A PRELIMINARY STUDY ON THE SUITABILITY OF INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA) FOR IDENTIFYING HATHAWAY FORMATION CHERT FROM THE NORTHERN CHAMPLAIN VALLEY OF VERMONT

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This preliminary study provides an overview of the Hathaway formation chert of the Champlain Valley, as well as two Native Americans quarries that are located within it. Using geochemical analysis the authors attempt to determine the most likely source of debitage recovered at a nearby lithic scatter. The resulting conclusion is examined from a geographic standpoint, and the authors propose the existence of a natural travel corridor connecting two high-resource-yield areas, the lithic scatter, and the known quarry district. This testable hypothesis helps to explain the existence, location, and cultural significance of the lithic scatters in the area, and provides direction for future research.

INTRODUCTION

Lithic artifacts are commonplace on pre-Columbian Native American sites in the Northeast, and the confident identification of potential sources would greatly contribute to our understanding of Native American travel corridors and trade networks. A wide variety of lithic materials suitable for stone tool manufacture crop out within New England. Chert, quartzite, rhyolite, and quartz, as well as a variety of metamorphic rocks were commonly used by Native Americans for flaked stone tools. Many tools or flakes are not easily identified by macroscopic examination (Calogero 1992, 1995; Luedtke 1996). Macroscopic identification techniques are problematic, resulting in widespread confusion among regional archaeologists about the potential sources of these lithic artifacts (Luedtke 1996).

Archaeologists in New England increasingly utilize petrographic (Calogero 1995, 2002; Hermes and Ritchie 1997a; Pollock 1987; Pollock et al. 1999) and geochemical (Burke 1997, 2000; Hermes and Ritchie 1997b; Jarvis 1998; Kuhn and Lanford 1987) methods to help resolve the "chaos" described by Luedtke (1996). Despite the availability of these options, macroscopic identification remains the primary method to identify lithic artifacts in Vermont, as well as in much of the Northeast. This method of lithic sourcing is often inconclusive (Calogero 1992; Luedtke 1992).

Most archaeological projects within Vermont are undertaken by Cultural Resource Management (CRM) firms working on a relatively restricted budget, and are oriented toward compliance with legal regulations. This emphasis on site-centric archaeology has led to the identification of many small sites described in technical reports, but rarely allows for meaningful analysis of cultural patterns. As part of a compliance-oriented project, the archaeologist must also piece together the historic context of an identified site – a task that can be difficult when analyzing small sites with minimal artifact inventories.

Sites that contain a high percentage of lithic debitage and little else, so-called 'lithic scatters,' present a dilemma for the archaeologist seeking to develop a historic context. Often, these sites contain few, if any, diagnostic artifacts, identifiable features, or faunal remains. When interpreting this site type, archaeologists must expand their study to examine what role these sites play within the resource procurement patterns of Native American populations. A recent partial excavation of a Native American campsite containing evidence of post-quarry lithic reduction in St. Albans, Vermont provides an opportunity to test whether instrumental neutron activation analysis (INAA), a method of geochemical analysis, can be successfully employed to characterize and discriminate between chert sources in the northern Champlain Valley of Vermont.

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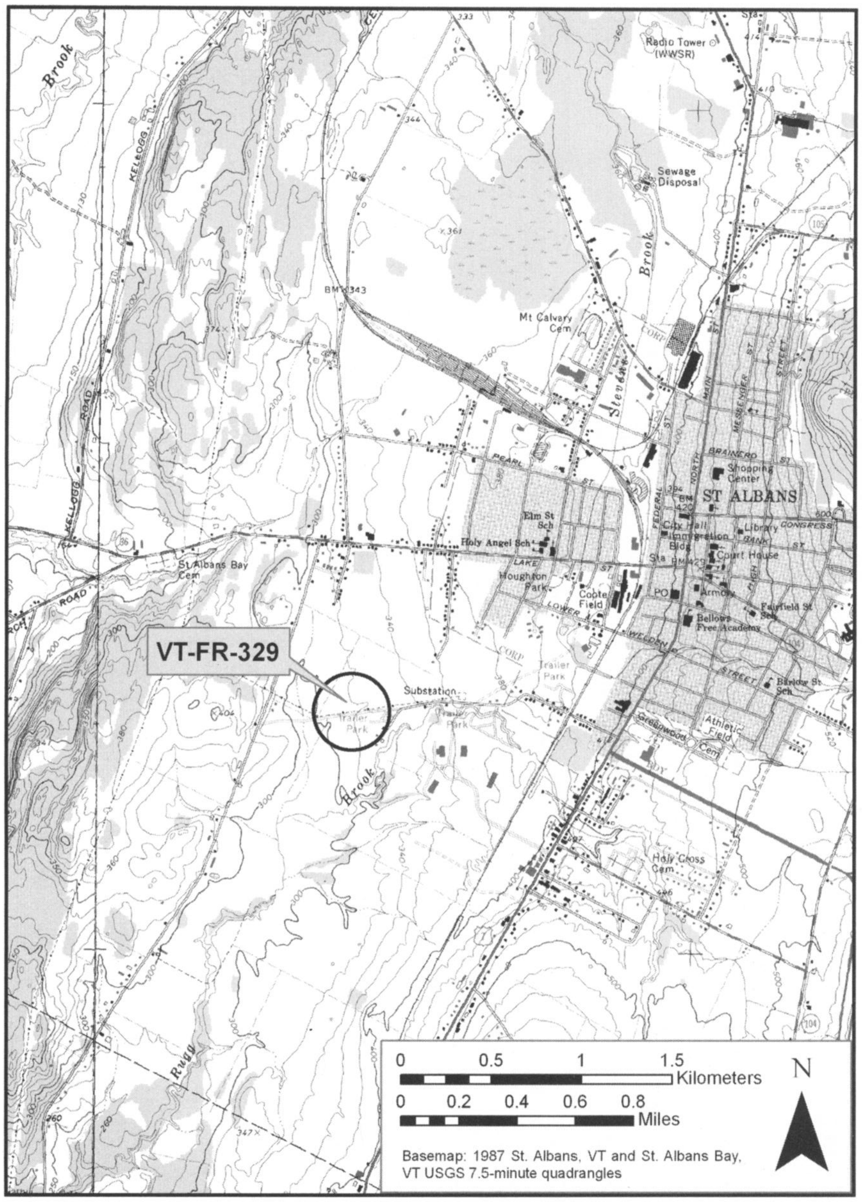


Figure 1. Location of VT-FR-329 (Nason Road Site), in the Town of St. Albans, Franklin County, Vermont.

SUMMARY OF STUDIES AT VT-FR-329

During a Phase I (archaeological site identification) study associated with a proposed natural gas pump station, Archaeology Consulting Team, Inc., of Essex Junction, Vermont (ACT) identified a Native American archaeological site, designated VT-FR-329 (Figure 1). Vermont Gas Systems, Inc. of South Burlington, Vermont relocated the proposed pump station to the south of VT-FR-329. However, the pipeline associated with the station could not be re-routed to avoid the site. A subsequent partial Phase III (archaeological site mitigation) study consisted of a 1-meter by 72-meter excavation along the proposed pipeline route (Figure 2) (Frink and Hathaway 2005).

VT-FR-329 was identified on the basis of one core, four broken biface fragments similar to Stage 2 and 3 bifaces defined by Callahan (1979), and 29 flakes. The partial mitigation at VT-FR-329 resulted in the recovery of an additional 635 Native American lithic artifacts. As with the Phase I study, the majority of artifacts recovered during the Phase III study consisted of flakes, exhausted cores, and broken bifaces (Frink and Hathaway 2005). The majority of lithic materials recovered during both studies are black chert with gray to olive-gray mottling and banding. This chert appears (macroscopically) to be derived from the locally available Hathaway formation (Hawley 1957, 1969).

The nature of the artifact assemblage from VT-FR-329 suggests that the site was a lithic processing station associated with nearby quarry activity. Two major activities can be characterized from the artifact assemblage: the reduction of quarry ore into Stage 1-2 bifaces (rough blanks), and the finishing of bifaces into Stage 3-4 bifaces (pre-forms). Aside from one Levanna-style triangular projectile point made of quartzite, no other finished tools (projectile points, scrapers, etc.), utilized tools (retouched flakes, flakes showing use wear, etc.) or other artifacts (calcined bone, fire-cracked rock, etc.) were recovered from the site, suggesting that Native Americans limited their activities at VT-FR-329 almost exclusively to lithic reduction.

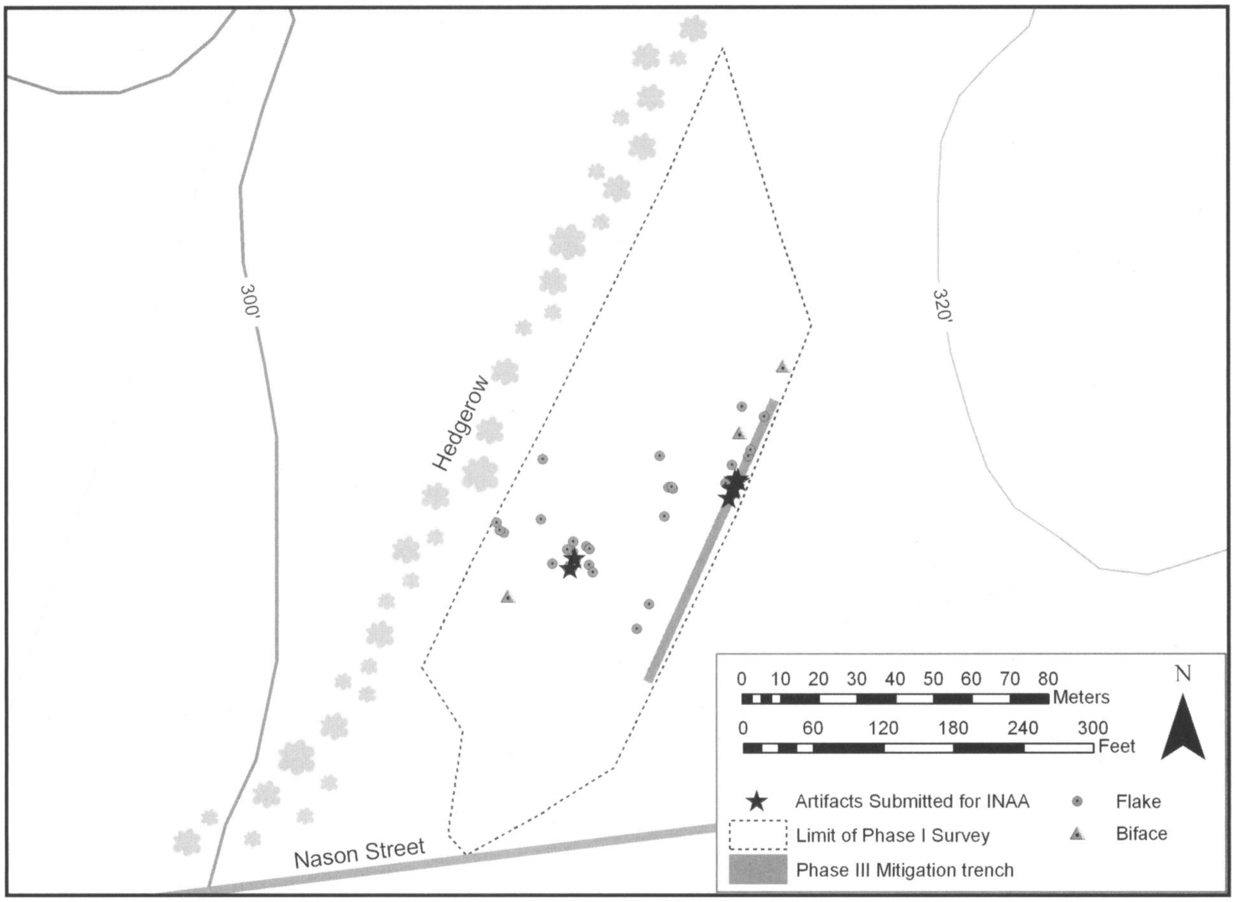


Figure 2. Plan of VT-FR-329 in the Town of St. Albans, Franklin County, Vermont. Star = artifacts submitted for INAA. Dot = flake. Triangle = biface. Dotted line is limit of Phase I survey. Dark gray line is Phase III mitigation trench.

POTENTIAL SOURCES

Vermont's Champlain Valley includes several possible sources for the chert recovered at VT-FR-329. The Middle Ordovician Hathaway formation (defined by Hawley [1957]) is the closest chert-bearing formation to the site, and at least two Native American quarries are located less than five kilometers (3.1 miles) away: VT-FR-2 (Brooks Farm Quarry) and VT-FR-22 (Lazy Lady Island) (Figure 3). In addition to these quarries, Hawley (1957, 1969) identifies several outcrops of the Hathaway formation, the closest being approximately six kilometers (3.7 miles) west of VT-FR-329.

Chert also occurs as thin beds, veins and nodules within the Lower Ordovician Cuttings formation (C-2 and C-4 members) and the Upper Cambrian/Lower Ordovician Clarendon Springs, Ticonderoga and Whitehall formations (Doll et al. 1961; Stone and Dennis 1964; Welby 1961). Chert from all of these formations is generally described as black to blue, sometimes mottled, and having a glassy luster.

The nearest known Clarendon Springs formation outcrop is approximately 25 kilometers south of VT-FR-329, and although numerous archaeological sites have been identified around this outcrop, no evidence of quarrying has been reported (Frink and Baker 1992). The Cuttings Formation outcrops approximately 40-50 kilometers south of VT-FR-329 at Thompson's Point in the Town of Charlotte (Welby 1961). The nearest known Native American quarry of the Ticonderoga and Whitehall formations is located at Mount Independence, approximately 60 kilometers south of VT-FR-329 (Loring 1985; Seidel et al. 1997).

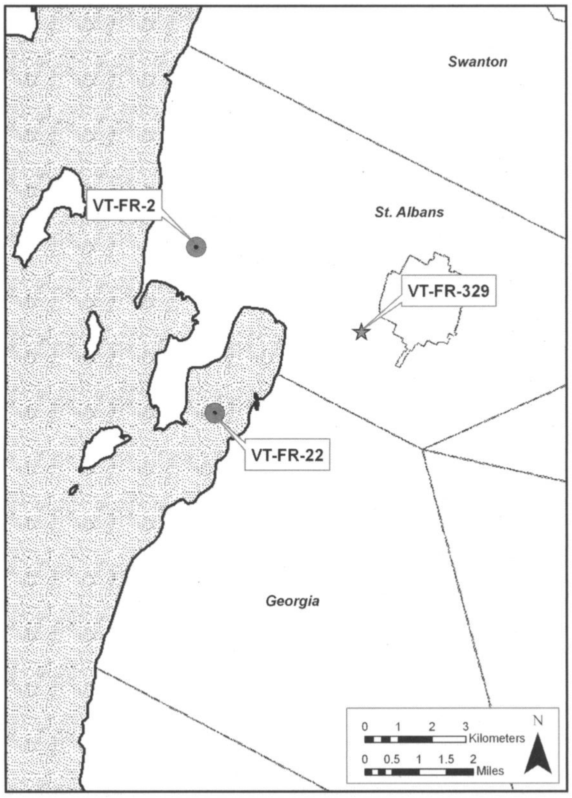


Figure 3. Location of potential Hathaway chert quarry sources (VT-FR-2 and VT-FR-22) and VT-FR-329.

Mottled, black to gray and olive green chert is also found within the Hudson Valley of eastern New York State. Various names (Normanskill, Deepkill, Coxsackie, and Mount Merino) are used by archaeologists to describe this chert; however, recent geological and archaeological investigations in the Hudson Valley (Brumbach and Weinstein 1999 and references therein) have shown that these names refer to chert originating in the Mount Merino formation of the Taconic Allochthon. Known quarries and outcrops of this formation are located approximately 150 kilometers south of VT-FR-329 (Brumbach 1987; Brumbach and Weinstein 1999; Hammer 1976; Kuhn and Lanford 1987; Wray 1948).

Macroscopically, the chert artifacts recovered from VT-FR-329 are generally black with grey and olive mottling and streaking. Mottles are generally common, and range from approximately 2 millimeters to 20 millimeters in diameter. When weathered, the chert exhibits a white to grey patina. These characteristics are consistent with chert found in the Hathaway formation of the northern Champlain Valley. The macroscopic similarities of the artifacts to Hathaway chert, together with the site's proximity to known Hathaway chert quarries, suggest that this formation is the most likely source of lithics encountered at VT-FR-329.

HATHAWAY FORMATION: DEPOSITIONAL HISTORY

The Hathaway Formation is a chaotic mélange that represents the uppermost member in the sequence of Ordovician shales in the Northern Champlain Valley (Figure 4). Older literature refers to the formation as a submarine slide breccia composed of pebble- to boulder-sized clasts of chert, limestone, dolomite, greywacke, and sandstone within a bedded radiolarian chert and deformed argillite (Hawley 1957).

Teetsel (1984) suggests that the Iberville shale underlying the Hathaway, and the Hathaway itself, formed in deep water (greater than 4 kilometers) from sediments deposited on the hinterland (eastern) side of the Taconic Foreland Basin. Coeval and later thrusting projected the Champlain (Rosenberg) and Highgate Springs thrust slices into, and over, the still-soft sediment. These thrust slices are believed to have eroded and crumbled into the still-soft sediment, resulting in mélange-type deposits (Teetsel 1984; Zen 1968).

More recent analysis of mélange and flysch (a bedded shale with interbedded conglomerate, greywacke and sandstone) deposits within the Taconic Foreland Basin reveals greater geologic complexity than has previously been recognized (Kidd et al. 1995; Rowley et al. 1979). Because of the intense faulting during the Taconic Orogeny, formations such as the Hathaway are more likely to represent "thrust slices of far-travelled continental rise sediments containing bedded chert (Taconic slices), or clasts in shaly melange zones, which are the thrust fault zones themselves" (W. Kidd, personal communication 2005) rather than conformable beds.

Whether derived from submarine slides, or in stratigraphic sequence within a thrust slice, both interpretations of the structural genesis of the Hathaway suggest that the formation derives from deep-sea sediment that has been largely displaced from the bottom of the Taconic Foreland Basin. Both interpretations imply the presence of chert derived from the same basin-bottom sediment throughout the Taconic Foreland Basin, which stretches from Quebec to Virginia.

Pollock (1987) analyzed thin sections of Hathaway chert for comparison to samples recovered from the Michaud site in Maine. He describes the chert as a mottled, very-fine grained radiolarian chert, with a micro- to cryptocrystalline groundmass. Detrital silt makes up less than five percent of the rock, and "rhombohedral grains of calcite locally replace the groundmass, but comprise less than 5% of the rock" (Pollock 1987: 212). Pollock notes that a major characteristic of the Hathaway samples is the presence of "burrow structures" that cause the mottled color observed in the chert.

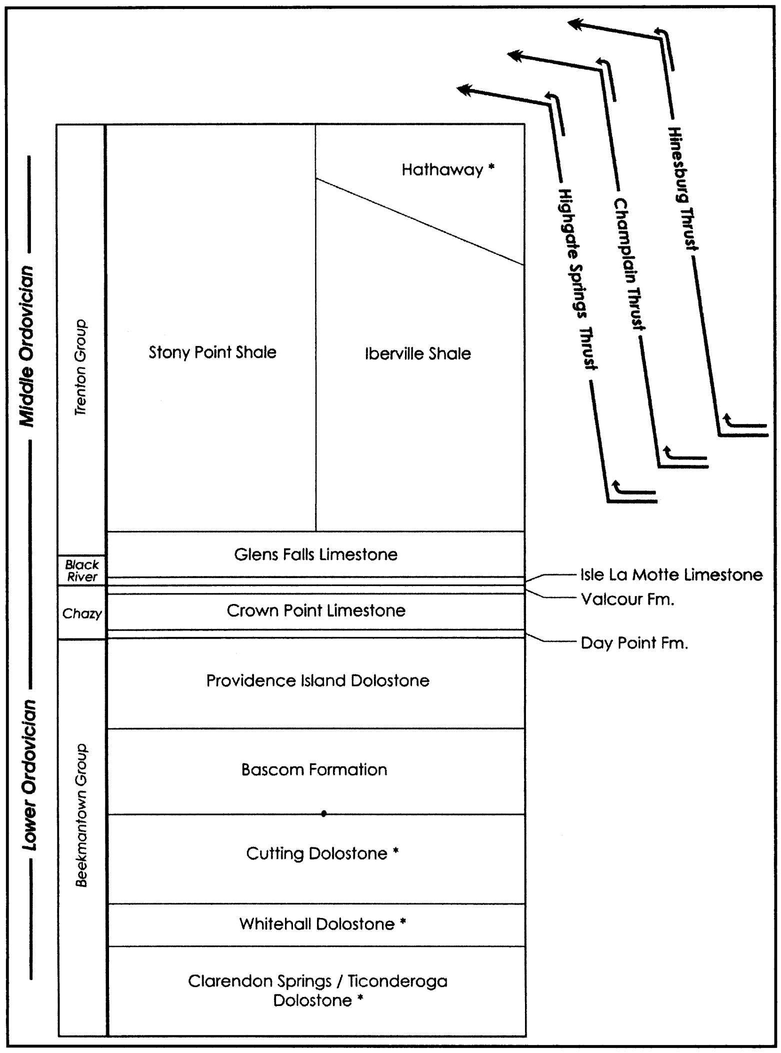


Table 4. General stratigraphic column of the autochthonous geological sequence of the northern and central Champlain Valley of Vermont. Asterisks indicate chert bearing formation (Baldwin 1982; Droll et al. 1961; Mehrtens and Borre 1989; Mehrtens and Dorsey 1987; Stone and Dennis 1964; Teetsel 1984; Van Diver 1987; Welby 1961).

HATHAWAY FORMATION: NATIVE AMERICAN CONTEXT

The Hathaway formation was an important source of high quality chert for Native Americans until European contact (Haviland and Power 1981; Loring 1972), and artifacts that appear to be Hathaway chert are commonplace on archaeological sites throughout the Champlain Valley (Vermont Division for Historic Preservation, 1969-present). Chert interpreted to be from the Hathaway formation, on the basis of macroscopic analysis, has been identified at sites dating to as early as the Paleoindian period in Vermont (Loring 1980; Ritchie 1953; Thomas et al. 1998) and further afield in New England at Paleoindian sites such as Michaud, Bull Brook, Bull Brook II, and Vail (Spiess and Wilson 1987). Pollock et al. (1999: 291) interpreted the majority of chert debitage at Michaud and other Paleoindian period sites as originating from the Munsungun Lake formation of northern Maine, although they note that some of the material unidentified in their analysis may have originated in the Hudson or Champlain valleys.

VT-FR-2 (Brooks Farm Quarry)

VT-FR-2, the Brooks Farm Quarry (Bolton 1930; Burke 1997; Eldred 1935; Haviland and Power 1981; Noel 1977; Paquin 1986; Ross 1932), is located in the town of St. Albans, Franklin County, Vermont. Recent publications describe VT-FR-2 as a small but prominent knoll. However, early accounts (Bolton 1930; Eldred 1935; Olsen 1936; Ross 1932) describe pit quarries in the farm fields surrounding the knoll.

The Brooks Farm Quarry has been known to amateur archaeologists and artifact collectors since the early 1900s (Bolton 1930; Eldred 1935; Olsen 1936; Ross 1932). Virtually no systematic study has been conducted at the site to date. This has led to a wide variety of descriptions and references that, at times, contradict each other. Garman (1991) and Ritchie (1968) conducted limited subsurface testing at the site but did not report on their findings. The site is listed on the National Register of Historic Places, and the Vermont Land Trust holds an archaeological conservation easement on portions of the site.

Samples from VT-FR-2 were analyzed by X-Ray Fluorescence (XRF) by Burke (1997), who distinguished between chert from the Hathaway and Clarendon Springs formations based upon differences of iron (Fe) and strontium (Sr). Additionally, Burke (1997) concluded the chemical profile of Hathaway Formation chert is homogeneous, even though the analyzed samples varied widely in color and mottling. Burke (1997: 49-50) also noted that the XRF technique and thin-section petrography revealed distinct differences between Hathaway chert and samples of the Normanskill (Mount Merino) group chert (Le Centre de Recherche en Archeologie Prehistorique et Historique 1995).

Chert from VT-FR-2 generally appears Black (Munsell value N 2.5) to Dark Gray (N 4). Occasionally, the chert is Black with Greenish Gray (5GY 5/1) to Dark Greenish Gray (10Y 3/1) mottling or banding. Some pieces appear predominantly Greenish Gray (5GY 6/1 to 10Y 6/1) with Dark Gray (N 4) mottling. Weathered surfaces range in color from Gray (N 6) to Light Gray (2.5Y 7/2), from Light Greenish Gray (10Y 7/1) to Greenish Gray (10Y 6/1), and from Light Yellowish Brown (2.5Y 6/3) to Yellowish Brown (10YR 5/4).

VT-FR-22: Lazy Lady Island

VT-FR-22, or Lazy Lady Island, was first identified by avocational archaeologist, William Ross in the early to mid 1900s (Vermont Division for Historic Preservation 1969-Present). Ross' notes identify a chert quarry on the island based on the presence of outcrops of fine-grained chert and the recovery of at least one bifacially worked projectile point (Ross n.d.). Except for Ross' collecting activities, there have been no archaeological investigations at the site. During a visit to the site, the authors identified intact soil horizons, and documented quarried chert outcrops on the northern and northeastern sides of the island.

Astley (1998) suggests that, until approximately 3500 YBP, the water level of Lake Champlain was low enough to access Lazy Lady Island via a peninsula from the eastern shore in the Town of Georgia. After 3500 YBP, the peninsula was submerged and land access to the quarry was limited. The southern half of the island is now capped by soil, brought to the island during construction of a seasonal residence (Mr. Truman Hoenke, personal communication 2003).

The chert found at VT-FR-22 is generally Very Dark Grey (N 3/) with Light Grey (N 5/) mottling and streaking. The chert has a slightly waxy luster, and weathers to a chalky Light Gray (2.5Y 7/2) or Light Greenish Gray (10Y 7/1) color.

PROCEDURES

Sample Collection

Generally, when attempting to characterize the geochemical composition of a chert source, it is preferable to obtain samples directly from their geologic context rather than a secondary cultural context (Jarvis 1998; Klawiter 2000; Luedtke 1978). The Brooks Farm Quarry (VT-FR-2) is protected by a Vermont Land Trust conservation easement and listed on the National Register of Historic Places. Obtaining samples from the quarried bedrock would require locating and excavating into quarry pits or removing geological samples from the already largely depleted knoll outcrop. Lazy Lady Island (VT-FR-22) is located on private property, and quarried outcrops may be buried beneath several meters of fill. Procuring samples from a primary geologic context at these quarries would require undertaking a project beyond the scope of this study.

The authors agreed that collecting samples from surficial quarry debris would be the best compromise for this pilot project. This strategy may lead to the inadvertent collection of non-local materials, although past quarry studies have utilized this method of sampling, and produced meaningful results (Church 1995; Hoard et al. 1993; Hoard et al. 1995; Hoard et al. 1992).

We collected more than 30 samples of quarry debris with clear evidence of flaking from each site. The samples represented a full range of observed colors, mottling, and banding. Locations of samples were recorded with a Trimble Pro-XL global positioning satellite (GPS) system with a Trimble TDC1 Asset Surveyor data collector. GPS positions were differentially corrected using base station data from a local constantly operated reference station (CORS) maintained by the Vermont Agency of Transportation (VTrans) in Montpelier, Vermont. The data points were translated from the WGS 1984 coordinate system to the Vermont State Plane 1983 system to allow incorporation with state-wide geographic data.

Previous attempts to characterize chert with instrumental neutron activation analysis (INAA) suggest that approximately 15 to 30 samples from each potential source are needed to fully explore the chemical variation within and between sources (Glascock 2003; Jarvis 1998; Luedtke 1992; Malyk-Selivanova et al. 1998), although meaningful results have been obtained from fewer source samples (Glascock 2004). Significant variations within individual sources are generally identified after analysis of seven to 10 samples from each source. Seven samples from each quarry site and eight artifacts from VT-FR-329 were submitted to the Archaeometry Laboratory at the Missouri University Research Reactor (MURR) in Columbia, Missouri. An inventory, contextual information, and background literature were provided with the samples (Table 1). The remaining quarry samples are curated at ACT's laboratory for future testing and refinement of the results of this study.

Sample Preparation and Analysis

Upon arrival at MURR, the chert specimens were assigned individual analytical IDs (anids) according to standard MURR format. The 22 chert samples were assigned IDs ranging from CHR032-CHR055. Two anids were not used—CHR033 and CHR054.

All samples were washed with deionized water to remove any adhering dirt or other loose particles. Samples were then wrapped in paper towels and crushed by a laboratory press. The resulting fragments were examined under low-power magnification, and samples were selected for analysis. Fragments with metallic streaks or crush fractures resulting from the laboratory press, or with weathered outer surfaces (cortex) were avoided.

Two analytical samples were prepared from each crushed specimen. One was used for short irradiation, and the second was used for long irradiation. The short irradiation sample consisted of approximately 200 mg of fragments sealed in a high-density polyvial, while the long irradiation sample consisted of approximately 800 mg of fragments sealed in a high-purity quartz vial. Standards made from the National Institute of Standards and Technology (NIST) certified standard reference materials SRM-1633a Fly Ash, SRM-278 Obsidian Rock, and SRM-688 Basalt Rock were similarly prepared.

At MURR, INAA of chert consists of two irradiations and three gamma counts (Glascock 1992). Short irradiations involve a pair of samples being transported through a pneumatic tube system into the reactor core for a five-second neutron irradiation using a flux of 8 x 1013 n cm-2 s-1. After 25 minutes of decay, the samples are counted for 720 seconds using a high-resolution germanium detector. This count yields data for nine short-lived elements: Al, Ba, Ca, Dy, K, Mn, Na, Ti, and V. For the long irradiation, bundles of 34 or 68 of the encapsulated quartz vials are irradiated for 70 hours at a flux of 5 x 1013 n cm-2 s-1. Following the long irradiation, samples are permitted to decay for seven days, and then are counted for 2,000 seconds (the "middle count") on a high-resolution germanium detector coupled to an automatic sample changer. The middle count yields determinations of seven medium half-life elements: As, La, Lu, Nd, Sm, U, and Yb. After an additional two-week decay, a second count of 10,000 seconds is carried out on each sample. This measurement permits quantification of 17 long-lived elements: Ce, Co, Cr, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr.

Table 1. List of specimens tested. Mass recorded in grams. Length, width, and thickness recorded in centimeters.

QS_ID	Site_No	Unit	Level	Depth	Mass	Length	Width	Thickness	Munsell Value	MURR_ID
4002	VT-FR-0022	Quarry Stope, WPT 111	Surface	Surface	102.0	8.3	4.7	2.4	5PB 3/1	CHR032
4005	VT-FR-0022	Quarry Stope, WPT 111	Surface	Surface	161.6	8.1	4.6	4.5	N 3/ weathered portions are N 6/	CHR034
4004	VT-FR-0022	Quarry Stope, WPT 111	Surface	Surface	81.6	7.0	5.2	1.8	10Y 3/1	CHR035
4006	VT-FR-0022	Quarry Stope, WPT 111	Surface	Surface	172.0	7.1	6.7	3.1	10B 3/1, weathered portions are 5B 5/1 and N 6/	CHR036
4007	VT-FR-0022	Shoreline, WPT 110	Surface	Surface	316.8	7.2	5.9	5.6	N 2.5/	CHR037
4008	VT-FR-0022	Shoreline, WPT 110	Surface	Surface	299.2	6.9	6.5	4.7	N 3/ weathered portions are N 6/	CHR038
4009	VT-FR-0022	Shoreline, WPT 105	Surface	Surface	306.6	8.7	5.9	4.6	N 3/ with 5GY 4/1 mottling	CHR039
6028	VT-FR-0002		Surface	Surface	104.2	9.1	6.2	2.5	N 4/	CHR040
6019	VT-FR-0002		Surface	Surface	265.0	12.5	4.6	3.5	5GY 5/1 with N 3/ Mottling	CHR041
6025	VT-FR-0002		Surface	Surface	522.4	13.3	8.5	5.2	Exterior: 10YR 6/4, Interior: N 3/	CHR042
6003	VT-FR-0002		Surface	Surface	97.0	7.8	5.9	3.0	Exterior: 10YR 5/4 with 10YR 7/2 Banding, Interior N 4/	CHR043
6015	VT-FR-0002		Surface	Surface	201.4	9.7	7.2	2.8	Exterior: 10Y 6/1, Interior N 2.5/	CHR044
6024	VT-FR-0002		Surface	Surface	217.2	9.0	5.5	3.2	N 3/ with 10Y 6/1 Mottling	CHR045
6012	VT-FR-0002		Surface	Surface	150.2	7.5	5.5	3.9	N 3/ with 10YR 2/1 Banding	CHR046
102	VT-FR-0329	N157 E100 NW	Ap	0-22 cmbs	1.8	2.5	1.7	0.4	10Y 6/1 with N3/ Mottling	CHR047
103	VT-FR-0329	N154 E100 NW	Bs	24-39 cmbs	13.8	3.6	2.4	1.4	5GY 5/1 with N3/ Mottling	CHR048
104	VT-FR-0329	N157 E99 NE	Bs	26-33 cmbs	1.2	2.4	1.4	0.4	N4/ with 10Y 6/1 Weathering	CHR049
105	VT-FR-0329	N152 E100 SW	Ap	0-26 cmbs	40.6	6.4	3.1	1.6	10Y 5/1 with N3/ Mottling	CHR050
106	VT-FR-0329	N158 E99 SE	BC	39-72 cmbs	38.4	5.4	5.4	2.1	N4/ with 10Y 7/1 Mottling and Banding	CHR051
107	VT-FR-0329	GPS Pnt 116	Surface	Surface	45.8	3.6	3.5	3.2	N3/	CHR052
108	VT-FR-0329	GPS Pnt 107	Surface	Surface	60.0	5.2	5.8	2.2	N3/ with 10Y 6/ Mottling	CHR053
110	VT-FR-0329	N155 E100 SW	Ap	0-25 cmbs	9.4	4.1	2.7	0.8	N 4/ with 10Y 8/1 Mottling	CHR055

Table 2. Elemental concentrations of samples from VT-FR-2 (ANID CHR040-CHR046), VT-FR-22 (ANID CHR032-CHR039), and VT-FR-329 (ANID CHR047-CHR055). Samples are analyzed using neutron activation analysis, all data are listed in parts per million (ppm). Values returned that are below the detection limits are labeled b.d.l.

MURR_ID	Site_No	AS	BA	LA	LU	ND	SM	U	YB	CE	CO	CR	CS	EU
CHR032	VT-FR-0022	b.d.l.	396.5939	8.1629	0.1089	10.5355	1.4143	b.d.l.	0.7351	17.5575	10.4770	15.3326	1.0220	0.3094
CHR034	VT-FR-0022	b.d.l.	361.3400	7.1772	0.0815	9.7958	1.4977	b.d.l.	0.5827	16.3184	7.2872	14.2521	0.9129	0.3410
CHR035	VT-FR-0022	1.9677	769.7471	19.5346	0.1919	20.3556	2.8731	b.d.l.	1.4820	44.0202	11.4328	42.9367	1.9788	0.6557
CHR036	VT-FR-0022	b.d.l.	550.1677	9.8216	0.1083	10.8680	1.7154	0.5348	0.7529	21.5215	6.2730	22.9076	1.3447	0.3662
CHR037	VT-FR-0022	b.d.l.	444.4888	11.9773	0.0996	25.1390	2.4293	b.d.l.	0.6478	33.5168	6.8797	14.5871	0.8990	0.5377
CHR038	VT-FR-0022	b.d.l.	589.4437	9.0474	0.1135	10.5748	1.5578	b.d.l.	0.7297	15.1653	11.4820	22.0951	1.0788	0.3189
CHR039	VT-FR-0022	b.d.l.	515.3687	8.3917	0.1242	12.7006	1.4982	b.d.l.	0.7972	14.4961	9.4250	16.9228	1.1187	0.3738
	Mean	0.2811	518.1643	10.5875	0.1183	14.2813	1.8551	0.0891	0.8182	23.2280	9.0367	21.2906	1.1936	0.4147
	STDev	0.7437	137.9662	4.2283	0.0350	6.0114	0.5662	0.2183	0.3013	11.2712	2.2097	10.1724	0.3771	0.1310
CHR040	VT-FR-0002	6.3694	365.4355	15.5561	0.1576	19.3975	3.0488	b.d.l.	1.1144	40.6642	39.2481	26.2622	1.3821	0.7715
CHR041	VT-FR-0002	9.6601	355.3990	19.4099	0.2283	19.4625	3.4953	0.7437	1.5160	53.9274	17.5094	30.1267	2.2079	0.8373
CHR042	VT-FR-0002	b.d.l.	419.1115	15.2866	0.1729	14.1209	2.6058	b.d.l.	1.1469	37.0637	10.1347	26.9923	1.4306	0.5907
CHR043	VT-FR-0002	b.d.l.	305.3077	13.1180	0.1529	15.3705	2.5384	b.d.l.	1.0646	23.8286	18.3756	18.0088	1.2800	0.5476
CHR044	VT-FR-0002	12.1894	301.7478	12.4186	0.1631	13.8710	2.1015	0.5877	1.0661	27.9675	16.2834	18.5164	1.1311	0.4463
CHR045	VT-FR-0002	0.8438	270.4247	11.5995	0.1335	13.6881	2.2214	b.d.l.	0.8851	22.8255	33.7711	15.7581	1.0369	0.4634
CHR046	VT-FR-0002	b.d.l.	357.5501	10.6936	0.1087	13.6930	1.9658	0.6074	0.7759	27.9880	11.5325	16.0218	1.0217	0.4594
	Mean	4.1518	339.2823	14.0118	0.1596	15.6576	2.5681	0.2770	1.0813	33.4664	20.9793	21.6695	1.3558	0.5880
	STDev	5.2044	49.9243	2.9809	0.0370	2.6407	0.5468	0.3489	0.2333	11.1786	11.1437	5.9320	0.4086	0.1579
CHR047	VT-FR-0329	b.d.l.	400.6678	8.9130	0.1224	17.7233	2.9571	b.d.l.	0.8759	26.1283	4.8343	18.2663	1.0861	0.8455
CHR048	VT-FR-0329	b.d.l.	323.9179	10.0431	0.1342	14.4643	1.7591	b.d.l.	0.8328	22.7431	12.3234	20.1300	1.2790	0.4341
CHR049	VT-FR-0329	b.d.l.	323.0875	10.4109	0.1232	13.6185	1.9703	b.d.l.	0.8396	27.3390	14.9549	16.5843	1.2431	0.4948
CHR050	VT-FR-0329	b.d.l.	318.5286	9.1497	0.0939	7.3868	1.6069	b.d.l.	0.6571	21.9400	17.2107	20.6284	1.2893	0.4203
CHR051	VT-FR-0329	b.d.l.	310.2396	9.2496	0.0953	9.8115	1.3736	b.d.l.	0.6651	23.5439	19.9080	22.2921	1.3087	0.3332
CHR052	VT-FR-0329	b.d.l.	280.7774	5.9594	0.2267	5.9879	1.0637	b.d.l.	1.4826	12.3720	40.9478	5.5650	0.5595	0.2994
CHR053	VT-FR-0329	b.d.l.	332.6220	9.6542	0.1088	9.7215	1.6929	b.d.l.	0.7166	24.4488	11.4076	20.1823	1.5026	0.4225
CHR055	VT-FR-0329	b.d.l.	234.6030	6.0107	0.0614	6.0213	1.2055	0.3198	0.5112	14.1236	7.3109	14.9319	0.8217	0.2850
	Mean	b.d.l.	315.5555	8.6738	0.1207	10.5919	1.7036	0.0400	0.8226	21.5798	16.1122	17.3225	1.1362	0.4418
	STDev	b.d.l.	46.9984	1.7291	0.0485	4.2885	0.5881	0.1131	0.2926	5.4486	11.1797	5.3060	0.3055	0.1780

The data were converted to base-10 logarithms of concentrations. Use of log concentrations compensates for differences in magnitude between major elements, such as Al, and trace elements, such as the rare earth or lanthanide elements (e.g., La, Ce, Sm, Dy, and Yb). Transformation of data to base-10 logarithms also yields a more nearly normal distribution for many trace elements (Luedtke 1992).

RESULTS

The INAA data were analyzed using an array of multivariate statistical procedures. The results suggest that chert from the Hathaway formation is relatively homogeneous despite a wide variety of macroscopic characteristics. Generally, Hathaway chert is high in transition metals, specifically manganese (Mn), cobalt (Co), iron (Fe) and antimony (Sb) (Tables 2, 3 and 4).

A comparison of all the Hathaway chert samples (n=22) to other Northeast lithic sources processed at MURR supports the tentative conclusion that the Hathaway samples are compositionally unique, especially

Table 3. Elemental concentrations of samples from VT-FR-2 (ANID CHR040-CHR046), VT-FR-22 (ANID CHR032-CHR039), and VT-FR-329 (ANID CHR047-CHR055). Samples are analyzed using neutron activation analysis, all data are listed in parts per million (ppm). Values returned that are below the detection limits are labeled b.d.l.

MURR_ID	Site_No	FE	HF	NI	RB	SB	SC	SR	TA	TB	TH	ZN	AL
CHR032	VT-FR-0022	12763.5322	0.6824	b.d.l.	23.1241	0.1424	4.3249	140.7939	0.1227	0.1813	1.6013	19.1239	16715.4785
CHR034	VT-FR-0022	6899.5376	0.6513	b.d.l.	22.3556	0.1091	3.2698	45.1679	0.1358	0.2212	1.5968	17.0314	17553.0977
CHR035	VT-FR-0022	21816.5762	1.9108	b.d.l.	58.7771	0.3168	8.8447	70.7431	0.3640	0.4073	5.1006	37.7485	49197.3125
CHR036	VT-FR-0022	14836.1396	0.9672	b.d.l.	33.0346	0.1324	4.1323	71.1642	0.1823	0.2318	2.5393	21.9490	22254.6211
CHR037	VT-FR-0022	18653.1406	0.7179	b.d.l.	15.1996	0.0792	3.9514	101.0648	0.1475	0.2463	2.2120	17.9292	18712.3496
CHR038	VT-FR-0022	25803.5684	0.8962	b.d.l.	26.7771	0.1394	5.4745	46.3364	0.1850	0.1607	2.7304	23.9760	22963.2930
CHR039	VT-FR-0022	18843.5078	0.7844	b.d.l.	20.1531	0.1659	3.3827	b.d.l.	0.1633	0.2126	1.9496	24.3474	b.d.l.
	Mean	17088.0003	0.9443	b.d.l.	28.4887	0.1550	4.7686	67.8958	0.1858	0.2373	2.5329	23.1579	21056.5932
	STDev	6210.5918	0.4413	b.d.l.	14.4537	0.0764	1.9386	44.7666	0.0819	0.0805	1.2124	7.0425	14588.6155
CHR040	VT-FR-0002	23080.9707	1.0672	b.d.l.	39.2913	1.5649	6.9087	b.d.l.	0.2313	0.4262	3.2090	31.9721	31108.4531
CHR041	VT-FR-0002	20246.6230	1.3337	b.d.l.	48.6968	0.5423	7.6810	b.d.l.	0.2608	0.4809	3.7368	31.7115	44268.4141
CHR042	VT-FR-0002	20564.7188	0.8908	b.d.l.	37.3445	0.7988	7.9707	120.6351	0.2056	0.3561	2.8158	29.8528	29400.3359
CHR043	VT-FR-0002	27473.8184	0.6874	b.d.l.	32.8413	0.7074	6.1920	b.d.l.	0.1651	0.3100	2.1287	31.4729	34208.1914
CHR044	VT-FR-0002	17947.4238	0.8275	b.d.l.	29.0097	0.5688	4.9388	b.d.l.	0.1841	0.2107	2.4446	20.7408	4198.2637
CHR045	VT-FR-0002	35479.5664	0.6679	b.d.l.	20.6092	0.7614	3.7110	b.d.l.	0.1438	0.2463	1.8740	18.9325	26272.3359
CHR046	VT-FR-0002	10424.0703	0.6471	b.d.l.	25.2688	0.1178	3.7263	b.d.l.	0.1487	0.2852	1.9627	24.9931	13743.5820
	Mean	22173.8845	0.8745	b.d.l.	33.2945	0.7231	5.8755	17.2336	0.1913	0.3308	2.5959	27.0965	26171.3680
	STDev	7833.4553	0.2516	b.d.l.	9.4295	0.4357	1.7795	45.5958	0.0437	0.0969	0.6939	5.5271	13317.7327
CHR047	VT-FR-0329	9831.9043	0.7481	b.d.l.	31.4634	0.2234	4.2141	49.6863	0.1675	0.6478	2.0863	19.4238	19655.7422
CHR048	VT-FR-0329	16007.6680	0.8958	b.d.l.	26.8989	0.2630	4.2208	b.d.l.	0.1886	0.2652	2.3864	20.2906	24627.0410
CHR049	VT-FR-0329	14298.2070	0.9210	b.d.l.	24.5741	0.1873	4.1810	b.d.l.	0.1829	0.3019	2.4386	18.3026	17892.9004
CHR050	VT-FR-0329	20429.1055	0.9010	b.d.l.	27.7037	0.2605	3.6539	b.d.l.	0.1823	0.2752	2.3489	21.7941	20781.7285
CHR051	VT-FR-0329	17644.4766	0.9293	b.d.l.	26.8196	0.2655	3.6934	b.d.l.	0.1854	0.1698	2.8120	19.1335	22363.1016
CHR052	VT-FR-0329	55254.3945	0.2630	b.d.l.	10.9579	0.1774	2.7755	b.d.l.	0.0543	0.2199	0.8468	10.9650	b.d.l.
CHR053	VT-FR-0329	14622.1074	0.8599	b.d.l.	32.5730	0.3004	4.8562	b.d.l.	0.1843	0.2379	2.2854	18.2472	19160.3164
CHR055	VT-FR-0329	12763.7275	0.6149	b.d.l.	17.4217	0.1492	2.3580	46.2004	0.1164	0.1502	1.5350	13.1124	8370.5166
	Mean	20106.4488	0.7666	b.d.l.	24.8015	0.2283	3.7441	11.9858	0.1577	0.2835	2.0924	17.6587	16606.4183
	STDev	14548.6327	0.2301	b.d.l.	7.2489	0.0526	0.8234	22.2130	0.0481	0.1560	0.6198	3.6947	8246.0555

when they are projected against compositional groups identified for the Cedar Ridge Quarry (VT-CH-705) (Frink and Fahy 1997) and an artifact (a gouge) found at nearby VT-CH-900 (Figure 5). Admittedly, the Cedar Ridge samples and the gouge are significantly different in both their geologic history and in composition. The Cedar Ridge samples are dolostones (of the Clarendon Springs formation), whereas the gouge has a composition consistent with that of jasper or other meta-volcanic. Their inclusion in the evaluation of the data permit us to better assess the overall homogeneity/heterogeneity of the Hathaway formation cherts (Table 5). A further comparison of the Hathaway chert samples to cherts and jaspers sampled by MURR supports the conclusion that Hathaway chert is compositionally unique (Figures 6 and 7).

One unexpected outcome of this analysis is the possibility that the two Hathaway formation quarries – Brooks Farm and Lazy Lady Island quarries – form compositionally discrete groups. A bivariate plot of barium (Ba) and thorium (Th) illustrates this separation (Figure 8). These findings are surprising, given that the two quarries are located less than 3.5 kilometers from each other and are considered part of the same geologic formation. Additional analyses are necessary to better document the compositional variability both within and between these two outcrops. While it appears that the chert at both locations is derived from the

Table 4. Elemental concentrations of samples from VT-FR-2 (ANID CHR040-CHR046), VT-FR-22 (ANID CHR032-CHR039), and VT-FR-329 (ANID CHR047-CHR055). Samples are analyzed using neutron activation analysis, all data are listed in parts per million (ppm). Values returned that are below the detection limits are labeled b.d.l.

MURR_ID	Site_No	CA	DY	K	MN	NA	TI	V
CHR032	VT-FR-0022	3597.1904	0.8219	5244.9497	1671.2583	3351.9885	797.0366	11.4115
CHR034	VT-FR-0022	1605.1489	1.3711	3429.6528	853.5136	2887.1851	840.7028	23.4440
CHR035	VT-FR-0022	b.d.l.	3.1082	18178.6445	992.6541	10775.9141	2533.8945	64.6651
CHR036	VT-FR-0022	2411.0217	1.0459	5045.1343	1521.3159	3210.9810	976.2554	30.2818
CHR037	VT-FR-0022	5347.9048	0.9743	b.d.l.	1841.1471	2370.3853	721.5031	b.d.l.
CHR038	VT-FR-0022	1603.4984	0.8826	4106.8306	1750.4883	3207.1370	958.6884	38.7561
CHR039	VT-FR-0022	b.d.l.	b.d.l.	b.d.l.	12174.5908	932.0632	2825.6287	b.d.l.
	Mean	2080.6806	1.1720	5143.6017	2972.1383	3819.3792	1379.1014	24.0798
	STDev	1923.3642	0.9507	6148.9579	4075.5532	3179.6746	896.8583	23.1718
CHR040	VT-FR-0002	2372.9854	1.5501	5709.5425	2139.2058	7039.7183	1021.4750	26.5707
CHR041	VT-FR-0002	1040.4366	3.6566	12788.9355	311.8586	8269.6709	1677.3370	55.8197
CHR042	VT-FR-0002	1461.0245	1.7757	9712.6143	1379.6283	5335.8892	1006.5044	31.7102
CHR043	VT-FR-0002	825.7119	2.2517	6974.4146	431.6678	6993.9785	1044.5769	44.5758
CHR044	VT-FR-0002	3939.2981	1.4987	b.d.l.	8376.2266	4560.7051	b.d.l.	b.d.l.
CHR045	VT-FR-0002	1014.3288	1.1360	b.d.l.	2563.2051	3212.1338	459.0943	25.6812
CHR046	VT-FR-0002	2051.0955	b.d.l.	b.d.l.	4029.9963	3966.7739	b.d.l.	b.d.l.
	Mean	1814.9830	1.6955	5026.5010	2747.3984	5625.5528	744.1411	26.3368
	STDev	1097.3258	1.1113	5200.5304	2795.7661	1855.5214	618.5478	20.8906
CHR047	VT-FR-0329	348.6425	2.4716	6157.6284	146.7232	2812.3486	363.6653	27.8766
CHR048	VT-FR-0329	1163.7283	1.5781	6110.3833	355.6444	3943.6580	927.4996	26.4283
CHR049	VT-FR-0329	1025.5421	1.7333	4400.8203	363.7745	2582.1428	487.5347	17.8674
CHR050	VT-FR-0329	471.1857	1.3566	5574.8833	624.0991	3066.2202	679.7040	22.1908
CHR051	VT-FR-0329	748.2872	1.2801	4969.5674	181.3643	3847.6592	1156.5042	23.9282
CHR052	VT-FR-0329	b.d.l.	b.d.l.	b.d.l.	47789.0000	b.d.l.	b.d.l.	b.d.l.
CHR053	VT-FR-0329	448.2121	1.4530	6307.5459	129.2222	2974.7844	1148.2345	20.7245
CHR055	VT-FR-0329	273.2776	0.7199	2874.9292	340.1429	2528.8538	650.7307	13.1388
	Mean	559.8594	1.3241	4549.4697	6241.2463	2719.4584	676.7341	19.0193
	STDev	392.3438	0.7257	2166.8038	16788.5948	1219.8481	397.8223	9.0083

same Taconic Foreland Basin-bottom sediment, the observed variation may be, in part, due to differing diagenetic histories although more research is needed to examine this hypothesis.

When attempting to determine the most likely source of chert debitage recovered at VT-FR-329, five of the eight chert artifacts from VT-FR-329 samples fall well within the distribution of samples from Brooks Farm Quarry (Figure 8). One of the samples from VT-FR-329 (CHR047) appears to fall between distributions of both quarries; however, in other projections of the data, it falls within the 90% confidence ellipse for samples from Lazy Lady Island. Two samples (CHR052 and CHR055) fall outside the confidence ellipses of both quarries regardless of the variables plotted. Given the variety in elemental concentrations observed between the two known quarries and the limited number of samples analyzed in this study, these two samples may represent chert from as yet unidentified quarries, or they may reflect additional chemical variation within the Hathaway formation.

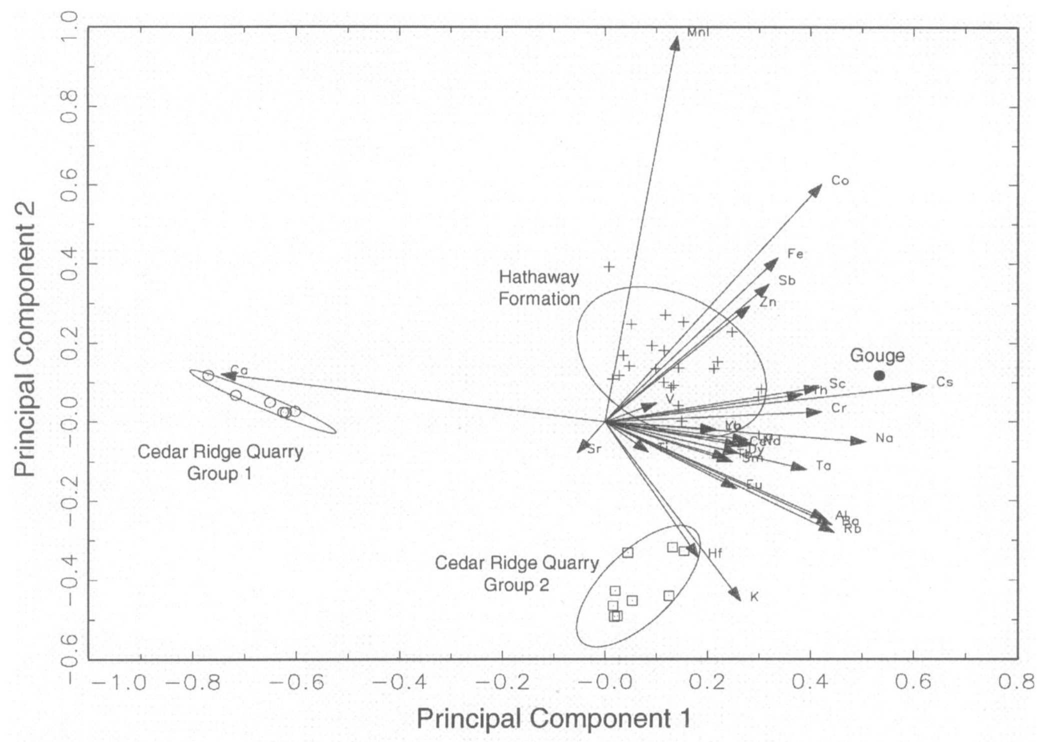


Figure 5. Principal components biplot showing coordinates for the variables (elements) together with the 38 individual specimens and 90% confidence ellipses for the reference groups. Vectors connect the origin to coordinates for the elements.

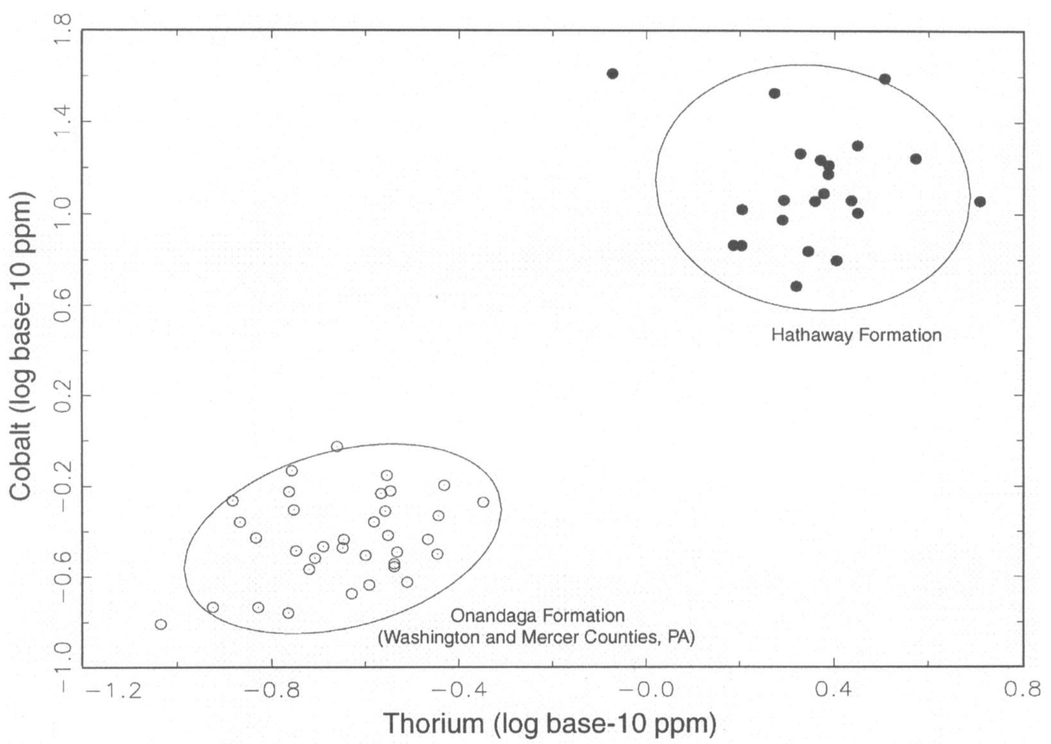


Figure 6. Bivariate plot of thorium and cobalt base-10 logged concentrations comparing Onondaga and Hathaway formation cherts. Ellipses represent 90% confidence interval for group membership.

Table 5. Summary Statistics for Vermont chert compositional groups. All data are in parts-per-million, except where otherwise noted.

	Cedar Ridge 1 ***(n=6)***		***Cedar Ridge 2*** ***(n=9)***		***Hathaway*** ***(n=22)***	
BA	27.45 ±	9.31	1275.69 ±	185.52	387.56 ±	123.79
LA	2.595 ±	0.448	12.99 ±	3.583	10.981 ±	3.713
LU	0.043 ±	0.012	0.152 ±	0.064	0.132 ±	0.043
ND	2.689 ±	0.544	15.895 ±	3.812	13.378 ±	4.838
SM	0.6 ±	0.147	3.175 ±	0.684	2.027 ±	0.663
YB	0.301 ±	0.08	1.042 ±	0.406	0.904 ±	0.292
CE	6.77 ±	1.606	31.243 ±	7.983	25.886 ±	10.51
CO	0.592 ±	0.026	0.532 ±	0.315	15.41 ±	10.129
CR	1.524 ±	0.214	12.496 ±	2.365	19.968 ±	7.295
CS	0.026 ±	0.007	0.494 ±	0.074	1.224 ±	0.358
EU	0.136 ±	0.03	1.092 ±	0.263	0.48 ±	0.169
FE %	0.183 ±	0.029	0.249 ±	0.21	1.98 ±	1.017
HF	0.64 ±	0.432	5.926 ±	3.135	0.857 ±	0.312
RB	2.62 ±	0.72	102.35 ±	15.22	28.68 ±	10.75
SB	0.033 ±	0.015	0.036 ±	0.014	0.362 ±	0.348
SC	0.376 ±	0.076	2.311 ±	0.649	4.748 ±	1.736
SR	155.44 ±	12.67	161.31 ±	22.13	98.21 ±	33.97
TA	0.024 ±	0.011	0.291 ±	0.115	0.177 ±	0.059
TB	0.084 ±	0.018	0.412 ±	0.131	0.284 ±	0.119
TH	0.254 ±	0.052	1.32 ±	0.496	2.393 ±	0.86
ZN	3.768 ±	0.617	4.594 ±	3.362	22.41 ±	6.599
AL %	0.227 ±	0.084	6.663 ±	0.791	2.297 ±	1.032
CA %	21.18 ±	0.294	0.153 ±	0.048	0.199 ±	0.157
DY	0.418 ±	0.152	2.05 ±	0.841	1.557 ±	0.734
K %	0.239 ±	0.078	8.409 ±	1.074	0.721 ±	0.352
MN %	0.021 ±	0.004	0.001 ±	0.001	0.409 ±	1.018
NA %	0.018 ±	0.003	0.365 ±	0.073	0.408 ±	0.23
TI	786.66 ±	245.43	1766.78 ±	723.18	1097.48 ±	626.98
V	20.245 ±	11.844	20.5 ±	7.119	27.76 ±	13.021

DISCUSSION

Based on limited analyses, it appears that INAA may be a viable analytical approach for characterizing and discriminating geographically and geologically similar chert sources in Vermont. By determining that the majority of chert from VT-FR-329 was likely quarried from VT-FR-2, it is possible to examine VT-FR-329 within a broader cultural landscape and to interpret the site's location and purpose.

VT-FR-329 is located on the northern end of the *Lake Champlain to St. Albans Bay/Mill River/Rugg Brook* watershed (VCGI 2004). The site is also located at the northern end of a natural travel corridor,

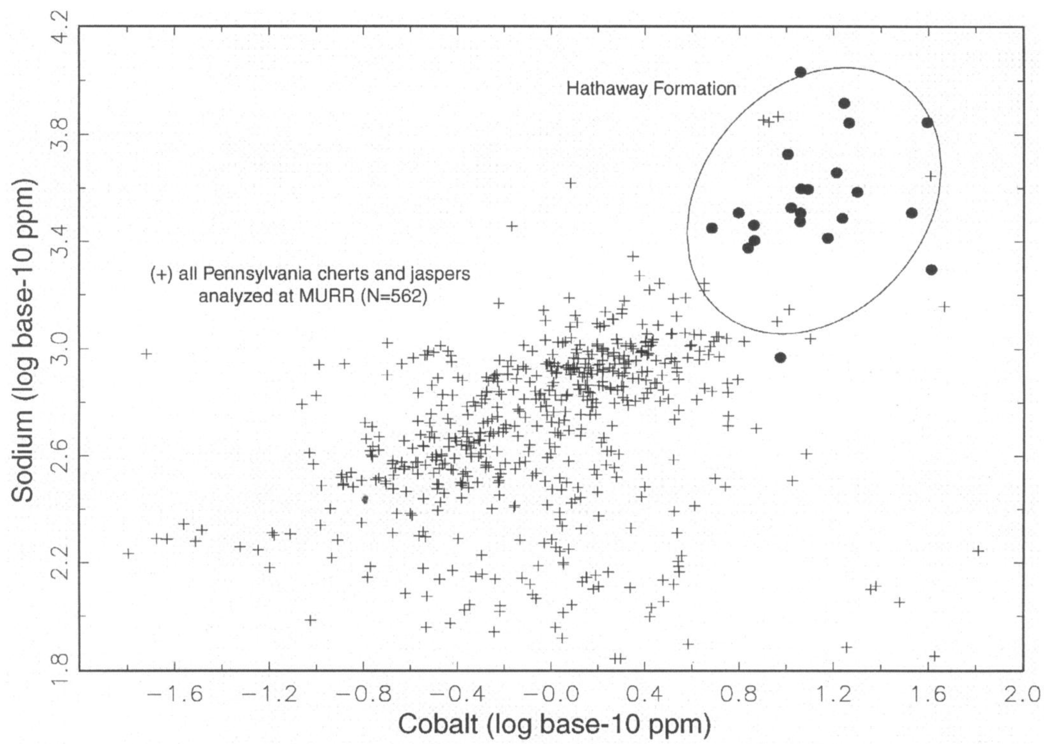
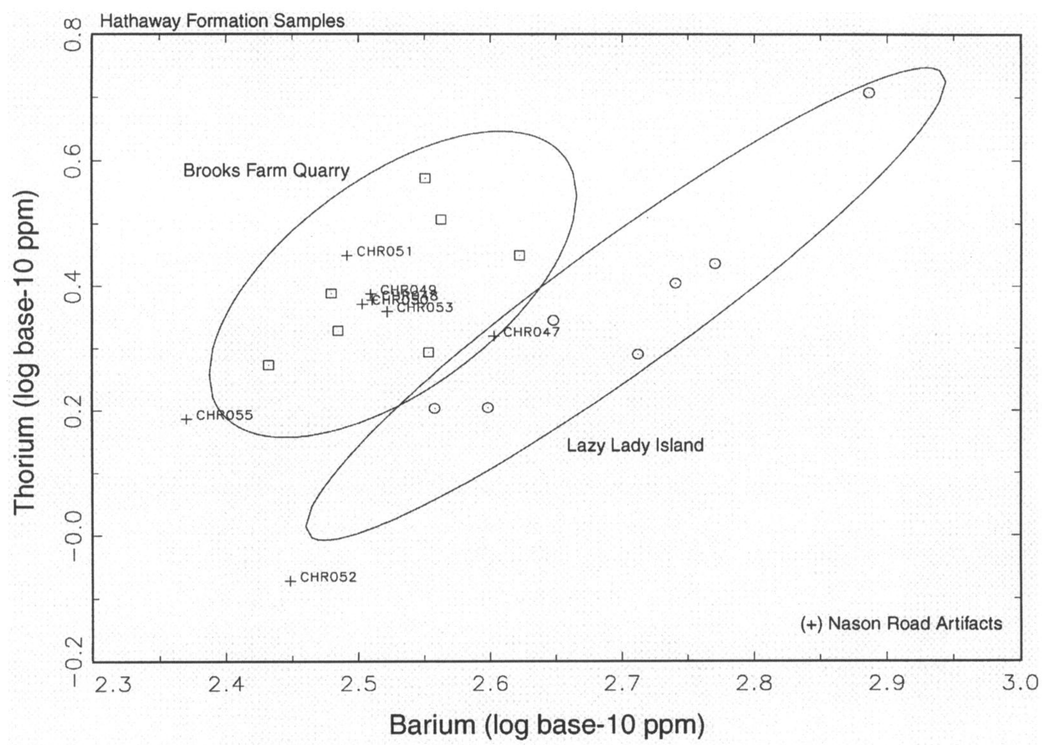


Figure 7. Bivariate plot of cobalt and sodium base-10 logged concentrations comparing Hathaway formation cherts to all Pennsylvania cherts analyzed by INAA at MURR. Ellipses represent 90% confidence interval for group membership. Pennsylvania materials falling within 90% confidence interval for the Hathaway formation can be eliminated by changing projections.

Figure 8. Bivariate plot of barium and thorium base-10 logged concentrations for the Hathaway Formation samples. Ellipses are drawn at the 90% confidence interval.



characterized by relatively flat, easily traversed terrain. This travel corridor would have led Native Americans southward towards Arrowhead Mountain and the Lamoille River which, prior to being dammed in the mid 1900s, would have been flanked by a relatively broad floodplain (USGS 1915). This portion of the Lamoille floodplain would have provided Native Americans with a high density and wide variety of resources (Frink 1996), and is similar to riverine floodplains elsewhere in Vermont that contain significant Native American base camps (Heckenberger et al. 1992; Petersen et al. 1983; Thomas et al. 1996). In addition to the Lamoille floodplain, the Streeter Brook wetland, a large eutrophic wetland, is located immediately east of the river (United States Fish and Wildlife Service 1983). Vermont's Native American populations are known to have relied heavily upon the high density of natural resources available within freshwater wetlands (Frink 1996; Frink and Hathaway 2003; Petersen et al. 1985).

Both of these geographic features are surrounded by high densities of sites dating from the Paleoindian through the Woodland periods. Although only a few of these sites have been systematically tested, many of them include chert flakes and fractured Stage 2 or 3 bifaces similar to those found at VT-CH-329 (Table 6).

We hypothesize that Native Americans visited VT-FR-2 to extract chert as part of their seasonal resource procurement pattern. After extracting chert from the quarry, they departed the quarry, and traveled eastward and south to VT-FR-329 (Figure 9). At VT-FR-329, Native Americans further reduced the quarry ore into preforms and bifaces to lessen their load and facilitate transportation. After a short period, likely a few days at most, the Native Americans continued southward on their seasonal round. Following the natural travel corridor southward would have led them to the vicinity of Arrowhead Mountain, either along the floodplain of the Lamoille River, or on the periphery of the Streeter Brook wetland east of the river. The wide range of available resources at both of these locations would have allowed for the establishment of seasonal base camps or long- term encampments.

CONCLUSION

The results of this study are promising, although they should be considered tentative until additional analyses of lithic samples from VT-FR-2 and VT-FR-22 can be conducted to quantify the range of chemical variability at both quarries. Comparative data are also needed to characterize other sources of black-to-olive gray mottled chert within the Champlain Valley and New England. Despite the limited scope of this study, and the fact that chemical analyses of cherts often times result in the inability to identify compositional groups indicative of specific chert sources, we are optimistic that additional research will demonstrate the potential of INAA for discriminating chert sources within New England.

Table 6. Sites identified adjacent to the Lamoille River and Streeter Brook Wetland. Additional information on all sites can be found within the Vermont Archaeological Inventory (Vermont Division for Historic Preservation 1969-Present).

Site No.	Site Name	Town	County	Associated With	Level of Study	Cultural Components	Reference
VT-CH-92	Manley Site	Milton	Chittenden	Wetland	Collector	Paleo-Indian, Middle to Late Woodland	Florentin and Doherty 1998, Loring 1980
VT-CH-107	Milton Sandblow	Milton	Chittenden	Wetland	Collector	Paleo-Indian, Late Archaic	Loring, 1980
VT-CH-144	Smith Site	Milton	Chittenden	Wetland	Collector	Undefined Precontact	
VT-CH-145	Manley Development	Milton	Chittenden	Wetland	Phase I	Undefined Precontact	
VT-FR-25	Buckland Sandblow	Georgia	Franklin	Lamoille River	Phase I	Archaic, Woodland	Haviland and Basa 1973
VT-FR-27	Georgia Estuary	Georgia	Franklin	Lamoille River	Phase I	Early-Middle Archaic	Haviland and Basa 1973
VT-FR-71	Gilles Rainville	Georgia	Franklin	Lamoille River	Phase I	Late Archaic, Middle-Late Woodland	
VT-FR_72	Depression Edge	Georgia	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-73	Mcnall	Fairfax	Franklin	Lamoille River	Phase I	Late Archaic, Middle-Late Woodland	Thomas et al. 1980
VT-FR-74	Bannerstone	Fairfax	Franklin	Lamoille River	Phase I	Archaic	Thomas et al. 1980
VT-FR-75	Grass	Fairfax	Franklin	Lamoille River	Phase I	Archaic	Thomas et al. 1980
VT-FR-76	Keefe 1	Fairfax	Franklin	Lamoille River	Phase I	Possible Archaic, Woodland	Thomas et al. 1980
VT-FR-77	Keefe 2	Fairfax	Franklin	Lamoille River	Phase I	Middle-Late Woodland	Thomas et al. 1980; Thomas et al. 1999
VT-FR-78	Blaisdell	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-79	Hawthorn	Georgia	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-80	Holstein 5	Georgia	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-81	Tracy Brook	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-115	Bellows	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-116	Riehle	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-117	Gina's Site	Georgia	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-119	Scott's Biface	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-120	Roadside Flake	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-121	White Pine	Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Thomas et al. 1980
VT-FR-143		Fairfax	Franklin	Lamoille River	Phase II	Undefined Precontact	
VT-FR-144		Fairfax	Franklin	Lamoille River	Phase II	Undefined Precontact	
VT-FR-148	Kilburn Site	Georgia	Franklin	Wetland and River	Collector	Early Archaic	
VT-FR-209		Fairfax	Franklin	Lamoille River	Phase I	Undefined Precontact	Robinson et al. 1991
VT-FR-241	Site 1	Georgia	Franklin	Lamoille River	Phase I	Undefined Precontact	Hotopp, 1994

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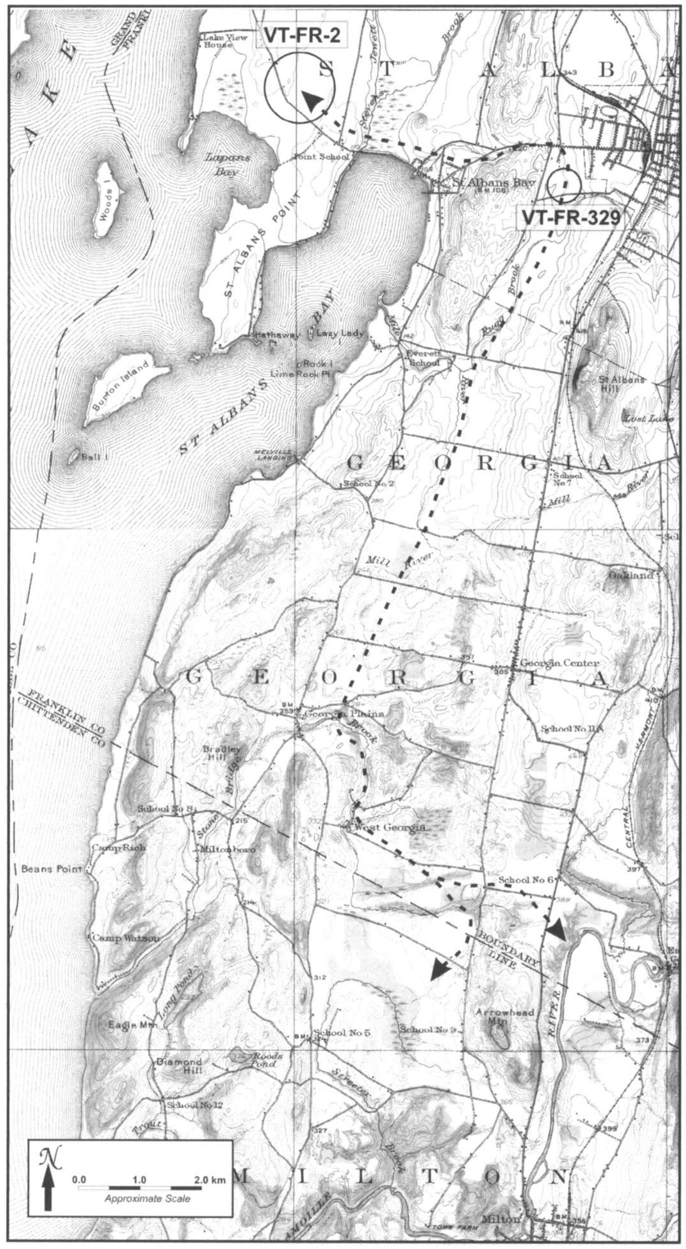

Figure 9. Composite of the 1915 USGS Milton, Vermont and the 1916 USGS St. Albans, Vermont 15-minute quadrangles showing the hypothesized travel corridor connecting VT-FR-2, VT-FR-329, the Streeter Brook wetland complex adjacent to Arrowhead Mountain, and the Lamoille River prior to damming.

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