of uranium anomalies in the highlands suggest it is improbable that a remobilized deposit underlies the terrain. In addition, meta-sandstone units of the Grenville Complex are commonly interlayered with carbonates and are thought to be of marine, not fluvial, origin. It is concluded that the occurrence of unconformity-type uranium deposits is unlikely, although not impossible. Further work on this uranium environment would be facilitated by definite identification of unconformities.

Leucogranitic Gneiss

The leucogranitic gneiss unit of the Adirondacks is the subject of much debate. Buddington and Leonard (1962) thought the unit was a volatile-rich, late stage granitic differentiate, but a volcanogenetic origin has recently been proposed by Carl and Van Diver (1975). Either environment is favorable for uranium enrichment, as late-stage differentiates are known to be enriched in uranium and Grauch (1978) has proposed a volcanogenetic model for uranium concentration in the Hudson Highlands. However, chemical analyses show that although the leucogranitic gneisses have high thorium content, there is no uranium enrichment (table 2). This suggests that the leucogranitic gneiss was originally low in uranium or that uranium has been lost from the rocks.

Magnetite Ore

Uranium is associated with magnetite deposits in the Adirondack Highlands, where it is usually found with rare-earth-bearing minerals such as apatite or allanite (fig. 1). Uranium is not present in high concentrations in these magnetite bodies. The occurrences are interesting in that they are similar to magnetite-uranium associations in the Hudson Highlands where ore-grade concentrations of uranium do occur (Grauch, 1978).

CONCLUSION

The amphibolite to granulite facies terrain of the Adirondacks is similar to that of uraniferous regions in Canada and in the Hudson Highlands, and anomalously high concentrations of uranium are found in pegmatites and in magnetite deposits in the Adirondacks. There are not, however, any known large uranium deposits in the Adirondacks. It may be that the small uranium occurrences are indicative of vein-type or stratabound uranium concentrations at depth. It is thought, however, that there is a lack of large uranium concentrations in the Adirondacks, which suggests that the Adirondack region was originally impoverished in uranium, that uranium escaped from the rocks during the high grade metamorphism, that uraniferous rocks have been eroded, or that some process affecting and enriching the other Precambrian regions did not occur in the Adirondacks. It is concluded that although uranium concentrations are present, they are too small to be developed.

REFERENCES

Allen, J. M., 1980, Uraniferous migmatites near Mount Laurier, Quebec: Econ. Geol., in press.

Bateman, J. D., 1955, Recent uranium developments in Ontario: Econ. Geol., v. 50, p. 361-372.

Berning, J., Cooke, R., Hiemstra, S. A., and Hoffman, U., 1976, The Rossing uranium deposit, South West Africa: Econ. Geol., v. 71, p. 351-368.

Bright, E. G., 1976, Cavendish and Anstruther Townships, Peterborough County, in Milne, V. G., Cowan, W. R., Card, K. D., and Robertson, J. A., eds., Summary of field work, 1976, by the Geological Branch: Ontario Div. Mines, MP67, p. 122-126.

Brown, C. E., 1980, Differential deformation of the Grenville Complex and its basement in St. Lawrence County, New York: U.S. Geological Survey Professional Paper 1150, in press.

Buddington, A. F., and Leonard, B. F., 1962, Regional geology of the St. Lawrence County magnetite district, northwest Adirondacks, New York: U.S. Geol. Survey Prof. Paper 376, 145 p.

Carl, J. D., and Van Diver, B. B., 1975, Precambrian Grenville alaskite bodies as ash flow tuffs, northwest Adirondacks, New York: Geol. Soc. America Bull., v. 86, p. 1691-1707.

Doig, R., Rb-Sr geochronology and evolution of the Grenville province in northwestern Quebec, Canada: Geol. Soc. America Bull., v. 88, p. 1843-1856.

Engel, A. E. J., and Engel, C. G., 1958, Progressive metamorphism and granitization of the major paragneiss, northwest Adirondack Mountains, New York; Part 1, Total rock: Geol. Soc. America Bull., v. 69, p. 1369-1414.

Evans, A. M., 1964, Geology of the Bicroft uranium mine, Ontario: Canadian Mining Journal, v. 85, p. 106-107.

Fowler, A. D., and Doig, R., 1979, Origin of uraniferous granitoids, Grenville Province, Quebec and Ontario: Geol. Assoc. Canada, Program with Abstracts, v. 4, p. 51.

Gorden, J. G., and Masson, S., 1977, Uranium and thorium deposits, _in_ Milne, V. G., White, O. L., Barlow, R. B., and Robertson, J. A., eds., Summary of field work, 1977, by the Geological Branch: Ontario Geol. Surv., MP75, p. 192-194.

______1978, Uranium and thorium deposits, _in_ Milne, V. G., White, O. L., Barlow, R. B., and Robertson, J. A., eds., Summary of field work, 1978, by the Geological Branch: Ontario Geol. Surv., MP82, p. 181-185.

Grauch, R. I., 1978, Geology of the uranium prospect at Camp Smith, New York, with a new model for the formation of uranium deposits in metamorphosed submarine volcanogenic rocks: U.S. Geol. Survey Open-File Report 78-949, 29 p.

Grauch, R. I., and Zarinski, K., 1976, Generalized descriptions of uranium-bearing veins, pegmatites, and disseminations in non-sedimentary rocks, eastern United States: U.S. Geol. Survey Open-File Report 76-582, 114 p.

Hauseux, M. A., 1977, Mode of uranium occurrence in a migmatitic granite terraine, Baie Johan Beetz, Quebec: Canadian Inst. Mining and Metallurgy Bull., v. 70, p. 110-116.

Kalliokoski, J., Langford, F. F., and Ojakangas, R. W., 1978, Criteria for uranium occurrences in Saskatchewan and Australia as guides to favorability of similar deposits in the United States: Grand Junction, U.S. Dept. of Energy, Report GJBX-114, 480 p.

Little, H. W., 1974, Uranium deposits in Canada-their exploration, reserves and potential: Canadian Inst. Mining and Metallurgy Bull., v. 67, p. 155-163.

Little, H. W., Smith, E. E. N., and Barnes, F. Q., 1972, Uranium deposits of Canada: XXIV Int. Geol. Cong. at Montreal, guidebook to excursion C67, 64 p.

Lumbers, 1975, Pembroke area, District of Nipissing and County of Renfrew, in Milne, V. G., Hewitt, D. F., Card, K. D., and Robertson, J. A., eds., Summary of field work, 1975, by the Geological Branch: Ontario Div. Mines, MP63, p. 91-93.

Mackie, B., 1978, Petrogenesis of the Lac Turgeon Granite and associated uranium occurrences near Baie Johan Beetz, Quebec: Econ. Geol., v. 73, p. 1408.

Masson, S., and Gorden, J. B., 1979, Uranium mineralization and its control in the immediate Bancroft area, in Milne, V. G., White, O. L., Barlow, R. B., and Kustra, C. R., eds., Summary of field work, 1979, by the Ontario Geological Survey: Ontario Geol. Surv. MP90, p. 190-191.

Robinson, S. C., 1960, Economic uranium deposits in granitic dykes, Bancroft district, Ontario: Canad. Mineralogist, v. 6, p. 513-521.

Romey, W. D., Elberty, W. T., Jr., Jacoby, R. S., Christoffersen, R., Shrier, T., and Tietbohl, D., 1980, A structural model for the northwestern Adirondacks based on leucogranitic gneisses near Canton and Pyrites, New York: Geol. Soc. America Bull., Part II, v. 91, p. 505-588.

Ruzicka, Vladimir, 1979, Uranium and thorium in Canada, 1978: in Current research, part A, Geol. Surv. Can., Paper 79-1A, p. 139-155.

Satterly, Jack, 1956, Radioactive mineral occurrences in the Bancroft area: Ontario Depart. of Mines, v. 65, part 6, 181 p.

Selleck, B. W., 1980, The post-orogenic history of the Adirondack Mountain region: a review: Geol. Soc. America Bull., v. 91, p. 120-124.

Silver, L. T., 1969, A geochronologic investigation of the Adirondack complex, Adirondack Mountains, New York, in Isachsen, Y. W., ed., Origin off anorthosite and related rocks: New York State Museum and Science Service Memoir 18, p. 233-252.

Walton, M. S., and de Waard, Dirk, 1963, Orogenic evolution of the Precambrian in the Adirondack highlands, a new synthesis: Koninklijke Nederlandse Akademie van Wetenschappen Proceedings, Ser. B, v. 66, no. 3, p. 98-106.

Wynne-Edwards, H. R., 1972, The Grenville Province, in Price, R. A., and Douglas, R. J. W., eds., Variations in tectonic styles in Canada: Geol. Soc. Canada, Spec. Paper 11, p. 264-334.