GEOLOGIC AND RADIOMETRIC SURVEY OF THE CLARENDON SPRINGS AND HIGHGATE FORMATIONS AT THE O'BRIEN FARM, HIGHGATE SPRINGS, VERMONT

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Table of Contents

1. INTRODUCTION

The purpose of this study was to conduct a ground survey of radiometric anomalies located on the O'Brien farm in Highgate Springs, Vermont, and to determine the rock types associated with these anomalies. High concentrations of radioactive material have been detected by several previous studies (see References Cited, p.11).

2. METHODS AND RADIOMETRIC DATA

This study covers approximately 115 acres of the O'Brien farm and a small portion of the Roland Fortin farm (see Figure 1). Methods of study include the following: 1) A grid system was set up and radiometric readings were taken at predetermined intervals using a gamma ray spectrometer. All single underlined numbers on the Geologic and Radiometric map represent the arithmetic mean of five one-second total count readings with the spectrometer held at waist level. At points of anomalous radioactivity, ten-second readings were taken for total count, as well as Potassium (K), Uranium (U), and Thorium (Th). The longer counts were taken so that a radioelement assay could be performed, and were obtained with the spectrometer at both waist level and on the outcrop, as indicated on the map. 2) A detailed geologic map was compiled on the same grid system. The results of the above are presented in the Geologic and Radiometric Survey Map of this report (see Plate 1).

Our field work confirmed all of the anomalies shown on Figure 1, as well as one that does not appear on this map. Figure 1 is a map from a proposed drilling project prepared by Bendix Field Engineering Corporation for U.S.E.R.D.A.-N.U.R.E. project. Table 1 contains analytical data obtained by previous workers for the Clarendon Springs Formation near the O'Brien/Fortin boundary at the Canadian border. Table 2 is an average of one- and ten-second total count readings that were taken for each lithology in the study area. The data in Table 2 shows that the radiometric anomalies are associated with the dolomitic phosphorite breccia of the Clarendon Springs Formations. Table 3 is a list of anomalous radiometric and radioelement readings, along with the measured analytical data which were obtained from numbered localities in this study.

3. STRATIGRAPHY

Clarendon Springs Formation

The Clarendon Springs Formation in the Highgate Springs area has been designated by Pingree (1982) as the upper dolomite member of the Upper Cambrian Gorge Formation. Two important facies in the Clarendon Springs Formation are recognized in this study: 1) a homogenous bioturbated dolospar and 2) a dolomitic phosphorite breccia.

Bioturbated Dolospar

This unit is a massively bedded homogenous light to dark gray, coarse grained dolospar, commonly with beds of medium to coarse grained sand floating in the dolospar. Burrows are sometimes observed (both horizontal and vertical), most commonly as elongate light gray sandy pockets in a darker dolospar matrix. Burrows are up to 1 inch long. The bioturbated dolospar also contains distinctive nodules of chert and coarse recrystallized quartz, both of which stand out from weathered surfaces. The dolospar weathers to a brown or dark gray color with a thin (roughly 1/16 inch) outer rind. This unit appears to be more predominant in lower parts of the Clarendon Springs Formation, but breccia horizons have been observed throughout the Clarendon Springs in the study area.

Dolomitic Phosphorite Breccia

This is a highly variable unit which is recognized by the presence of dark gray and black clasts in a sandy dolospar matrix similar to that of the bioturbated dolospar. The clasts range in composition from shale to silty phosphorite to chert. Clasts of limestone and sandy dolospar have also been observed. The size of clasts ranges from 1/4 inch to 2 feet in diameter. Bedding is chaotic, with rare beds of silty and shaley phosphorite which terminate abruptly against the matrix and other clasts. Phosphorite beds and clasts show a distinctive white weathering surface which in some places has a sponge-like appearance. Yellowish-brown weathering is also sometimes associated with the silty phosphorite, and is presumably a by-product of uranium. Geochemical and petrographic analyses of the breccia show that Uranium has substituted for calcium in the hydroxylapatite [Ca5 (PO4)3 OH] structure (Lucius Pitkin, 1975). The dolomitic phosphorite breccias are consistently associated with high radiometric anomalies.

Quartz and chert nodules also occur in the breccia, as do pyrite and chaotic shale laminations. The breccia facies is further divided into a "sparse" breccia, containing only rare and scattered clasts, and a "dense" breccia which is dominated by clasts. The highest anomalies appear to occur in the "dense" breccias, where the highest concentrations of uranium-bearing phosphorite are found.

The contact with the overlying Highgate Formation is not completely exposed, but is marked by a laminated calcareous siltstone which is identical on fresh surfaces to other laminated units in the Highgate. It is distinguished however, by a 1 to 2 inch thick punky brown weathering zone which may be responsible for the general lack of outcrops along this stratigraphic horizon. Within the lower 10 to 15 feet of this transitional zone near the phosphorite breccia in the quarry, the weathered surface of the punky siltstone shows a whitish coloration which is probably due to the presence of phosphorite. The Clarendon Springs - Highgate transition occurs over an interval estimated at 30 to 50 feet thick.

Maps by Shaw (1958) and Pingree (1982) show a thrust fault separating the Clarendon Springs and Highgate Formations. No textural, structural, or stratigraphic evidence for such a fault has been found in this study. Instead, intermediate and transitional lithologies are seen to occur near the contact. Thus, the Clarendon Springs - Highgate contact is reinterpreted here as depositional and gradational in nature.

Highgate Formation

Three important facies have been documented for the Lower Ordovician Highgate Formation within the study area. They are: 1) a laminated calcareous siltstone, 2) a dolomitic limestone breccia, and 3) an argillaceous dolomite.

Laminated Calcareous Siltstone

This is a thinly laminated unit containing alternating bands of: A) medium grained dolomitic or limey sandstone, white to light gray fresh surface and tan brown or dark gray weathered surface; B) fine grained black silty micrite, light gray weathered surface; and C) thin black horizons of shale and silt which commomly stand out from weathered surfaces. The interlamination of dolomite and limestone beds is thought to be due to preferential dolomitization of coarser sandy horizons. Bed thickness ranges from 1/16 to 1 inch thick, with the silty shale layers generally thinner than the dolomitic sandstone and silty micrite beds. Weakly developed graded beds have been observed, suggesting that the laminated siltstone unit is a sequence of turbidite deposits representing off-shelf down slope slumping of unlithified carbonate shelf sediments.

This unit commonly exhibits limited amounts of broken up bedding where it grades into the breccia facies. One penecontemporaneous fault was found in which tabular clasts of the black silty micrite are oriented parallel to the fault surface, with a sandy dolomite matrix surrounding the micrite clasts. This is interpreted to represent block faulting in the unit shortly after deposition and partial lithification, in an unstable shelf edge and slope environment.

Variations in the laminated unit include dark homogenous calcareous siltstones that show little or no banding, and highly shale-rich siltstones that break easily along bedding and cleavage planes. The weathering rind of this unit is restricted to a thin (1/16 inch) zone, except at the base of the unit as described above.

Dolomitic Limestone Breccia

This facies occurs as discontinuous lenses within the laminated unit, and is distributed randomly throughout the Highgate Formation in the study area. It contains the same lithologies as the laminated unit, but in a brecciated or rarely a conglomeratic form. The breccia consists of tabular clasts of the silty micrite which are angular and roughly parallel to bedding planes, supported by a fine to medium grained sandy dolomite matrix. The matrix also occurs as a sandy limestone in some places, and includes rare shale pockets. Thus, continuous lateral gradations occur between the laminated and brecciated units where they are distinguished solely by textural parameters.

In one place the limestone breccia was found to occur as a limestone conglomerate containing lenticular blocks of fossiliferous limestone up to 3 feet long. These blocks contain abundant shell fragments and are supported by the darker sandy dolomite matrix.

Argillaceous Dolomite

The argillaceous dolomite occurs in only one place in the study area where it grades into both the laminated and breccia facies. It consists of a dark gray silty argillaceous dolomite with weakly developed light and dark gray bedding laminations. The presence of high amounts of shale in this unit results in a well developed cleavage which is generally not as strong in other facies. Weathered surfaces are a distinctive tan brown color with a rusty brown weathering zone up to 1/8 inch thick.

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Table 1. Analytical data obtained by previous workers from the Clarendon Springs Formation in the study area.

Rio Tinto Canadian Exploration, Ltd. -----	U_3O_8 = .46 lbs./ton
Lucius Pitkin, Inc. ----------	U_3O_8 = 317 ppm, ThO_2 = 34 ppm
Grauch & Zarinski ----------------------	U = 0.032%

Table 2. Average values for one- and ten- second total count radiometric readings in each lithology (taken with geiger counter at waist level). CPS = counts per second.

Highgate Formation:	
Argillaceous Dolomite----------------	26 cps
Limestone Breccia--------------------	26.2 cps
Laminated Calcareous Siltstone-------	25.6 cps
Clarendon Springs Formation:	
Phosphorite Breccia------------------	113.3 cps
Bioturbated Dolospar-----------------	49.5 cps

Table 3. Anomalous radiometric and radioelement readings, and measured analytical data. TC=Total Count, K=Potassium, U=Uranium, Th=Thorium. Readings are in counts per second, except where other units are given. (For accuracy in computing the % and ppm, the background radiation listed at the bottom of each location was subtracted from the actual reading for computation.)

Field Location #1:

	waist level	on bedrock
TC	130.8 cps	458.1 cps
K	6.0 cps = -2.40%**	22.0 cps = -5.16%**
U	4.6 cps = 45.94 ppm	18.9 cps = 232.92 ppm
Th	1.0 cps = -3.62 ppm**	0.9 cps = -42.06 ppm**

(background: TC=27.2; K=3.6; U=0.9; Th=0.8)

Field Location #2:

	waist level	on bedrock
TC	211.8 cps	380.4 cps
K	8.0 cps = -3.27% **	16.7 cps = -1.93%**
U	6.6 cps = 75.72 ppm	12.1 cps = 142.90 ppm
Th	0.5 cps =-18.40 ppm**	0.9 cps = -20.91 ppm**

(background: TC=33.9; K=3.9; U=0.9; Th=0.65)

Field Location #3:

	waist level	on bedrock
TC	82.8 cps	99.6 cps
K	4.8 cps = -1.44% **	9.7 cps = 1.87%
U	3.2 cps = 28.60 ppm	4.3 cps = 42.90 ppm
Th	0.7 cps = 5.48 ppm	0.6 cps = -8.22 ppm **

(background: TC=30.1; K=3.4; U=1.0; Th=0.7)

Field Location #4:

	waist level	on bedrock
TC	85.0 cps	163.4 cps
K	3.8 cps = -1.14%**	8.0 cps = -1.29% **
U	2.2 cps = 15.60 ppm	5.5 cps = 58.50 ppm
Th	0.3 cps = -2.99 ppm**	0.0 cps = -11.21 ppm **

(background: TC=30.1; K=3.4; U=1.0; Th=0.7)

Field Location #5: *

	waist level	on bedrock
TC	NO READINGS TAKEN.	156.0 cps
K		7.5 cps = -.26 %**
U		5.4 cps = 59.33 ppm
Th		0.1 cps = -32.12 ppm **

(background: TC=30.1; K=3.4; U=1.0; Th=0.7)

Field Location #6:

	waist level	on bedrock
TC	NO READINGS TAKEN.	79.5 cps
K		5.6 cps = 2.56%
U		1.7 cps = 5.84 ppm
Th		0.6 cps = -8.90 ppm **

(background: TC=30.1; K=3.4; U=1.0; Th=0.7)

*These readings were taken from a hole in the cliff where it looked like samples had been taken.

**Negative numbers indicate that a negligible amount of that element is present (Reference: EG&G Geometrics, makers of spectrometer).

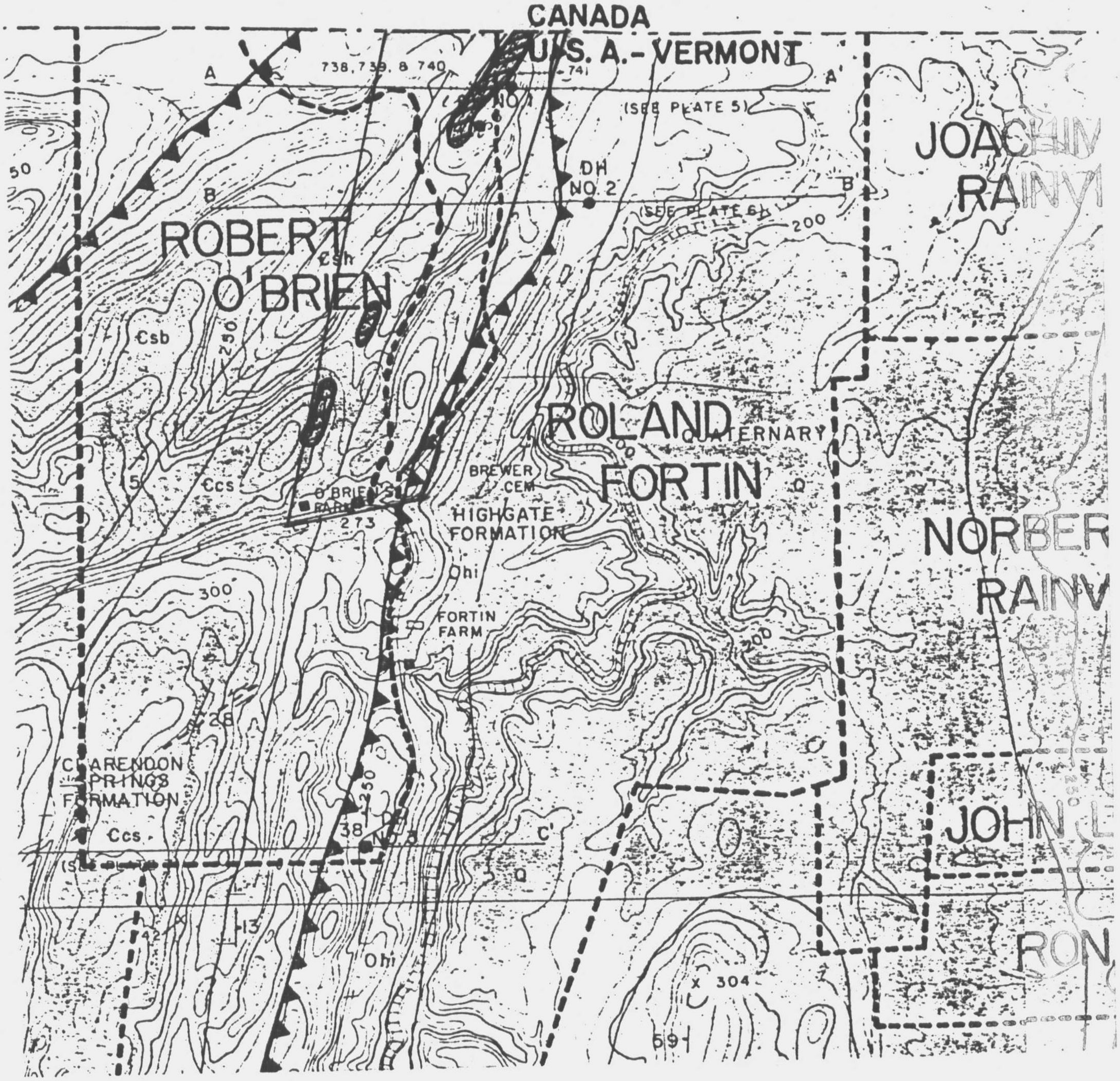

Figure 1. Map from proposed drilling project prepared by Bendix Field Engineering Corporation for U.S.E.R.D.A.-N.U.R.E. project (in bibliography under Rio Tinto, 1972).

Anomalous areas noted from above project.

Approximate placement of road/jeep trail.

Approximate outline of study area.

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Th		0.1 cps = -32.12 ppm **

(background: TC=30.1; K=3.4; U=1.0; Th=0.7)

Field Location #6:

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TC	NO READINGS TAKEN.	79.5 cps
K		5.6 cps = 2.56%
U		1.7 cps = 5.84 ppm
Th		0.6 cps = -8.90 ppm **

(background: TC=30.1; K=3.4; U=1.0; Th=0.7)

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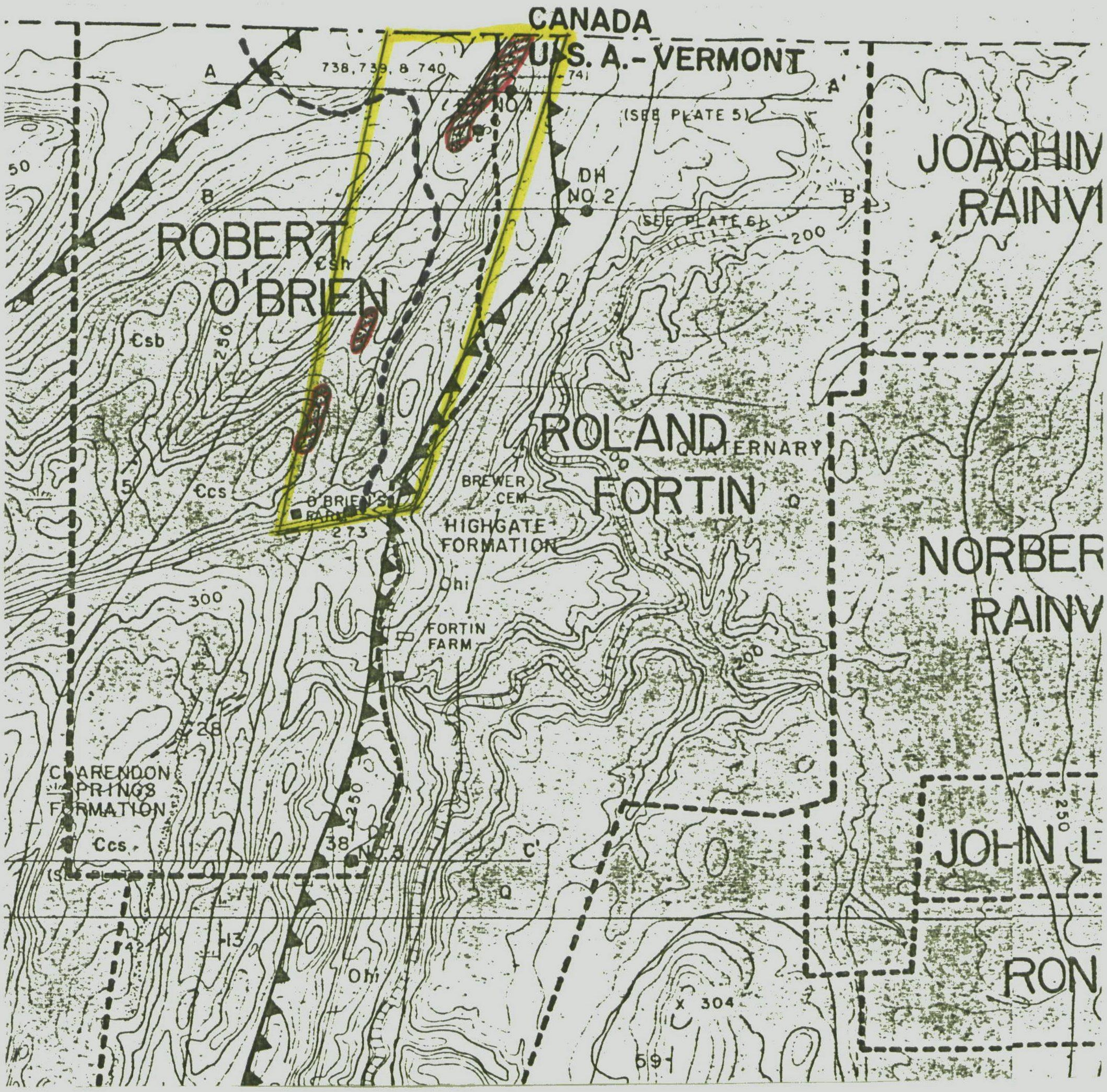

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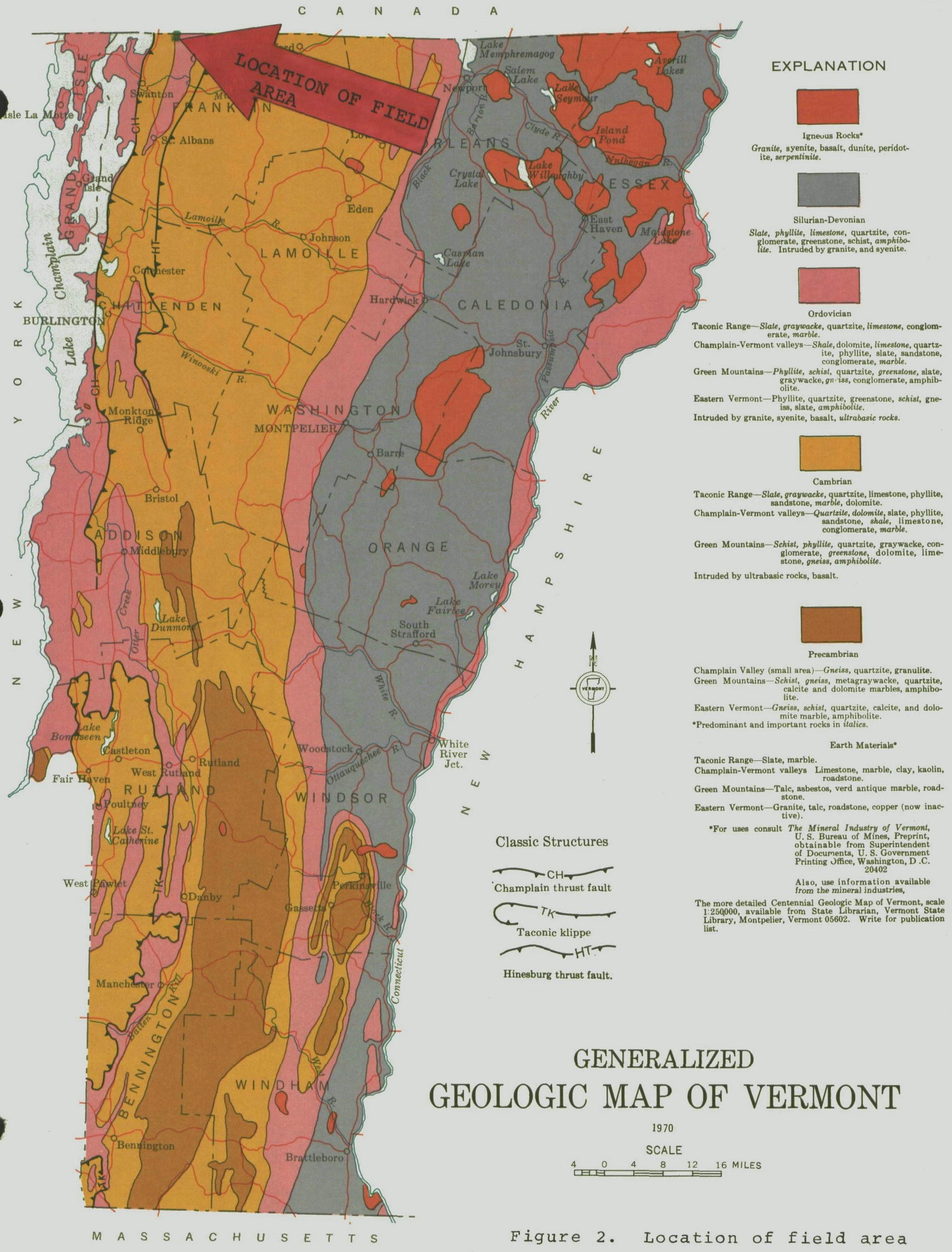

Figure 2. Location of field area

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