

INAA Characterization of Onondaga Chert:
A Preliminary Study in Western New York

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ABSTRACT

Using a systematic sampling strategy and INAA, material from a series of outcrops of Onondaga chert in western New York State was analyzed. The elemental concentration pattern established for bromine, chlorine, and sodium shows evidence of a facies shift in the Onondaga limestone formation which allowed "sourcing" of flakes from the French 3, Guenther, and Henry Long Sites. Future extension of this sampling base should produce favorable results for the rest of New York State and southern Ontario.

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CHAPTER ONE: THE PROBLEM OF ONONDAGA CHERT

Although artifacts made of Onondaga chert dominate New York State prehistoric artifact assemblages, only minimal success has been achieved at determining their origin. This study aims to examine this problem with the aid of neutron activation analysis and a systematic sampling strategy. First, the formation will be characterised by an analysis of geological material from a series of outcrops, and then this characterization will be used to "source" archaeological material from several prehistoric sites. This project will focus on western New York State, but success will allow future expansion to the rest of the state. (Chert is a sedimentary form of silicon dioxide, usually found as nodules or lenses inside limestone formations.)

For the archaeometrist, the ideal scenario for solving questions of artifact provenience is one in which all exploited sources are localized and have their own distinct physical and chemical properties. In some cases, visual distinctions can even make chemical analysis unnecessary. Unfortunately, in New York State, the only major chert resource is not only both visually and chemically very homogeneous, but also accessible across much of the state. Thus it is very difficult to determine where any artifact might have originated.

Past attempts to characterise the Onondaga chert using petrological or hard scientific approaches have been limited in scope and not very systematic. They have relied on small sample sizes from disparate sources, and thus have only been able to

show a few gross macroscopic differences in the chert, although they have been able to distinguish between the Onondaga and other cherts. However, no extensive, systematic attack has yet been performed to determine if the Onondaga as a resource can be adequately characterised so that artifacts can be "sourced" on a larger scale.

The benefits of such a characterization are clear. Elsewhere in North America, data on artifact provenance have been used, directly and indirectly, to draw inferences regarding many aspects of society, including economics, religion, social structure, and technology. Access to this data would be a boon to New York State archaeology. It might shed light on intriguing aspects of the region's prehistory, such as the apparent absence of Early Archaic occupation, or the nature of the Archaic adaptation itself. These goals are in line with current views regarding the role of archaeometry; i.e. to expand the knowledge of physical, chemical, and biological processes that underlie the data, and to elucidate significant archaeological problems (Luedtke 1987a).

Introduction

Ward (1974) outlines three phases required in the process of sourcing artifacts: delimitation of source variation; characterization of each source; and comparison of artifacts with characterised sources. The first phase involves careful sampling of the various sources and application of one of a number of chemical or petrological analytical techniques. The second phase involves the definition of patterns in the data that allow sources to be distinguished. The final phase applies the same analysis to artifacts, and their comparison with the geological patterns to ascribe their potential origin.

Sampling

In the first phase, at each source locality, a sample must be taken that is sufficiently large and physically widespread to contain the full range of internal, or intra-source variation (cf. Shotton and Hendry 1979: 78). (In this paper, intra-source variation will often be termed intra-outcrop variation.) At times, the degree of variation in a source outcrop can surpass that between sources; extensive variation has even been observed on an intra-nodular level (Luedtke 1978:415-416, 1979:746; Parkins 1987). A common flaw in trace element analysis studies is the failure to adequately delimit the intra- and inter-source variation (Ward 1974). Chemical characterization studies rely on the "Provenience Postulate" (Weigand, Harbottle, and Sayre 1977:24) which states that there is "greater variation in

chemical composition between sources than within them" (Luedtke 1987a:4). Without adequate knowledge of this variation, it is not possible to distinguish reliably between different sources, nor is it possible to source artifacts.

Unlike some studies in which "grab" samples have been collected from outcrop localities and material has been borrowed from collectors and institutions, this study follows a recent trend which advocates the need for stronger control over the sample (Meyers 1970:17-18; Luedtke 1978). All samples should be collected from a known position in their parent matrix, if any true notion of natural variation is desired (Luedtke 1978:422). As this caveat infers, knowledge of the resource's geology, as well as any quirks in the local geology, is a necessity. This knowledge will not only ensure control over variation, it will also aid in the interpretation of the data.

Some would presume that the best approach would be to target all known prehistoric quarries and trace cultural material back to them. However, to characterise a geological feature truly, it is necessary to sample more than just the suspected source localities. One must assess the overall natural variation in order to control for variation that may be too broad to be seen with only a few points sampled, and to allow for the possible prehistoric exploitation of currently unknown quarries.

Finally, the number of samples collected from each source must be large enough to allow for scientific analysis. A sample size of ten is usually considered the minimum (Shotton and Hendry

1979:78). Luedtke (1978:422) recommends at least ten and suggests thirty for even a homogeneous source. The sample sizes in this study may thus be too small.

Techniques

The first phase involves the use of an analytical technique to measure source variation. Various approaches are available for the characterization of exploited resources, including visual and microscopic petrology, optical emission spectrography, atomic absorption spectrometry, X-ray fluorescence (XRF), and instrumental neutron activation analysis (INAA). Different techniques vary in cost, ease of application, and sensitivity to particular elements. Visual analysis, or "eyeballing" is rather common among archaeologists, but its unreliability and inaccuracy in many cases have been repeatedly stressed by archaeometrists (Calogero and Philpotts:1987; Luedtke 1987b:2, 1979:745), and this is especially so when one tries to differentiate the homogeneous Onondaga cherts. Where a material is unusual, or rare, petrological techniques can be quick, inexpensive, and rewarding; but when the resource is widespread and its outcrops not visually distinctive, as in the case of Onondaga chert, they are much less effective. Despite the apparent homogeneity of a resource, there are often differences in the relative levels of trace and other elements that can only be detected by the more sensitive techniques noted above.

Unlike optical emission spectrography and atomic absorption spectrometry, XRF and INAA are more sensitive techniques and

produce data on many elements at once (Shotton and Hendry 1979: 78). The ability of INAA to analyse the composition of the entire sample, and not just its surface, as with XRF, reduces the effect of error due to surface contamination or heterogeneity, making it the most desirable for sourcing a material like chert (Aitken 1962:172; Harbottle 1982:23-4; Luedtke 1979:746).

Chert's chemical composition reflects the conditions of deposition, including such factors as climate, salinity, depth, and geological processes operating in and around the sea. Further post-depositional factors such as leaching and mineralisation can also have effect. The spatiotemporal differences in these conditions produce the present spatial variation seen in chert resources. (Luedtke 1978:414)

Although INAA is one of the most expensive methods, it is not difficult to conduct. INAA also has a few advantages for the author. He has worked with the technique before at the facility (SLOWPOKE) where the current analysis has been conducted. This has led to familiarity with the staff and operating procedures of the facility. As Harbottle has recommended (1982:38), the cost of INAA can be appreciably lessened if the archaeologist is trained by an analyst and then conducts the majority of the work himself (as in this study).

Chemical Characterization

Chemical characterization relies on the measurement of the levels of various elements in a sample. This data is then

examined by various visual and statistical methods for the presence of patterned variation, the purpose being to characterise the chemical composition of the sampled outcrops. To allow outcrop differentiation, traits must be found that show the conformity of all samples from a given outcrop, while clearly differentiating them from other outcrops' samples. Once such a pattern, a sort of chemical blueprint, is established, theoretically the chemical composition of any artifact will clearly match its source outcrop and no other.

Because chert deposits can be so chemically heterogeneous, the archaeometrist must deal with several levels of variation: variation within the formation (inter-source), variation within an outcrop (intra-source), and variation within a nodule (intra-nodular). For the characterization to be effective, intra-source variation must be controlled so that it does not interfere with the detection of inter-source variability.

Comparison with Artifacts

During this phase, the artifacts are analysed and compared to the source characterizations. An artifact that falls within the exclusive range of one source, can be ostensibly assigned to that source; however, it is not possible to assert that an object originated from one particular location, only that it is more like that than any of the other sources sampled - another untested source may yet exist (Shotton and Hendry 1979: 78). In order to make source classifications with any real confidence, the natural variation in the formation(s) must truly be understood.

The Study Area

The study area encloses a strip of New York State from Buffalo east to Phelps (see Figure 1), centered on the Onondaga Escarpment and its environs. Physiographically, the region is divided into the Allegheny Plateau and three narrow lowlands, the Lake Ontario plain, the Lake Tonawanda plain, and the Lake Erie plain.

South from the Lake Ontario shore, the land rises gently across the Lake Ontario plain to the Niagara Escarpment. Between this feature and the Onondaga Escarpment lies the Lake Tonawanda plain, named for a now defunct late Pleistocene feature. This region is a shallow east-west trough drained by the Tonawanda Creek and its tributaries. North of the Onondaga Escarpment, the Lake Erie plain rises slowly to the Lake Erie or Portage Escarpment which borders the Allegheny Plateau.

The lowlands are areas of wet, relatively flat land, and dissected frequently by large streams. The plateau is a southward tilted mesa, characterised by rolling hills and deeply eroded stream valleys, and has been well-rounded by glacial activity. Geologically, the lowlands rest on soft sedimentary rock, while the scarps are the uptilted edges of more durable strata. The larger streams tend to cut the scarps or cross them in waterfalls and cascades. (Buehler and Tesmer 1963:9)

The Onondaga Escarpment is the product of glacial and post-glacial erosion. Beginning in discontinuous exposures in

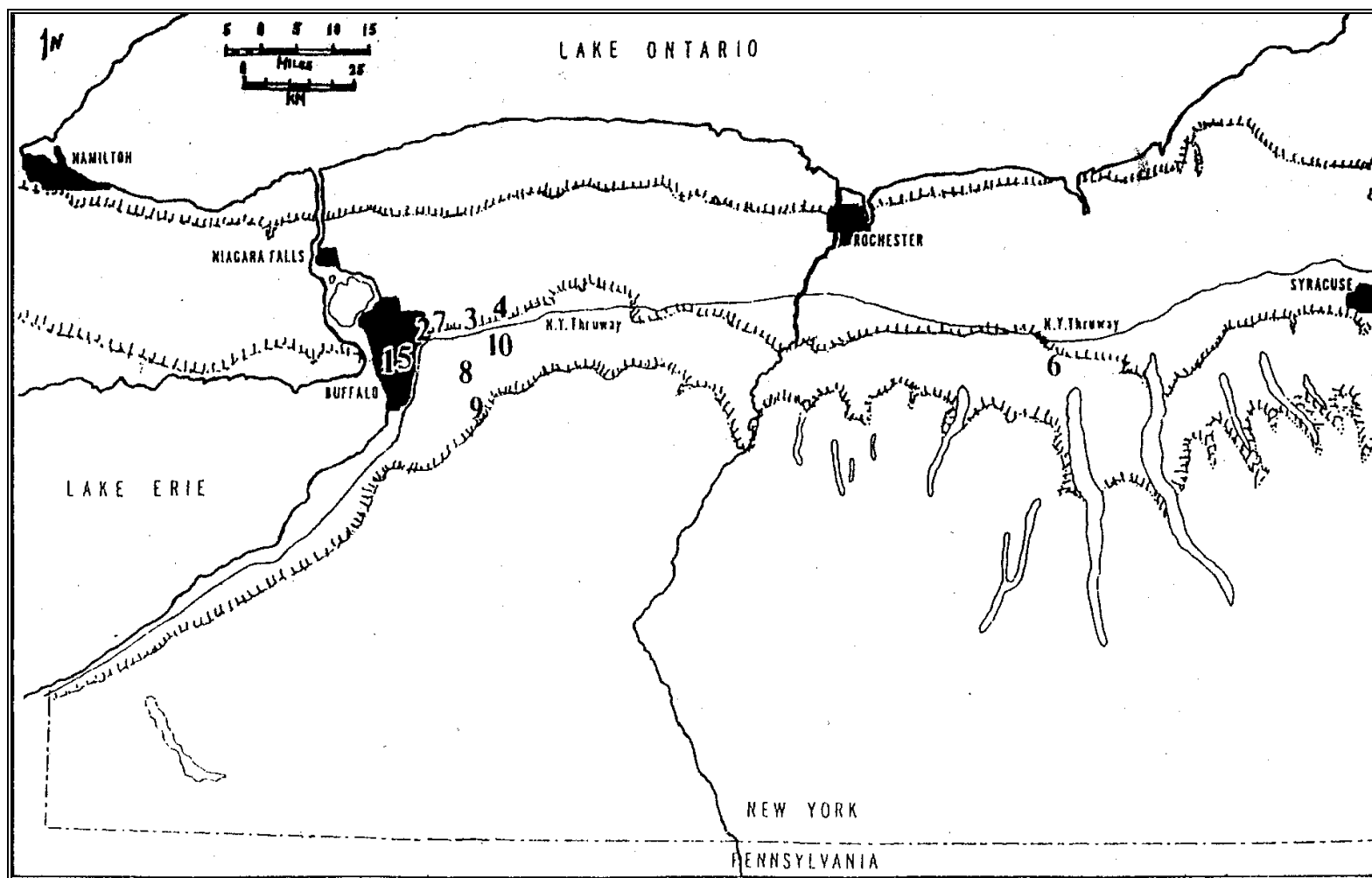


Figure 1: Map of the Study Area

(modified from Amos et al. 1968: 6)

OC 1	East Amherst St Roadcut	OC 6	Oaks Corners Quarry
OC 2	Williamsville	OC 7	Centerpointe Site
OC 3	Goodrich Road	OC 8	Guenther Site
OC 4	Akron Falls	OC 9	French 3 Site
OC 5	East Amherst St Quarry	OC 10	Henry Long Site

Ontario, on the north side of Lake Erie, it runs under the lake from Port Colborne to Buffalo. It continues generally eastward, almost to Albany, then turns southward into Pennsylvania. Above the scarp and in its upper component lies the Middle Devonian Onondaga Limestone Formation, while below are Silurian deposits, including the Bertie, Salina, and Lockport Formations. (see Appendix 1)

The Onondaga Formation is naturally exposed in frequent outcrops along the Onondaga Escarpment, and in the gorges and waterfalls of streams that cross the scarp. In historic times, more exposures have been made in quarries and roadcuts. Residual chert also can be found south of the scarp where shallow soil contains weathered bedrock.

The Study

In this study, chert from the Onondaga Formation was analysed using INAA. The following elements were analysed: Uranium, Dysprosium, Barium, Titanium, Strontium, Iodine, Bromine, Magnesium, Silicon, Sodium, Vanadium, Potassium, Aluminum, Manganese, Chlorine, and Calcium. Systematic variation in the relative concentrations of some of these elements was detected, and was used to establish a chemical blueprint of the Onondaga Chert against which prehistoric artifacts could be compared to determine their origin.

The chert samples were collected from a spaced series of outcrops intended to represent the western end of the Formation

from Buffalo east to Pembroke (see Figure 1). For comparative purposes, an outlying location, near Phelps, was also sampled. A systematic sampling approach was employed at each locale, in order to collect samples of known provenance, and, by collecting a controlled series of samples, to delimit accurately the variation within each sampling locale.

Then chert flakes from three prehistoric settlements located near the outcrops were analysed. This data will be compared with the geological data in a blind test. This step will indicate the study's value to Northeastern prehistory and to archaeology in general.

Stratigraphy and History of the Onondaga Formation

The Onondaga Limestone Formation is Middle Devonian in age. Although in eastern and southeastern New York State the formations are intact, in the study area the Onondaga often rests directly on the older Silurian deposits. The Lower Devonian deposits were almost entirely removed by erosion which occurred after the Helderbergian Stage. Occasionally, there are thin and discontinuous Lower Devonian deposits of the Bois Blanc Limestone. The Bois Blanc is not present east of the Genesee Valley, but becomes more evident to the west, and is quite thick in Ontario. (Rickard 1986:12-14; Sorauf and Oliver 1983:138-9) The unconformity provides a useful marker for interpreting the stratigraphy at sampling locations. Along the Escarpment, none of the formations which overlay the Onondaga remain.

The Onondaga Limestone was deposited in a transgressive sea which extended north from southern New York (Rickard 1986:13). In the east, it averages 75 meters in depth; the central portion is around 21 meters, and in the west its maximum is around 35 meters. There are four members, from earliest on: Edgecliffe, Clarence/Nedrow, Moorehouse, and Seneca.

The oldest member, the Edgecliffe, is fossiliferous, a coarse, light gray limestone, which becomes slightly darker and medium grained as it nears Buffalo (Oliver 1966:37). In the study area this member is very thin, decreasing from between three to five meters near Syracuse, to only one meter at Buffalo

(Sorauf and Oliver 1983:139). It is dominated by corals.

Localized coral structures vary in size from microreefs several meters in proportion, to reefs that are over 10 meters thick and eighty meters in diameter (Oliver 1954:636). The chert is light gray in color, but only irregularly present and mainly in the upper regions of the member (Oliver 1966:37).

Deposition of the Edgecliffe member was terminated by an influx of argillaceous material, correlating with the increasing erosion of uplifting landforms to the east. In the eastern state, these sediments form the Nedrow member and are shaly, a different facies from the Clarence member, west of Syracuse, which retains many of the characteristics of the Edgecliffe (Oliver 1966:33). The Clarence is fine-grained, thickening from five meters in central New York to around 14 meters at Buffalo. Dark blue and black chert is extremely abundant in this member, sometimes forming over half its bulk (Dunn and Ozol 1962).

The thickest member, the Moorehouse, increases from eight meters in the central state to around 16 meters near Buffalo. However, due to erosion, this thickness is only attained in the southern half of the state. In the study area, it no longer is evident at the escarpment. The sediment shows deposition of a fine grained, medium gray limestone infused with abundant noncarbonate mud in the central and eastern state (Oliver 1966:33). In the study area, the sediment was purer; there is more coral, and the limestone is medium grained and lighter in color. Throughout the member, fossils are abundant. Chert is

present, but in amounts that vary and color that ranges from light buff to dark gray (Oliver 1966:40; Buehler and Tesmer 1963:36).

Separating the Moorehouse from the younger Seneca member, is the Tioga Bentonite, a 15 cm thick stratum of clay minerals, possibly the product of Middle Devonian volcanoes in Virginia (Rickard 1986:14).

From Buffalo, east to the Syracuse area, much of the Seneca member has been lost to erosion, and thus little is known (Oliver 1954:637-41). In places, however, it does reach a thickness of a few meters (Sorauf and Oliver 1983:139). What does exist is a cherty, fine grained, fossiliferous limestone. Eastern limestone deposition ended earlier than in the west. The deposit is dark and fine grained, with few fossils, and upgrades into the black shales of the Hamilton group (Oliver 1966:33).

Of the four, the primary components of the Onondaga Escarpment are the Edgecliffe and Clarence members, especially in western New York (Buehler and Tesmer 1963:36).

Origin of Chert in Onondaga Formation

Ozol (1963:11) characterizes the Onondaga chert as "microcrystalline quartz in combination with chalcedony, cryptocrystalline quartz, minor amounts of isotropic silica (possibly related to opal), and mega-quartz", dolomite and calcite remnants, and occasional sulfides, clay, and organic material. These are all different types of sediment which have

become incorporated into the chert.

Chemical and physical weathering produces three major sediment types: quartz sand, clay, and calcite (CaCO_3) in solution. These settle ultimately in marine waters after being mechanically separated, and eventually form sandstone, shale, and limestone, respectively. Other, less abundant minerals in solution are halite (NaCl), gypsum (CaSO_4), and silica (SiO_2). All the dissolved minerals are capable of precipitating directly from the water. Calcite and silica can also be absorbed into organisms and then indirectly deposited after their death.

Silica Diagenesis

Silica is a common end product of the chemical weathering of terrestrial rock formations. It then dissolves and flows in river water to the sea. Once there it enters the sediment and finally becomes chert.

Controversy surrounds silica deposition. The older geological literature often assumed that the dissolved silica precipitated, usually around a seed such as colloidal particles, organic material, or electrolytes (cf. Laird 1935). This school found evidence for inorganic silica precipitation and suggested that this model was the most likely to supply the great quantity of silica required for chert diagenesis (Bien, Contois, and Thomas 1959; Krauskopf 1959; Peterson and Borch 1965). More recent work argues that chemical precipitation is very unusual and that the dissolved silica was probably organically fixed by marine organisms and deposited when they died (cf. Cressman 1962;

Heath 1974; Von Rad and Rosch 1974; Wise and Weaver 1974). This siliceous material would then have been the target of chemical reactions, eventually producing the characteristic nodules and lenses. Wise and Weaver (1974) support a "maturation theory" in which chert formed in stages: dissolved silica - biogenous silica - cristobalite - true quartz chert.

There are various theories regarding silica diagenesis during the formation of the Onondaga Limestone. Two main conflicting theories are post-lithification replacement and pre-lithification consolidation. Ozol (1963:137-154) supports a post-depositional theory in which the Onondaga Limestone was locally replaced by silica. Ozol observes that silicified fossils are of the same type and alignment as those in the surrounding limestone matrix. Some fossils straddle the interface and are part silica and part carbonate, while limestone texture also locally continues into the chert. Lindholm (1967) notes evidence for both theories. He cites similar observations as Ozol, but, in favor of the pre-lithification theory, he also notes that limestone laminations are deflected around chert nodules and that occasionally cracks in chert have been filled by carbonate mud. All the above observations suggest that many forms of diagenesis occurred, possibly alternating due to localized conditions.

Prehistoric Chert Exploitation in New York State

Little research has been conducted on aboriginal chert exploitation in the Northeast, especially concerning western New York State. Lithic studies have been mostly limited to artifact morphology (e.g. Ritchie 1961) and technology (Nelson 1987; Nelson and Giuliano 1988; Nelson and Spaulding 1987; among others). Indeed, very few cases of prehistoric quarrying have been noted in the literature, exceptions being the Brompton II Site (Sheehan and Cowan 1988), the Centerpointe Site (Hansen, in prep.), the Cocksackie Flint Mines (Parker 1925), the almost legendary Divers Lake Quarry (Prisch 1976), the Matteson-Harrington Site (Nelson personal communication 1988), and the West Athens Hill Site (Ritchie and Funk 1973:9-36). To date, the only excavated Onondaga chert quarry in Ontario is the Slack-Caswell Quarry, located in the Niagara Peninsula (Jamieson 1978; cf. Fox 1978); chert extraction may also have been conducted at the Surma Site, in Fort Erie, Ontario (Emerson and Noble 1966), and at the Boyd Lakefront Site (Spence and Fox 1987:21). Fox (1978) and Parkins (1977:85-6) discuss various chert resources, including beach cobbles, that have been used in Ontario, while short references to New York chert can be found in Granger (1974:177,325-6), Ritchie (1980:8), Wray (1948:28-30), and many others.

While the Onondaga Formation is widely assumed to have provided the dark gray and mottled tan chert artifacts found

throughout the state, sources are frequently not discussed, assumed to have been "nearby", or all material is vaguely linked to one of the few well known locations, such as Divers Lake (Wray 1948:28). Even if a possible source is mentioned, the application of any analytical technique (other than eyeballing) to verify these inferences is rare.

Analysis of New York State Cherts

The use of trace element analysis on lithic materials in archaeology is quite common. However, the application of these methods to New York State materials has been limited to a handful of studies (Brindle and Hancock 1987, Koffyberg 1987, Kuhn and Lanford, Luedtke 1976, Pavlish et al. 1987, among others). Although visual and microscopic studies have shown clear distinctions between New York State cherts (including Onondaga chert) and neighbors (Hammer 1976; Janusas 1984; Koffyberg 1987; Kuhn and Lanford 1987; Lavin 1983; Parkins 1977, 1974; Wray 1948), they have been only managed to show some gross differences between chert outcrops at the eastern and western ends of the Formation (Hammer 1976), (Lavin and Prothero 1981), (Wray 1948), and between chert from different members of the formation (Ozol 1963). No success has been won at characterising the entire Onondaga Formation, to allow sourcing of artifacts made from any of its outcrops. No study has yet systematically analysed a series of outcrops with controlled sampling of in situ chert.

CHAPTER SIX: SELECTION OF GEOLOGICAL SAMPLING LOCI

From geological literature, and through consultation with local flint knappers, a selection of Onondaga outcrops was isolated in the western state. The selection criteria were as follows: 1) known geology; 2) presence of chert in natural context; 3) accessibility; 4) sufficient exposure of chert to allow a vertical series of samples. With the exception of the Phelps locus, where the literary description was found to be misleading, all initial sampled loci fit these criteria. The Centerpointe Site locus was added later as a possible prehistoric quarry which is currently threatened by commercial development. As mentioned above, prehistoric quarries generally were not a priority for sampling.

The following locations were chosen: Akron Falls Park, the Centerpointe Site, East Amherst Street, Glen Park Falls, Goodrich Road Cut, and Oaks Corners Quarry (see Figure 1 and Appendices 1 and 2). All colors mentioned below were determined using the Geological Society of America's Rock Color Chart.

a) Akron Falls Park (OC 4)

In the Village of Akron, Erie County, Murder Creek cascades over the Onondaga Escarpment at Akron Falls, cutting a gorge through the underlying dolomite. By the falls, the gorge wall reveals Akron dolomite, the overlying Edgecliffe member, and possibly some of the Clarence member. From 1.7 meters of limestone, some 12 samples of chert were removed. A sample of the underlying rock was also collected for verification as

dolomite.

This chert varies in texture, but is generally rough with inclusions, and thus tends to produce a poor conchoidal fracture. Above the meter mark, the chert quality becomes consistently good. The chert fractures well and has a fine-grained texture. This textural transition may indicate a change from the Edgecliffe to Clarence member. At all levels, the chert was similar in color, ranging from dark gray to medium dark gray (N3 to N4), with lighter mottling.

b) Centerpointe Site (OC 7)

The Centerpointe Site (UB 2445) is located in the Town of Amherst, Erie County, and is only two kilometers from the Williamsville (OC2) location (Hansen, in prep.). The site is situated on a section of the Onondaga Escarpment where the slope is quite mild and the limestone extremely eroded. There is evidence of occupations from the Late Archaic, Middle Woodland, Late Woodland, and even Iroquoian periods. Grab samples of residual chert were taken from two areas as no chert was accessible in its original matrix. Twelve samples were collected from the east area, and eleven from the west central area. By comparison with the other samples, all appear to be from the Clarence Member.

The chert at this location is of good quality, being medium to fine in grain, and fractures well. It varies in color from a medium dark gray to a medium gray (N4 to N5).

c) East Amherst Street (OC 1 and 5)

In the city of Buffalo, Erie County, the formation is exposed on East Amherst Street near Kensington Park. Two locations were sampled, a road cut, and an old quarry now owned by the Public Works Department. At the roadcut, 16 chert samples were taken from a five meter section of Clarence and possibly Edgecliffe limestone, while, at the quarry, 32 chert samples were collected from a congruous seven meter piece of the Clarence and the Edgecliffe member. At the quarry, the basal unconformity of the Onondaga Formation was clearly visible. The Edgecliffe member lies on 10 cm of Bois Blanc Formation, and below that, 3.4 meters of Akron Dolomite. Seven samples of Onondaga limestone were also taken from the roadcut.

In the quarry, the chert in the lowest 2.5 meters (Edgecliffe) is medium to poor in quality. It fractures badly, having a coarse texture and many inclusions. Its color ranges from medium gray to medium dark gray (N5 to N4), with some darker gray material (N3), and much lighter mottling. Higher in the outcrop, the chert becomes a consistent, mottled dark gray (N3), and, with an even, medium texture and good conchoidal fracture, its quality is excellent.

In the roadcut, the first meter of chert samples are medium gray to medium dark gray in color (N5 to N4), with lighter mottling, and poor in quality. This material is probably Edgecliffe. Samples from the upper 3.5 meters range from dark gray to medium gray (N3 to N5) in color, again with lighter mottling, but are all excellent in quality. Presumably, they

represent Clarence chert.

d) Goodrich Road Cut (OC 3)

East of Williamsville, in the Town of Clarence, Erie County, Goodrich Road cuts through the Escarpment. Clearly exposed is the Onondaga and its basal unconformity. While the upper scarp includes Edgecliffe and probably some of the Clarence member, below lie the Bois Blanc and Akron strata. From 3.6 meters of the Onondaga limestone, some twenty chert samples were taken.

The quality of the chert sampled is quite variable. The texture is a medium grain size, but there are often pockets of coarser inclusions. Where the texture is homogeneous, the samples fracture very well, but the rest are of poor quality. The chert is generally a medium dark gray (N4), but becomes darker (N3) around the 5.5 meter mark. It is difficult to distinguish between Edgecliff and Clarence material at this location.

e) Oaks Corners Quarry (OC 6)

This location is an active quarry near Phelps, in the Town of Oaks Corners, Ontario County. Here, the Edgecliffe, Nedrow, and Moorehouse members are all exposed, lying on top of the Akron, Williamsville, and Scajaquada formations (Marshall 1987). While chert has been noted in the literature (NYSGA 1956: 110) for the Nedrow and Moorehouse strata, a careful search of the quarry wall revealed only occasional nodules in what was probably the Nedrow member. One sample of this chert was collected. At the top of the quarry, loose blocks of Moorehouse limestone contained more nodules. From this material, a grab sample of

seven chert pieces was collected. All of the observed chert was in the form of amorphous nodules. The chert is medium to coarse in grain. Fracturability was difficult to determine as the available nodules are small and pressure flawed from glacial activity. The Nedrow material is very dark, a grayish black (N2), while the Moorehouse chert is a medium dark to dark gray (N4 to N3).

f) Williamsville (OC 2)

In Williamsville, Erie County, Ellicott Creek cuts through the Onondaga Formation and then cascades over the edge at Glen Park Falls. Exposed in the falls are strata of the Akron Dolomite, the Edgecliffe member, and probably some of the Clarence member. Fourteen samples were taken from a five meter segment beside the falls, and from a further four meters of Clarence strata exposed in cascades just above the falls. A sample of the underlying rock was also taken for verification as dolomite.

All the chert from this location is medium gray to medium dark gray in color (N5 to N4). The samples from the first four meters are poor in quality, being coarse and fracturing poorly. These represent the Edgecliffe member. Above the falls, some of the samples are of excellent quality, flaking well and having a medium to fine texture, while others are of poor quality. These possibly represent the Clarence member. (This variability reflects the constrained sampling conditions. At this location, the chert was most accessibly exposed in the creek bed and banks,

where removal of good material was rather difficult. As a result, many of these samples are not representative and of poor quality.)

CHAPTER SEVEN: GEOLOGICAL DATA COLLECTION TECHNIQUE

Method

At each outcrop, consecutive samples were collected of every chert nodule located within a 20 cm wide vertical swathe up the face of the escarpment. This strategy will yield information about intra-source chemical variation. At measured locations, samples were removed with a geologist's hammer and bagged in plastic. Black and white photos and color slides were taken, and locational information noted, to allow collection of more data in the future. Samples of the underlying rock (assumed to be dolomite) were taken at several locations to verify their identity. Also a series of limestone samples was collected at the East Amherst Street Roadcut. These were thought necessary to introduce data from the chert's matrix. Limestone and chert have a close link relating to their genesis, and limestone is often incorporated in impure chert samples.

A standardized record form partly modeled after one used by Meyers (1970: 16) was established for all sampling activities (see Appendix 3). This form ensures the accurate record of information regarding the sampling location, including the outcrop's physiographical form, identity of constituent geological members, approximate locus of sample removal, photo numbers, and so on.

For this study, a minimum sample size of ten cases from each outcrop was attempted and succeeded for all but the Oaks Corners Quarry where the standard approach was thwarted by the scarcity

of chert.

In an attempt to maintain a focus on chert and not chert-like rock (e.g. cherty limestone), an effort was made to estimate the quality of the chert in each sample piece, and then to remove the actual INAA sample only from the highest quality part of that piece. In this fashion, it was hoped that the target of this sampling strategy would be equivalent to that of the prehistoric people who were exploiting the material. Since chert is the siliceous end of a calcareous-siliceous continuum (limestone to chert), the "best" quality chert in a particular sample should represent the most cherty component of the sample. It can be shown (see below) that there is a relationship between subjective quality estimates based on physical properties and the actual concentrations of calcium and silicon in a sample.

Frank Cowan, an experienced flint knapper and archaeologist, suggested a rough set of classificatory characteristics by which the quality could be estimated - texture, homogeneity, and fracturability. The best cherts will have the finest textures, least number of inclusions, such as fossils or quartz crystals, and have a consistently good conchoidal fracture. Homogeneity, a consideration of variability in texture and presence of rough inclusions, was found difficult to measure and was not used for this analysis. Each sample was thus classified by texture (no tangible grain = fine; some grain tangible but not rough or variable = medium; rough to touch = coarse) and fracturability (good or poor). The resulting coding system rated fine-textured,

good fracturing material as good to excellent in quality; medium-textured, good fracturing material as marginal in quality; and all poor fracturing material as poor in quality. (Appendix 5 records the quality estimations for the samples.)

Controlling for Variation

This sampling strategy attempts to control for intra-source variation by using a vertical series of samples from each locus. It has been noted that there is much more vertical than lateral variation in the trace elements in sedimentary rock (Sieveking et al. 1972:156). For all but the Oaks Corners Quarry locus, a congruous section of Edgecliffe and Clarence member strata was sampled. Although the small INAA sample weight makes the data susceptible to intra-nodular variation, the size of each outcrop sample should average out most of the deviation.

CHAPTER EIGHT: SELECTION OF ARCHAEOLOGICAL SAMPLING LOCI

From the records of the SUNYAB Archaeological Survey, all prehistoric archaeological sites existing within roughly five miles of the geological sampling locations were noted. From them three sites were chosen, using the following selection criteria. The artifact collection from the site had to be located close to SUNYAB, and, ideally, in the M. E. White Museum. There had to be sufficient numbers of flakes in the collection to allow for permanent removal of a sample for INAA. The assemblage had also to contain early reduction stage flakes (likely to be site-local material). After these criteria were met, sites that had been the subject of lithic analysis or were part of ongoing research were thought most desirable. No attempt was made to limit the sites chosen to one period or culture. The following sites were chosen: the French 3 Site, the Guenther Site, and the Henry Long Site. Of these, the former have been subjected to extensive lithic analysis by Frank Cowan (Cowan and Hartner 1987). (See Figure 1, and Appendices 1 and 2)

a) French 3 Site (UB 2292)

French 3 is located in the Town of Marilla, Erie County (East Aurora Quad), on a sandy knoll. Nearby is a small stream, part of the Little Buffalo Creek Watershed. There is evidence of two occupations, Early Woodland and Late Woodland. All chert artifacts were of a mottled brown and gray material thought to be Onondaga Chert. A dense lithic scatter and surrounding sparser collection, roughly 40 meters by 30 meters, produced 648 flakes and diagnostic tools. The site's function is not yet known.

While no features have been found, the lithic assemblage retains evidence of many different activities. (Hartner and Nelson 1987: 57-64; Cowan and Hartner 1987: 60-69)

French 3 is located 18 kilometers due south of the Goodrich Road sampling location (OC3), 24 km southeast of East Amherst Street (OC1 and 5), 22 km SSE of Williamsville (OC2) and the Centerpointe Site (OC7), and 22 km SS× of Akron Falls (OC4).

b) Guenther Site (UB 2287)

This was an Early Woodland campsite, located in the Town of Lancaster, Erie County. The encampment was on a gentle, well drained slope on the south bank of the Ellicott Creek. This site was investigated by members of the SUNYAB archaeological Survey. All chert artifacts were of a gray material, attributed to the Onondaga Chert. In a diffuse lithic scatter, roughly 85 meters by 20 meters, 91 flakes and several bifaces were found. All collected cultural material resides in the Marian E. White Museum. (Hartner and Nelson 1987: 22-31; Cowan and Hartner 1987: 23-29)

The Guenther site is located south of the escarpment, midway between the Centerpointe Site (OC7) and Akron Falls (OC4) sampling locations. It is approximately six kilometers south of the Goodrich Road location (OC3), 10 km from the Centerpointe Site (OC7) and 14km from Akron Falls.

c) Henry Long Site (UB 294)

The Henry Long Site is located in the Town of Newstead, Erie

County, near Clarence. The existence of the site has been known since Squier's work in 1851 (1851:79). More recently, White's excavations (1963) revealed a palisaded village of the Niagara Frontier Iroquois. The settlement was roughly 60 meters by 50 meters and located on a low peninsula of land jutting out into a swamp. The artifacts reside in the Marian E. White Museum. Although her report does not discuss the lithics in detail, the projectile points are gray Onondaga chert. (cf. Miller 1977)

The site is located six kilometers southeast of Goodrich Road (OC3), and eight km southwest of Akron Falls (OC4).

Method

For the archaeological material, an attempt was made to sample only flakes from early on in the reduction sequence; i.e. flakes that are the product of removing the cortex, edging, and preliminary thinning the preform or core (Waldorf 1984:25). These flakes will generally be of chert from sources that are very close to a site on which they are found, assuming that people seldom transport large quantities of unreduced chert for any great distance, especially when acceptable material is available locally. Late reduction stage flakes could, on the other hand, reflect the further reduction of local material, or the maintenance of non-local material.

A minimum sample size of ten was set and maintained for each site collection sampled. Visually classified Onondaga chert flakes were selected as a grab sample from each site's collection. Flakes that were macroscopically distinct from the norm were not selected.

Sample Preparation

Small pieces of best quality chert were removed from each geological sample, with an effort being made to avoid surface and cortex material. Small fragments were removed with a sandstone cobble hammerstone, preweighed on a OHAUS model C501 Port-o-gram scale, and placed into polythene vials ready for INAA. A Mettler H-15 Analytical balance was then used to measure sample weights to ± 0.1 mg accuracy.

Sample Analysis

All INAA was conducted at the SLOWPOKE Reactor Facility, at the University of Toronto, Toronto, Canada. This reactor produces slow, thermal, neutrons with a flux of less than 2.5×10^{11} n/cm²s (Hancock 1976). Most of the geological samples (SMP 1-107) were analysed on January 13, 1988. The Centerpointe Site sample (OC7, SMP 110-125) and all archaeological samples (SMP 130-159) were analysed on March 23, 1988, while the limestone samples (SMP 107-109 and 126-129) were analysed on April 15, 1988.

Samples were placed in polythene vials and irradiated for 5 minutes at 5 kilowatts, or at two kilowatts for the limestone. A delay of around 19 minutes was instituted to allow the ^{28}Al to decay to a level such that it did not mask other less active isotopes. Gamma ray products of the radioisotope decay were counted with a Canberra Ge(Li) detector coupled through a 452 Ortec spectroscopy amplifier to an 8100 series, 4096 channel

Canberra analyzer (relative counting efficiency of less than 6.7%). Measurements were taken of gamma ray peak and background levels at known energy levels (Hancock 1976).

The neutron flux at SLOWPOKE, based on many observations, has been demonstrated to be within $\pm 2\%$ over long periods. This degree of consistency is sufficient to allow the use of house standards which have been kindly loaned by the facility director, R.G.V. Hancock - standards are routinely run by the facility staff to ensure reliability, and arithmetic constants have been created. Access to these data made it unnecessary to include experimental standards with each sample run. Their use, unfortunately, makes easy comparison to data from other studies more difficult (Shotton and Hendry 1979:82), but greatly speeds the sample analysis.

CHAPTER ELEVEN: DATA ANALYSIS

Data Reduction

The raw gamma ray count data from SLOWPOKE were reduced on an APPLE IIe using an Appleworks database file with embedded equations. Elemental concentrations were calculated using the following equation:

$$\text{concentration (ppm)} = \frac{\text{peak counts} - \text{background counts}}{P \times F \times e^{-dT(\ln 2/t)} \times M \times kw}$$

where P, is the relative distance between the sample and detector; F, is a constant created from the inhouse standards in counts/ng; dT, is the delay time between sample irradiation and counting; t, is the isotopic half-life; M, is the sample mass in mg; and kw, reflects the reactor power level. (This equation is tailored to SLOWPOKE.)

The concentration data are listed in Appendix 4. In each case, the magnesium concentrations have been reduced by 16% of the aluminum concentration to correct for a partial overlap by one of the aluminum isotopes.

Method of Data Analysis

The concentration data was analysed on the SUNY Buffalo IBM mainframe using SPSS-X. A Pearson's Correlation table was created for the geological sample data. Groups of strongly correlated elements were noted and plotted with their geographical location on simple x-y graphs. These graphs were examined for elements or combinations of elements whose

concentrations vary systematically in relation to their geographical origin. Whenever such relations were found, the archaeological data was then introduced onto the graphs so that the values could be directly compared to the geological values. Inferences could then be directly made regarding the origin of the archaeological material. Multivariate statistical approaches were not found to be necessary for this limited study, however, in any future larger study they may quite likely be of value.

Discussion of Data

In all, 159 samples were analysed, including 120 geological chert samples, seven limestone samples, and 30 archaeological samples. Two dolomite samples that were analysed (SMP 18 and 65) are not relevant to this study. The concentrations of sixteen elements were determined: U, Dy, Ba, Ti, Sr, I, Br, Mg, Si, Na, V, K, Al, Mn, Cl, and Ca. (See Appendix 4 for trace element concentrations and Appendix 5 for sample weights, quality estimation, and other general information.) All concentrations are by mass.

As expected, the most common element in the chert samples is silicon, averaging 45%. (Chert is silicon dioxide, which is 46% silicon when pure.) The next most common element, calcium, ranges from 0 to 5%. Aluminum, chlorine, magnesium, and potassium are minor elements (below 1%), while the other elements are all at trace levels (less than .01%). The concentrations of barium, iodine, potassium, and strontium are extremely variable and frequently fall below the detection limit: barium in 26

cases; iodine in 103 cases; potassium in 32 cases; and strontium in 60 cases.

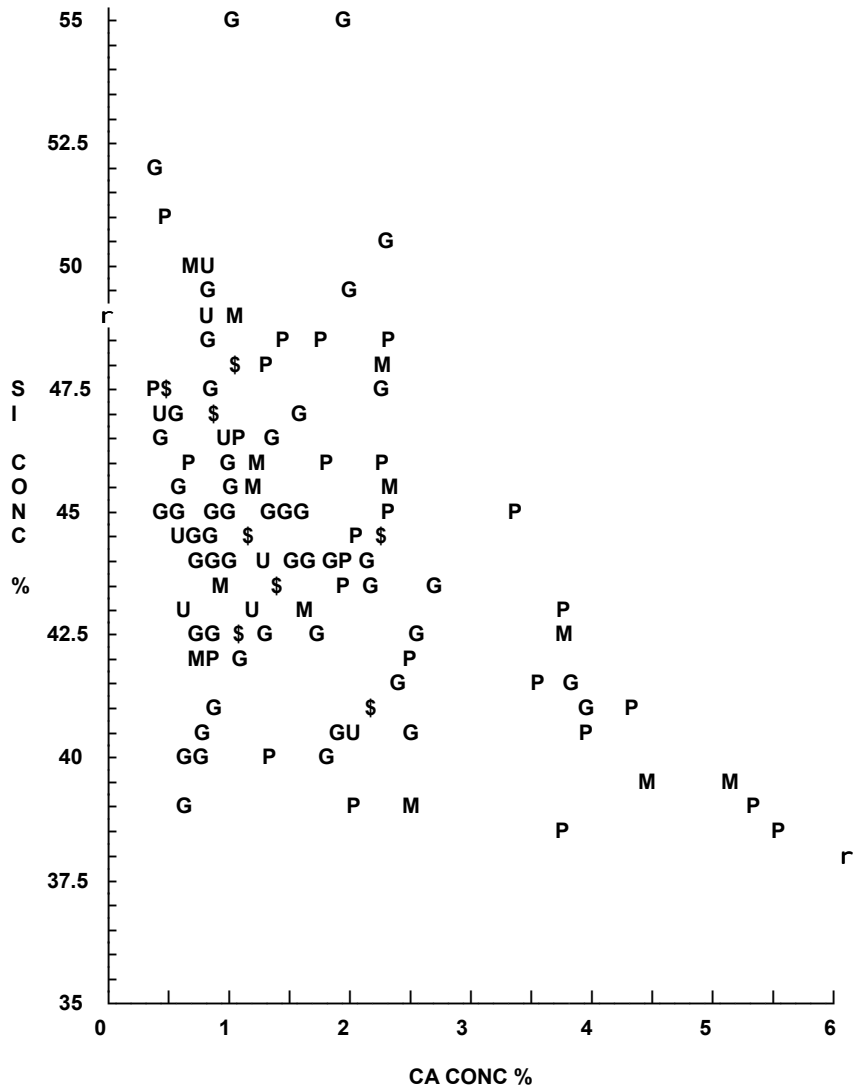
The limestone calcium concentrations are in the range for normal limestones (30-40%), while the two dolomite samples have a typical composition, averaging roughly 19% calcium and 10% magnesium.

a) Si/Ca Ratio and Chert Quality

When the principal components, silicon and calcium, are plotted for all geological chert (Figure 2), a considerable variation in silica purity is evident among the values. Inclusion of estimated sample quality shows that the ratio of silicon to calcium has important implications for knapping quality: high-rated material (QU=1) tends toward a high Si:Ca ratio, while poorer samples (QU=3) have lower ratios. Although the values are somewhat dispersed, there is a definite linear relationship with a negative correlation coefficient of $r = -.43$ ($P\{2\text{-tail}\} < .0000$). This correlation is noted in the literature (cf. Dunn and Ozol 1962:31).

The phenomenon is not surprising considering that chert forms in calcareous sediment. A continuum may exist from "pure" chert (ca. 46% Si and <1% Ca) to "pure" limestone (<1% Si and ca. 37% Ca). Intranodular elemental concentrations have been observed to vary significantly from center to cortex (Luedtke 1978:415-6). This continuum would presumably also correlate with the relative levels of any elements which are linked chemically to the silica or calcium carbonate.

Figure 2: Graph of Si/Ca by Quality for Geological Chert



120 cases plotted.

Regression statistics of Si on Ca: (y-axis intercepts marked "r")

Correlation = $-.43045$ $R^2 = .18529$ $P\{2\text{-tailed}\} = .0000$

G:GOOD M:MEDIUM P:POOR U:UNKNOWN \$:Multiple occurrence

b) Descriptive Statistics Table

Table 1 contains the elemental mean concentrations, standard deviations, and ranges for all the geological chert, and then for each outcrop. When the mean concentration values for each outcrop are compared, some general trends are visible. Oaks Corners and Akron samples are the "dirtiest", having the highest levels of most of the minor and trace elements. Akron has the highest mean values of U, Dy, Ti, V, K, Al, Mn, and Cl. Oaks Corners is the highest in Ba, Br, Mg, and Na, and is the only outcrop to have a large amount of Sr. Next "dirtiest" is the Goodrich Road sample, with the next highest levels of Dy, Ba, Ti, K, and Al. Then follow Centerpointe, Williamsville, and East Amherst Street in varying order. This sequence parallels the geographical location of the outcrops, with the "dirt" increasing towards the east. In geological terms, such a transition in a formation is called a facies shift.

c) Pearson's Correlation Table Discussion

Since the primary constituents of the chert are silica and calcium carbonate, many of the other elements which are bonded to these minerals would presumably correlate with the Si/Ca ratio. However, this is not the case. Table 2 shows the Pearson's Correlation Coefficients for all geological chert. Only aluminum and dysprosium correlate with the Si/Ca ratio, and not strongly. Aluminum has a positive ($r=0.38$) correlation with silicon and a strong negative correlation with calcium ($r=-0.43$). Dysprosium has a strong positive correlation with calcium ($r=0.63$), but only a very weak correlation with silicon ($r=-0.18$).

Table 1: Descriptive Statistics

key: μ = sample mean S = sample std dev R = sample range (ppm unless noted)

<u>All Geological Chert Samples</u> (120 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.463	.151	20.7	135	22.4	.135	11.3	.200	44.6	.070	4.75	.101	.409	16.2	1090	1.68
S	.109	.074	12.5	48	25.3	.353	4.6	.062	3.4	.023	2.23	.076	.082	9.5	430	1.10
R	.699	.459	46.2	300	117	1.83	26.2	.334	17.7	.111	10.2	.341	.439	59.4	2130	5.01

<u>East Amherst St (OC 1 and OC 5) Chert Samples</u> (49 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.443	.135	17.8	121	14.1	.077	9.1	.182	45.8	.061	4.07	.079	.404	11.5	864	1.52
S	.077	.047	11.6	50	17.8	.268	2.4	.056	3.5	.014	1.63	.070	.082	3.5	209	.79
R	.367	.259	38.5	249	45.1	1.26	12.1	.277	17.2	.090	8.02	.288	.354	16.8	997	3.34

<u>Williamsville (OC 2) Chert Samples</u> (15 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.435	.177	15.4	132	12.2	.105	9.5	.222	43.2	.061	4.76	.085	.401	20.6	935	1.84
S	.158	.106	13.4	38	21.3	.278	1.7	.058	2.7	.008	2.15	.068	.064	14.3	142	1.47
R	.630	.459	33.3	121	55.7	.863	5.9	.198	11.8	.027	6.45	.174	.228	56.8	539	4.68

<u>Goodrich Roadcut (OC 3) Chert Samples</u> (19 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.435	.184	23.3	142	31.0	.256	10.4	.178	42.9	.067	5.83	.121	.426	15.9	1050	2.45
S	.042	.043	8.9	27	20.0	.401	2.1	.040	2.6	.016	1.73	.068	.064	3.3	240	1.45
R	.125	.158	32.5	112	53.7	1.09	8.8	.138	9.4	.066	5.91	.262	.214	14.2	940	4.92

<u>Akron Falls (OC 4) Chert Samples</u> (12 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.609	.214	25.9	186	34.3	.336	15.9	.216	44.4	.102	8.42	.197	.505	27.7	1800	1.73
S	.151	.113	14.3	54	26.2	.645	4.6	.078	3.0	.025	2.46	.073	.079	14.4	550	1.05
R	.526	.450	45.0	213	62.8	1.83	16.7	.259	9.2	.088	7.23	.235	.261	48.3	1940	4.00

<u>Oaks Corners Quarry (OC 6) Chert Samples</u> (9 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.468	.085	34.7	167	60.8	.134	22.6	.287	45.6	.113	4.60	.062	.417	26.9	1690	1.03
S	.095	.085	7.8	29	39.1	.403	2.3	.060	3.21	.009	1.03	.076	.034	6.9	596	.44
R	.338	.211	20.5	110	117	1.21	6.2	.196	9.55	.026	3.64	.174	.117	23.2	1990	1.48

<u>Centerpointe Site (OC 7) Chert Samples</u> (16 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	.469	.122	19.5	112	16.8	.045	11.0	.195	43.5	.060	2.84	.105	.335	12.1	1070	1.41
S	.092	.039	12.5	36	20.1	.182	3.1	.045	3.5	.015	.79	.053	.061	1.8	104	.94
R	.287	.178	33.7	152	46.7	.727	14.3	.189	11.3	.055	2.74	.198	.217	6.9	314	3.36

<u>Limestone Samples</u> (7 cases)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	1.35	.944	41.1	110	259	1.94	.63	.451	2.4	.021	7.74	.147	.283	79.4	245	35.8
S	.21	.074	42.9	106	39	1.40	1.67	.082	4.4	.005	3.18	.121	.126	3.8	39	3.2
R	.56	.206	101	240	99	3.41	4.43	.247	11.1	.016	9.68	.336	.384	12.1	108	9.7

<u>Dolomite Samples</u> (SMP 18 and 65)																
	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%
μ	1.06	.984	80.4	665	0	0	0	9.80	0	.039	14.9	.865	1.02	214	505	18.6
S	.14	.144	2.4	71	0	0	0	.01	0	.004	3.1	.154	.19	60	17	.7
R	.20	.204	3.4	100	0	0	0	.02	0	.005	4.4	.218	.26	85	24	1.0

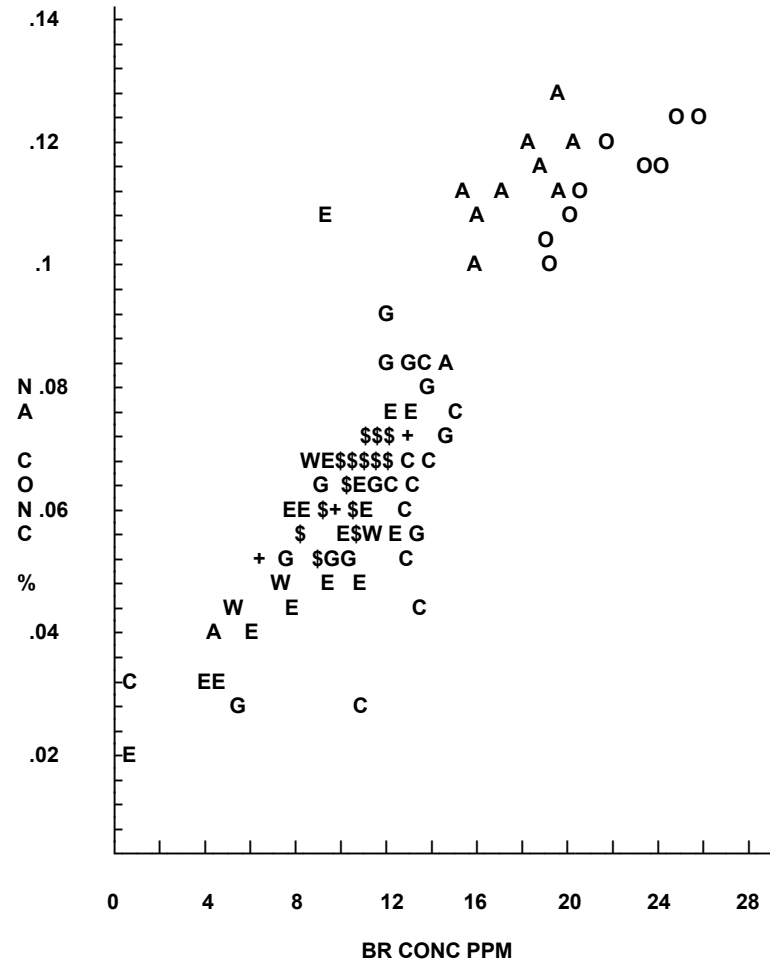
The table does show two groups of strongly intercorrelated elements. Bromine, chlorine, and sodium are intercorrelated at $r \geq 0.8$ ($P\{1\text{-tail}\} \ll .000$). The second group is larger, but the strength of its intercorrelations vary. Its members are aluminum, dysprosium, manganese, uranium, and vanadium. With the exception of manganese which has many correlations at $r \geq 0.34$, the other coefficients are all greater than $r = 0.4$. (Barium, iodine, potassium, and strontium have been ignored because their concentration levels were not measurable for all cases.)

d) Bivariate Plots

When pairs of the strongly correlated elements are plotted, two things are apparent. The graphs visually repeat all the previously noted trends. Secondly, the values of certain elements, especially bromine, chlorine, and sodium, are clearly better for separating the geological outcrops and will thus be most suitable for characterisation.

The graph of sodium by bromine (Figure 3) clearly shows the facies shift from Williamsville and East Amherst Street, through Centerpointe and Goodrich Road, to Akron, and finally Oaks Corners. On this graph, the Oaks Corners sample forms a distinct cluster with the highest sodium and bromine concentrations. The Akron Falls sample lies in its own cluster with slightly lower sodium and bromine levels. The other samples show a lot of overlap, making their differentiation difficult. If the East Amherst Roadcut sample (OC1) is removed (Figure 4), the picture becomes clearer, and some general trends can be suggested. While

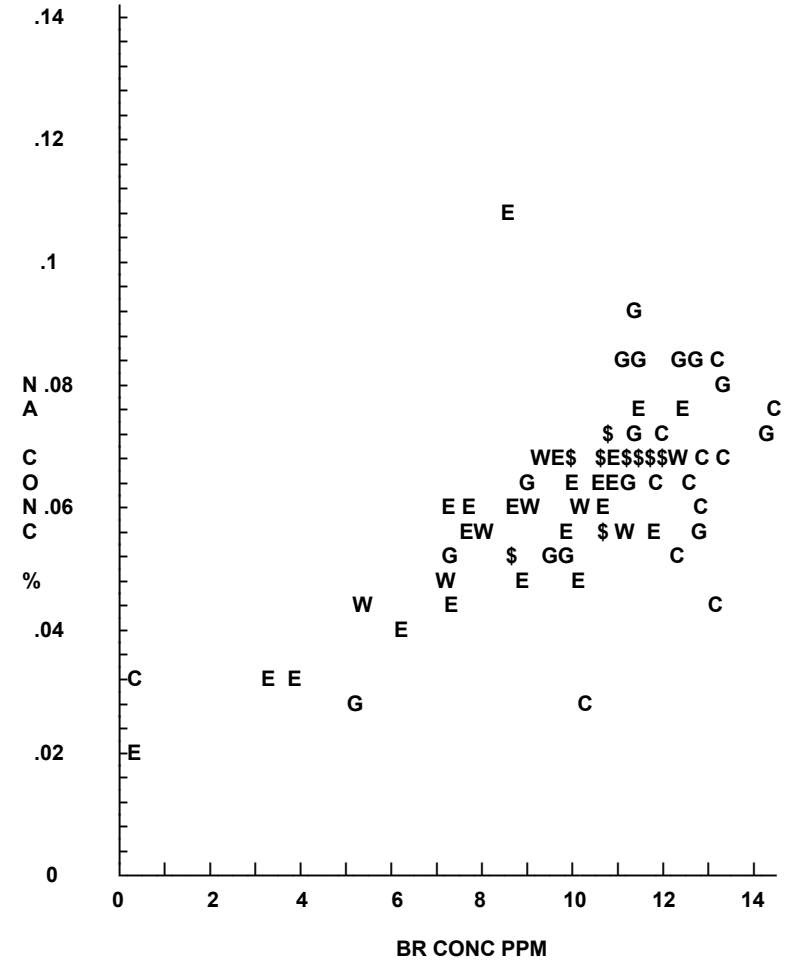
Figure 3: Graph of Na/Br by Outcrop for all Geological Chert



120 values plotted.

+ : E Amherst St Roadcut W : Williamsville G : Goodrich Roadcut A : Akron Falls
 E : E Amherst St Quarry O : Oaks Corners Quarry C : Centrepointe Site
 \$: Multiple occurrence

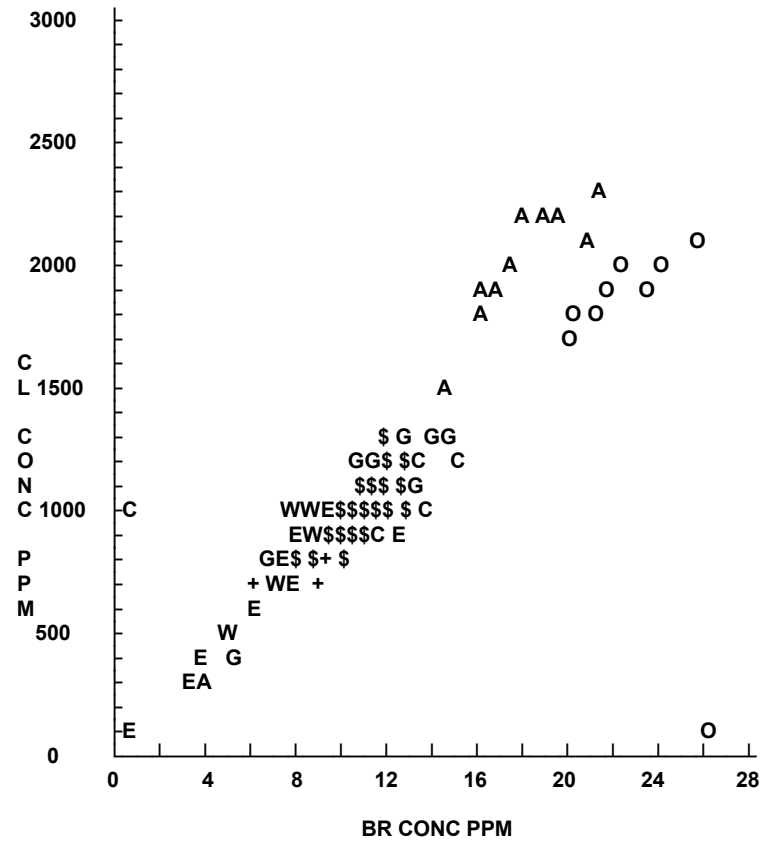
Figure 4: Graph of Na/Br by Outcrop for Geological Chert Except Outcrops 1, 4, and 6



82 values plotted.

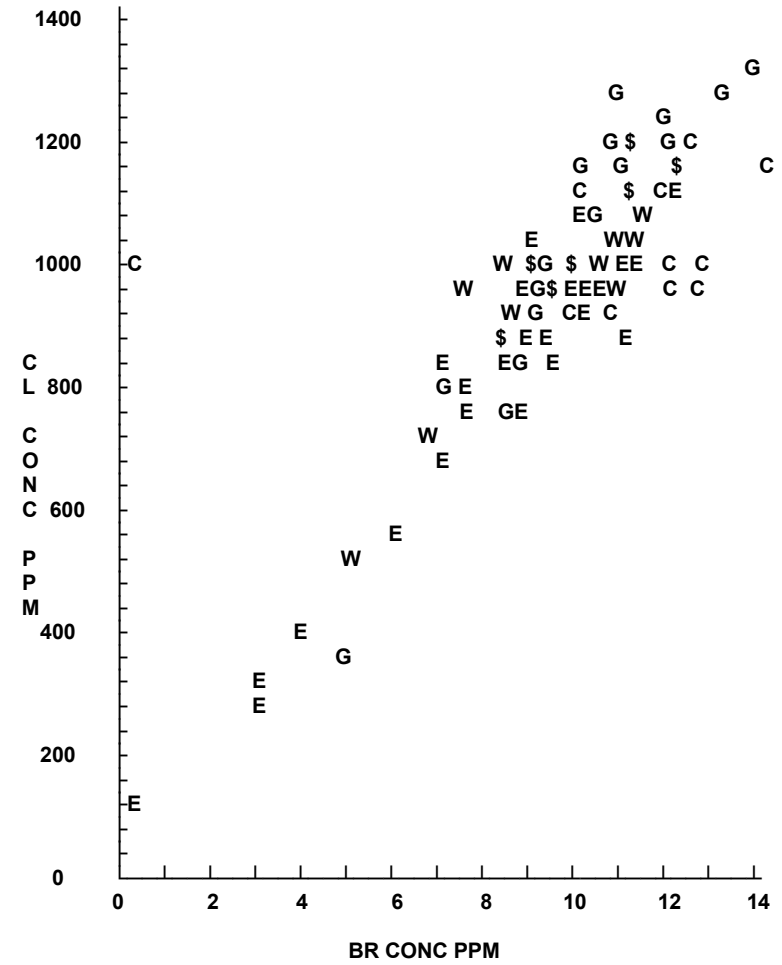
W : Williamsville G : Goodrich Roadcut E : E Amherst St Quarry
 C : Centrepointe Site \$: Multiple occurrence

Figure 5: Graph of Cl/Br by Outcrop for Geological Chert



120 values plotted.
 +:E Amherst St Roadcut W:Williamsville G:Goodrich Roadcut A:Akron Falls
 E:E Amherst St Quarry O:Oaks Corners Quarry C:Centerpointe Site
 \$:Multiple occurrence

Figure 6: Graph of Cl/Br by Outcrop for Geological Chert Except Outcrops 1, 4, and 6



82 values plotted.
 W:Williamsville G:Goodrich Roadcut E:E Amherst St Quarry
 C:Centerpointe Site \$:Multiple occurrence

the data from East Amherst Street and Williamsville are too dispersed to be characterised, the Centerpointe values appear to cluster at a higher bromine concentration. Similarly, the Goodrich Road sample can be differentiated by its higher sodium values.

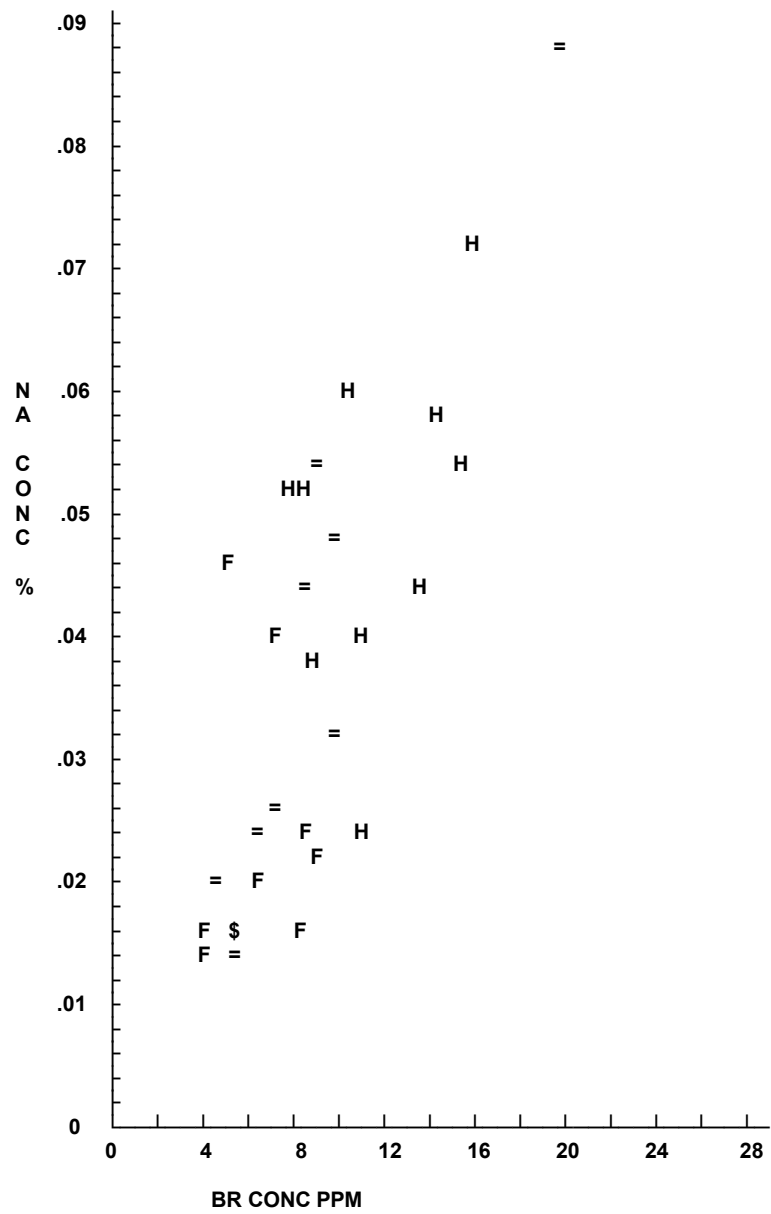
These same trends are repeated in the graphs of chlorine and bromine (Figures 5 and 6). Again we see the distinct Oaks Corners and Akron clusters at high chlorine and bromine levels. The Goodrich Road cluster is shown even clearer by chlorine than by sodium, but the Centerpointe cluster is more dispersed.

Artifact Sourcing

The same elements were graphed to examine the archaeological data. In Figure 7, the French 3 values are low in sodium and bromine, clustering at the bottom left of the graph. The Guenther and Henry Long values are more dispersed, although the Henry Long sample shows the highest levels of both elements. Figure 8, chlorine graphed by bromine, the Henry Long sample again has the highest values. The French 3 sample has low concentrations, but is dispersed. Again, the Guenther sample is spread in the middle.

When both geological and archaeological samples are plotted (Figures 9 and 10), the French 3 values still have the lowest levels of all three elements. While the Guenther sample blends in with the Williamsville and East Amherst samples, the Henry Long values are as high in bromine and chlorine as those of

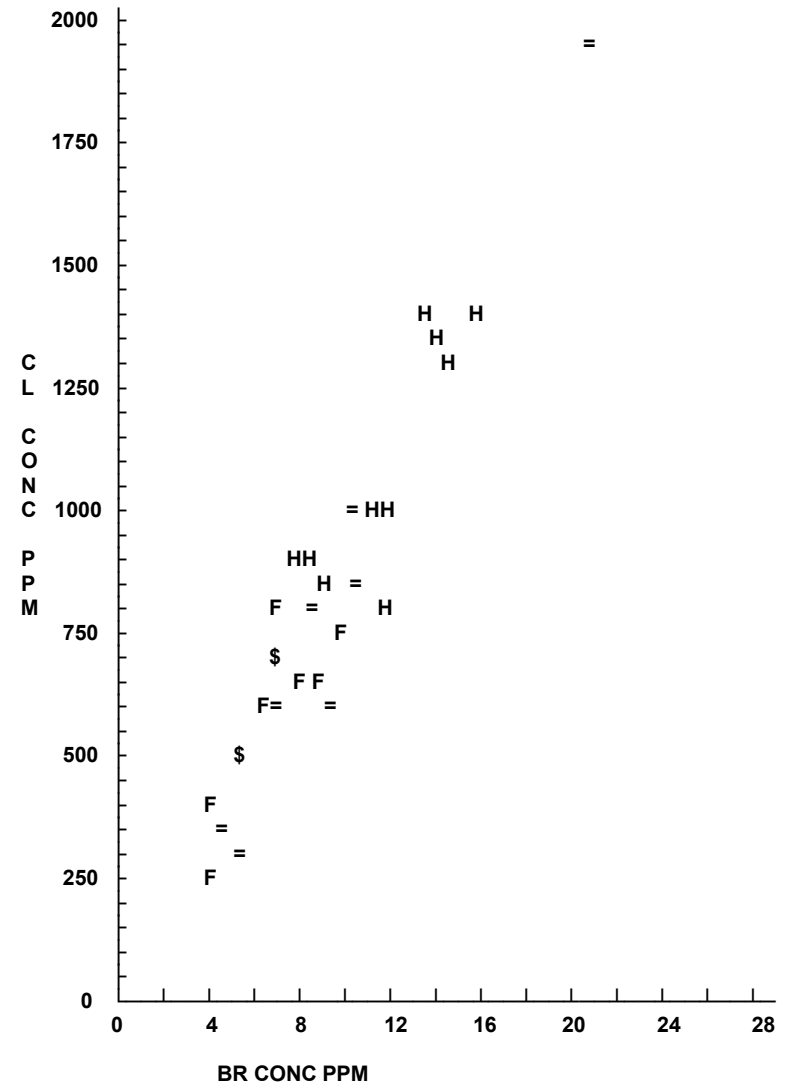
Figure 7: Graph of Na/Br by Outcrop for Archaeological Chert



30 values plotted.

==:Guenther Site F:French 3 Site H:Henry Long Site \$:Multiple occurrence

Figure 8: Graph of Cl/Br by Outcrop for Archaeological Chert



30 values plotted.

==:Guenther Site F:French 3 Site H:Henry Long Site \$:Multiple occurrence

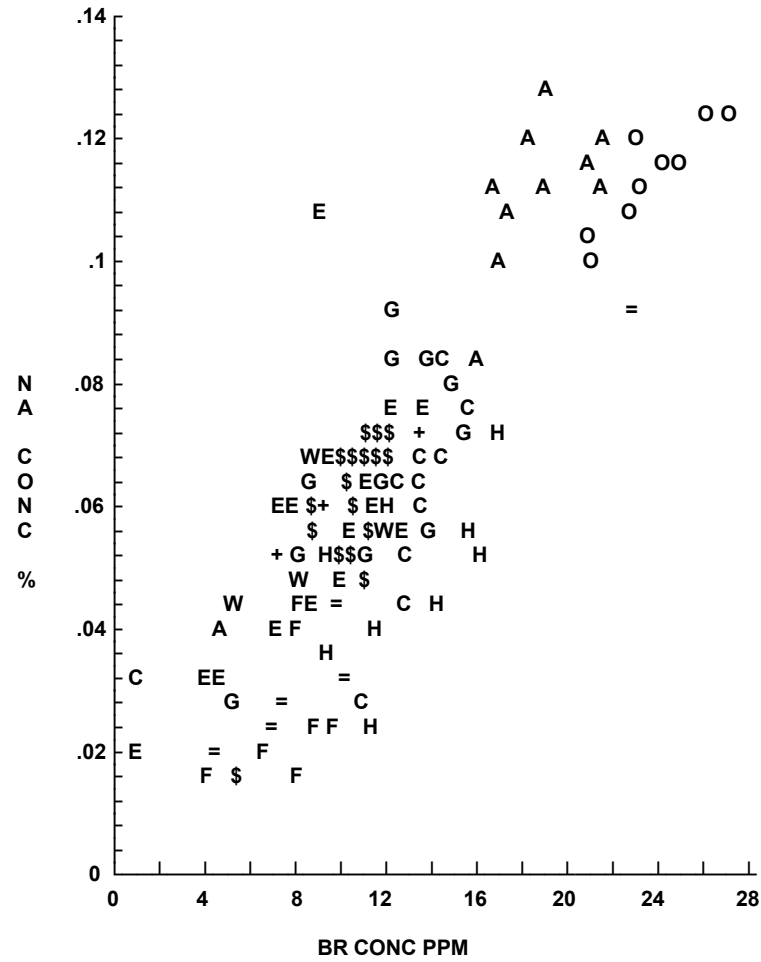
Goodrich Road and the Centerpointe Site.

When the archaeological Cl/Br values are compared to those of the geological samples (Figure 10), the linear patterns are parallel and overlap. However, similar examination of the Na/Br values (Figure 9) shows that, while the patterns are parallel, the sodium levels in the archaeological samples are lower than those in the geological samples. Since the artifacts sampled were thin flakes, less than 3 mm thick, their sodium levels may have been reduced by natural soil processes such as leaching.

Luedtke (1978:418-20) has discussed the effects of chemical weathering on artifacts. Flakes are especially vulnerable due to their small size and extreme thinness. She noted that the majority (62%) of her archaeological samples had mean elemental concentrations that were below those of their probable sources, and that iron and sodium levels were especially low.

If we look again at the combined Na/Br graphs (Figures 9 and 11), a small arbitrary inflation of the archaeological sodium values would shift their location into the range of the geological samples. The Guenther sample values would lie among those of East Amherst and Williamsville. The Henry Long sample would move into the range of the Centerpointe values, or even into the Goodrich Road cluster. The French 3 values would now lie at the lower end of the East Amherst/Williamsville range.

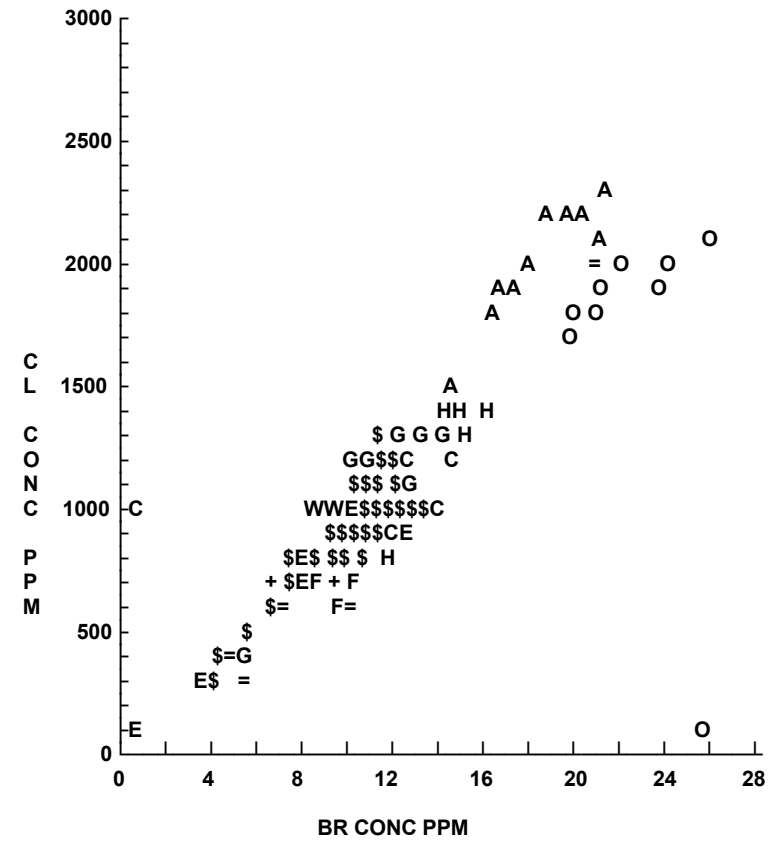
Figure 9: Graph of Na/Br by Outcrop for All Chert



150 values plotted.

+:E Amherst St Roadcut W:Williamsville G:Goodrich Roadcut A:Akron Falls
 E:E Amherst St Quarry O:Oaks Corners C:Centerpointe Site
 =:Guenther Site F:French 3 Site H:Henry Long Site \$:Multiple occurrence

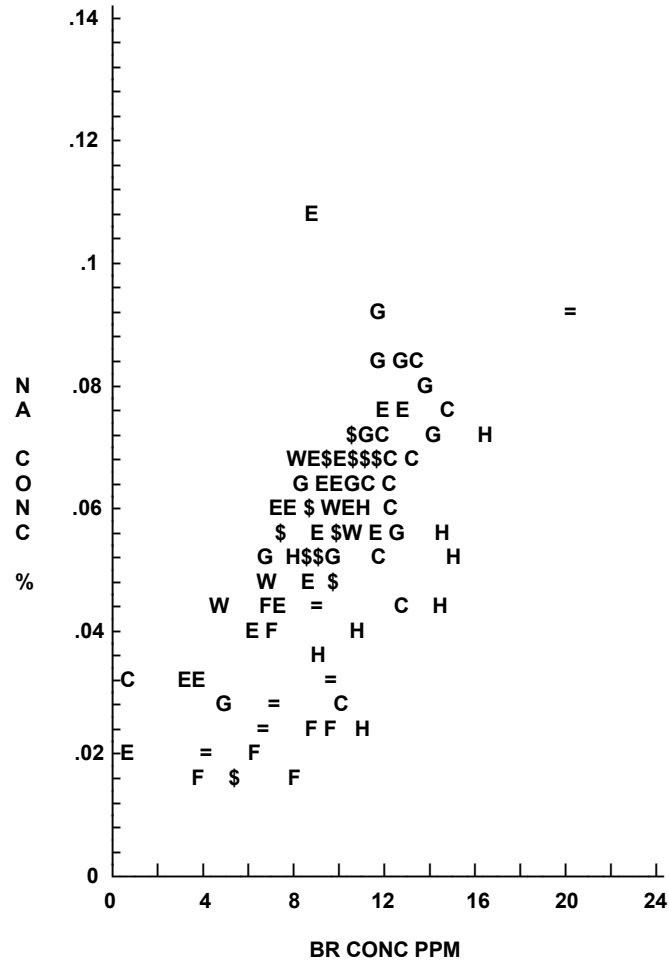
Figure 10: Graph of Cl/Br by Outcrop for All Chert



150 values plotted.

+:E Amherst St Roadcut W:Williamsville G:Goodrich Roadcut A:Akron Falls
 E:E Amherst St Quarry O:Oaks Corners C:Centerpointe Site
 =:Guenther Site F:French 3 Site H:Henry Long Site \$:Multiple occurrence

Figure 11: Graph of Na/Br by Outcrop for All Chert
 Except Outcrops 1, 4, and 6



112 values plotted.

W:Williamsville G:Goodrich Roadcut E:E Amherst St Quarry
 C:Centerpointe Site =:Guenther Site F:French 3 Site
 H:Henry Long Site \$:Multiple occurrence

The "Dirt" Sequence

An initial scan of the literature suggests an explanation for the increasing level of many of the elements (the "dirt" sequence) in samples eastward across the study area. A facies shift has been detected which reflects differences in the depositional environment of the sediment. This facies shift may indicate increasingly shallow waters towards the east of the study area, which would then entail higher precipitation rates, producing a "dirtier" chert (Pavlish, personal communication). Parkins (1977:83) has also noted evidence that a land mass existed to the north or east of the study area during the deposition of the Clarence member, from which large amounts of fresh water and argillaceous material entered the Onondaga Sea. The facies shift may also be a reflection of the general state-wide trend from the cleaner Clarence to the contemporaneous Nedrow member. The Nedrow has a high shale content and is generally coarser in texture, aspects which are characterised to be the result of increased erosion of the uplifting landforms to the east (Oliver 1966).

If the "dirt" in the chert is the product of an influx of argillaceous sediment from a river, there may be a measurable cline in the marine levels of many minor and trace elements that have been captured in the chert. If this cline exists, we would expect to see a definite pattern in the "dirtiness" of outcrops running from the south and west towards the north and east. This

study's data support this hypothesis.

Chemical Characterization of Outcrops

As shown above, it is possible to characterise Onondaga chert outcrops based on a facies shift that is well represented in the relative levels of bromine, chlorine, and sodium. This means of characterization differentiates some of the outcrops, but is incapable of distinguishing every one. As noted by Luedtke (personal communication), intra-outcrop variation in chert is often greater than inter-outcrop variation. However, with increased geographical distance, the chance of characterization becomes much improved. This study was able to easily distinguish Buffalo and Akron samples located only 28 km apart, and was showed some difference between Buffalo and Goodrich Road samples located only 16 km apart.

Artifact Sourcing

This study met with mixed success at sourcing the archaeological samples. Their elemental concentrations do show the east-west "dirt" sequence. They also have bromine, chlorine, and sodium values that are similar to the nearer outcrops sampled, namely East Amherst, Williamsville, and Goodrich Road. Since the artifact samples were picked to favor site-local chert, it is not surprising that the chert from the most distant site, French 3, should be the most unlike all other outcrops and assemblages sampled, and that the other two sites should be more similar to relatively nearby outcrops. If the sodium values are slightly inflated to correct for hypothetical sodium leaching, so

as to overlie the geological values, the graph would even more strongly show that the French 3 sample represents a distinct source, that the Henry Long sample is like its immediate neighbors, Goodrich Road and the Centerpointe Site, and that the Guenther Site sample has a general similarity to the East Amherst Street, Williamsville, and Centerpointe Site sample values. Considering the proximity of most of the sampling locations, the study has met with a good deal of success.

Recommendations

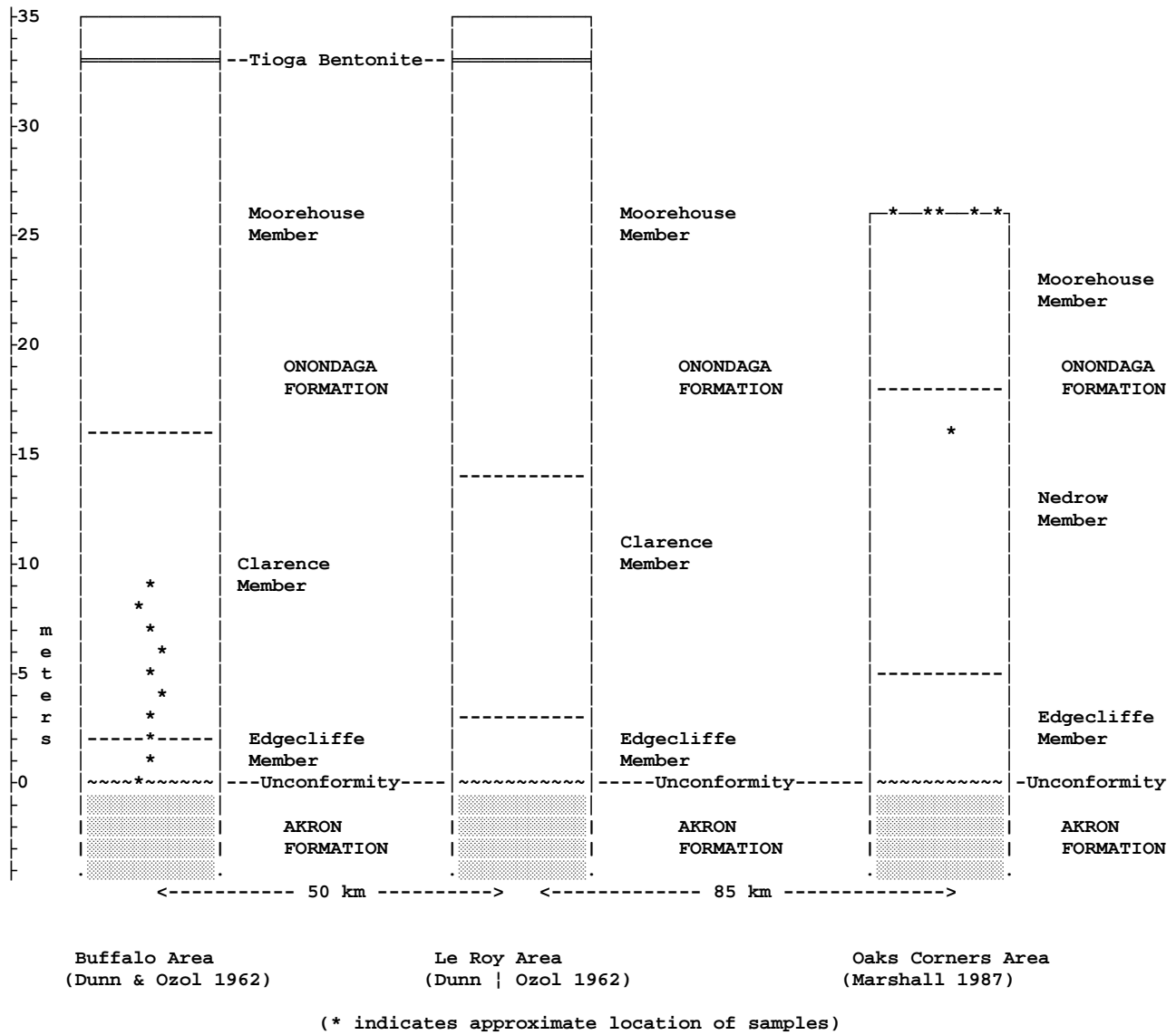
In order to determine if this approach to sourcing Onondaga chert artifacts is really a success, and to further explore the "dirt" sequence, a larger data base is required. As demonstrated by the East Amherst and Williamsville samples, there is a high tendency for intra-outcrop variation which can only be controlled by larger outcrop samples. Collection of samples in a series of vertical runs (a grid pattern) rather than the single vertical series used in this study is recommended.

Naturally, to properly attempt the sourcing of archaeological material, more outcrops than the few examined in this study must be sampled. Since this study shows that the effectiveness of an INAA characterization of outcrops increases with the geographic distance between sampling locations, outcrops should be sampled on a spacing that is at least the 12-13 kilometers which separates the distinguishable Goodrich Road and Akron Falls outcrops and the Guenther and French 3 Sites. An increased data base will allow a more thorough examination of the

"dirt sequence", and hopefully lead to insight into prehistoric behavior.

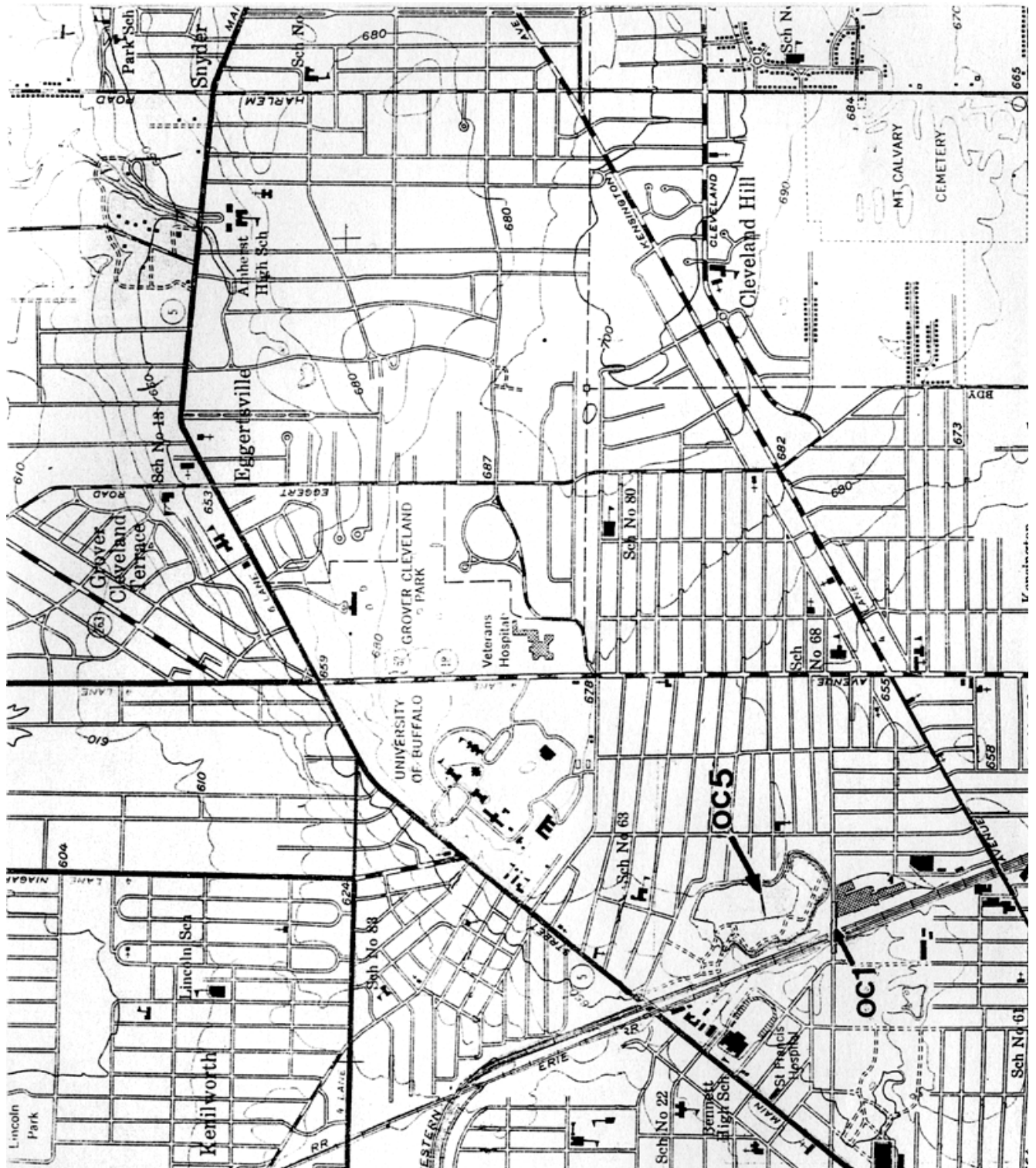
Any large-scale INAA analysis of the Onondaga chert should incorporate international standards as recommended by Shotton and Hendry (1979:82) to allow melding with other data bases such as that collected by Luedtke (1976).

Appendix 1: Composite Stratigraphic Profiles for the Onondaga Formation in the Study Area

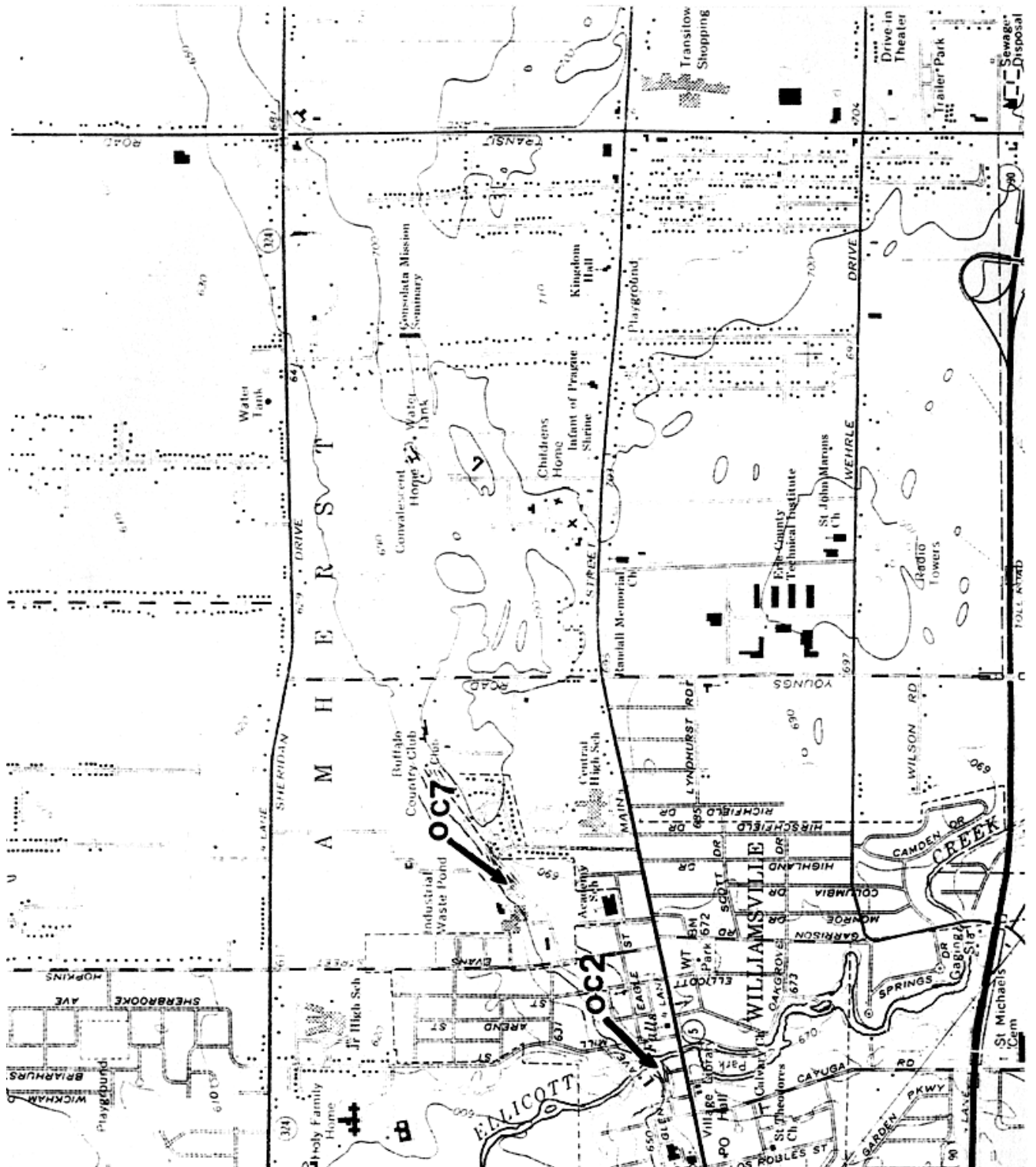


Appendix 2: Geological Sample Locations

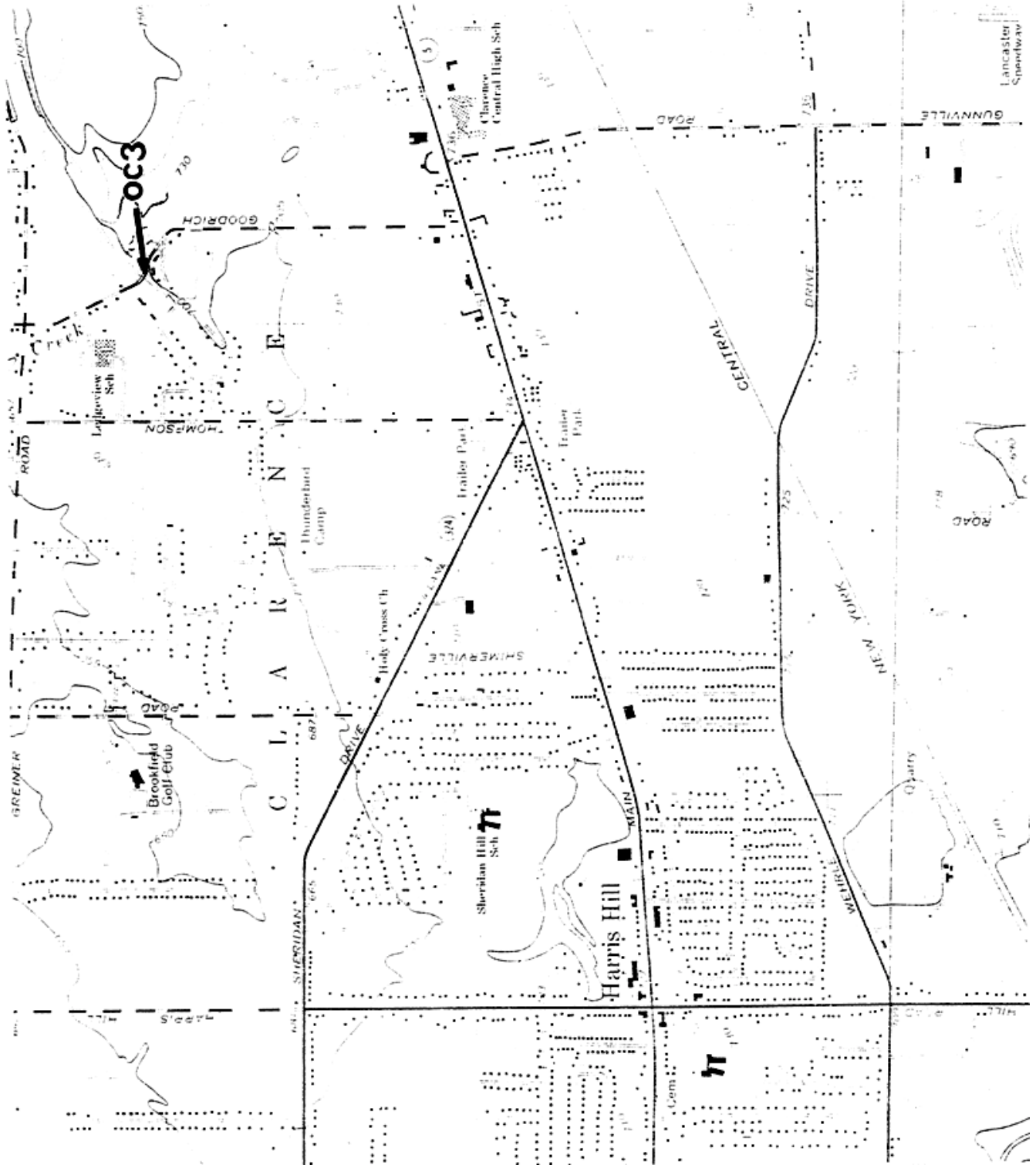
(Each map section is from the USGS
1:24 000 Topographic Maps)



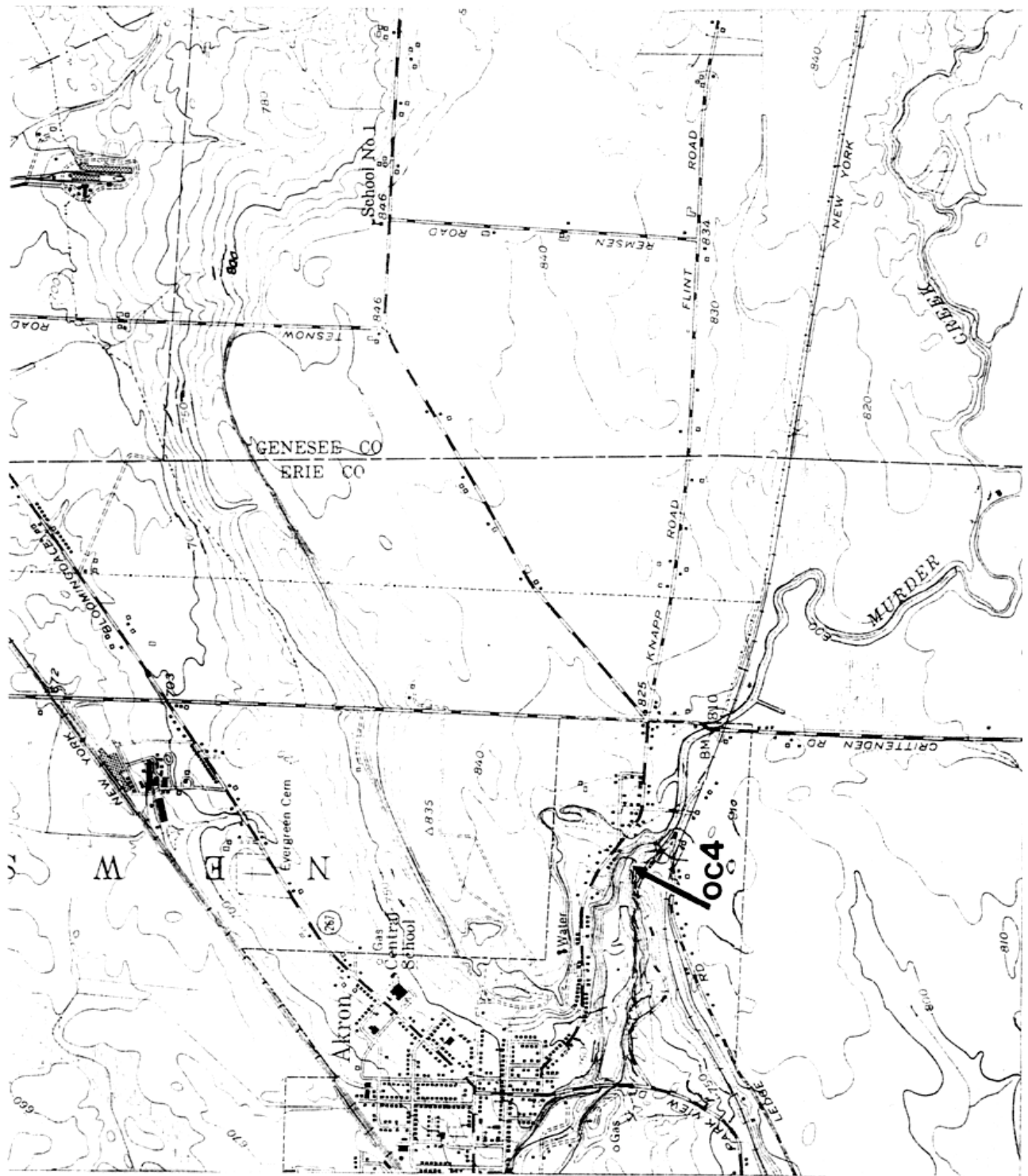
East Amherst St Roadcut (OC 1) and Quarry (OC 5)
 (Buffalo NE Quad 1948 Edition Scale 1:24 000)



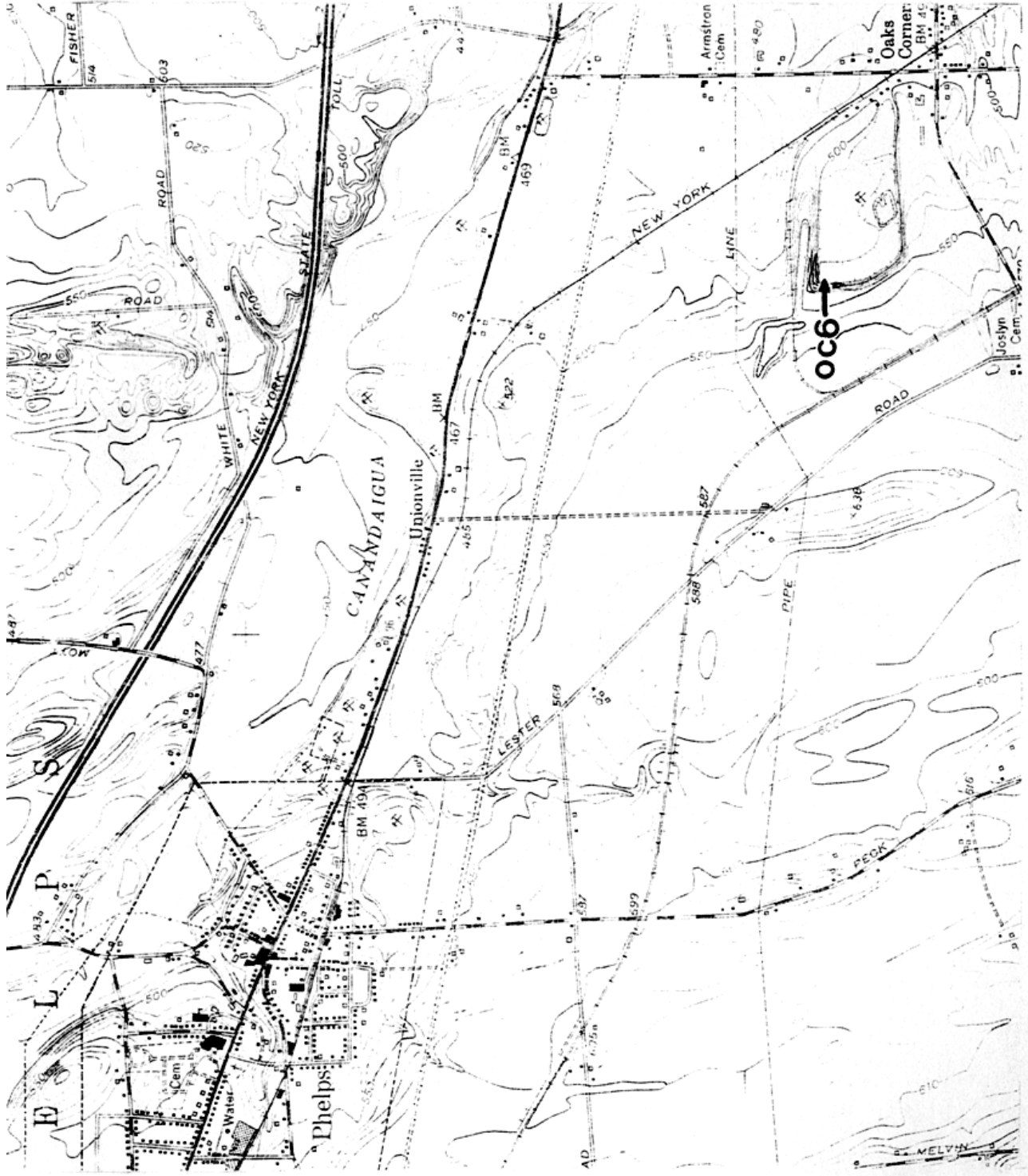
Williamsville (OC 2) and Centerpointe Site (OC 7)
 (Lancaster Quad 1965 Edition Scale 1:24 000)



Goodrich Roadcut (OC 3)
 (Clarence Quad 1965 Edition Scale 1:24 000)



Akron Falls (OC 4)
 (Akron Quad 1951 Edition Scale 1:24 000)



Oaks Corners Quarry (OC 6)
 (Phelps Quad 1953 Edition Scale 1:24 000)

Appendix 3: Chert Outcrop Record Form

CODE #:..... TYPE(S):.....

LOCATION:map.....
town..... county.....
property.....
description.....

NATURE: nodular ... tabular ... other

COLOUR:.....

QUALITY (estimate):.....

OTHER OBSERVATIONS (e.g. bioforms, geo info):
.....
.....
.....
.....
.....
.....
.....

DATA SAMPLED: (D/M/Y): / /

SAMPLERS:.....

QUALITY OF SAMPLES: best.. all.. other..

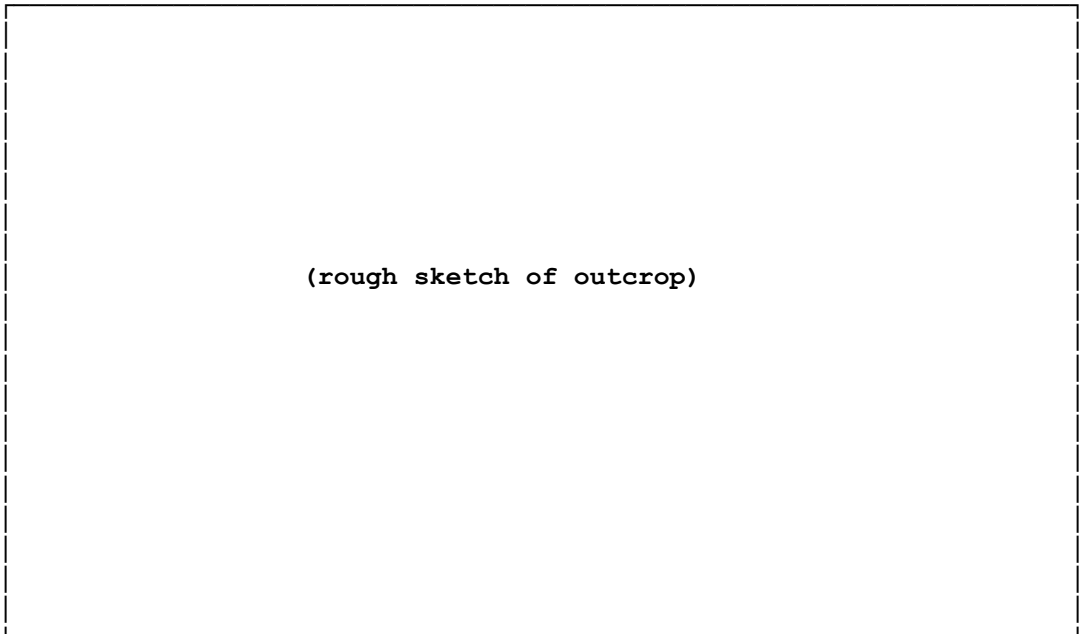
PHOTO #'s: B/W Colour

SAMPLING STRATEGY: vertical.. grid.. grab.. other..

INTERVAL: horiz... cm vert...cm natural...

OF SAMPLES:

Approx. Scale:=.... Bearing:-.....



Sketch a map of the sampling location on back of page.

Appendix 4: INAA Data

Sample Element Concentrations

key: SMP = INAA sample #

OC = outcrop #

POS = vertical position

Q = quality (1=excellent, 2=fair, 3=poor)

MASS = INAA sample mass in mg

Note: all element concentrations are expressed
in ppm except where noted as %

SMP	OC	POS	Q	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%	Mass
2	1	38	9	.41	.15	24.36	107.1	34.42	.00	9.65	.22	43.9	.07	4.29	.1	.39	14.32	975.66	1.34	299
4	1	67	3	.39	.17	.00	121.1	31.09	.00	10.0	.16	45.9	.07	3.70	.1	.34	11.75	964.92	2.33	313
6	1	140	1	.43	.12	27.62	105.3	.00	.00	12.1	.17	45.0	.07	4.33	.1	.38	9.43	1025.1	.58	314
8	1	195	3	.38	.10	.00	66.78	38.43	.00	10.0	.13	44.7	.07	2.72	.0	.36	9.43	956.57	1.25	279
10	1	265	1	.49	.10	18.19	89.06	36.32	.00	9.93	.16	40.3	.06	2.83	.0	.31	10.08	936.64	2.49	310
12	1	350	1	.48	.13	18.11	124.2	30.86	.00	11.0	.17	55.6	.07	4.33	.1	.66	10.74	1070.4	1.91	300
14	1	400	1	.38	.09	.00	93.43	36.63	.00	10.5	.15	45.1	.07	2.96	.1	.36	8.71	975.83	.66	303
16	1	440	1	.33	.08	19.90	55.90	44.41	.00	10.8	.16	46.9	.07	2.03	.1	.34	7.60	1008.3	.72	352
18	2	0	8	1.2	1.1	78.72	714.9	.00	.00	.00	9.81	.00	.04	12.7	.8	.89	256.8	492.90	18.1	300
20	2	410	3	.59	.24	24.55	114.1	.00	.00	9.45	.18	44.5	.07	5.67	.1	.42	32.32	1010.6	2.26	364
22	2	460	1	.45	.13	.00	111.4	.00	.00	11.2	.15	44.2	.07	5.87	.1	.40	13.44	1043.8	.98	382
24	2	500	3	.44	.17	18.71	163.5	39.36	.71	11.3	.25	50.8	.07	7.61	.2	.49	12.95	1064.8	.63	354
26	2	620	3	.47	.26	.00	169.0	55.70	.00	7.21	.26	41.0	.05	4.47	.2	.43	25.97	708.22	4.25	318
28	2	775	1	.45	.25	23.71	143.6	48.63	.00	10.8	.23	41.4	.07	3.56	.2	.39	19.27	973.89	3.79	312
30	2	815	3	.26	.12	27.03	103.3	39.95	.00	11.1	.17	43.6	.07	3.21	.0	.35	11.33	1034.0	1.46	288
32	2	873	2	.31	.10	19.65	86.23	.00	.00	10.6	.14	42.5	.07	3.44	.0	.37	9.98	1005.8	.95	300
34	3	260	1	.46	.18	29.15	172.3	34.05	.00	11.2	.17	44.5	.09	7.13	.2	.50	14.90	1293.3	.85	381
36	3	290	1	.38	.15	25.36	118.7	44.65	.00	12.1	.18	39.8	.08	5.72	.1	.36	17.49	1254.9	1.81	355
38	3	335	9	.38	.12	25.33	145.8	29.06	.00	10.4	.16	43.0	.07	6.15	.2	.47	11.85	1150.7	.57	381
40	3	370	1	.45	.17	32.53	193.7	41.57	.00	12.1	.21	45.1	.08	8.10	.3	.56	15.13	1213.0	.86	346
42	3	410	1	.39	.21	31.05	162.2	.00	.00	13.3	.21	42.4	.08	6.80	.2	.47	18.13	1274.7	2.63	350
44	3	460	1	.38	.16	28.38	137.6	53.57	.75	10.7	.21	41.7	.06	4.94	.0	.40	16.51	1068.2	2.44	358
46	3	490	3	.45	.17	24.53	142.2	37.72	.00	9.68	.19	44.3	.05	7.06	.1	.45	16.79	986.97	2.08	326
48	3	530	3	.42	.21	31.42	120.7	53.69	.00	7.40	.16	38.3	.05	3.51	.1	.35	20.79	787.82	5.48	290
50	3	580	1	.38	.14	.00	116.0	42.17	.00	10.9	.10	44.6	.07	3.17	.1	.35	12.49	1183.0	2.29	305
52	3	623	3	.41	.21	22.93	123.5	53.20	.75	12.2	.11	45.0	.06	3.16	.1	.38	15.57	1148.9	3.45	316
54	4	20	2	.73	.45	45.03	299.6	.00	1.4	4.14	.39	39.5	.04	11.9	.3	.64	41.35	316.24	4.48	328
56	4	50	3	.74	.21	37.95	221.3	62.80	.00	18.1	.32	46.3	.12	11.8	.3	.60	20.70	2174.2	1.15	309
58	4	70	2	.62	.26	26.53	196.0	59.75	.00	19.4	.23	48.2	.13	9.43	.2	.55	17.73	2243.7	1.10	354
60	4	100	1	.64	.24	37.84	198.0	59.98	.00	15.7	.20	43.3	.10	10.1	.2	.51	35.40	1762.4	2.31	332
62	4	130	1	.46	.00	.00	161.2	.00	.00	20.8	.14	45.7	.12	6.35	.2	.49	30.65	2255.7	.68	355
64	4	165	1	.45	.17	19.93	141.9	43.87	.81	18.8	.13	43.8	.12	4.64	.1	.41	23.99	2154.7	1.58	369
66	5	0	2	.66	.24	34.37	231.1	31.82	.00	4.01	.28	45.7	.03	9.73	.3	.61	19.33	404.74	2.35	335
68	5	40	2	.48	.14	24.61	183.8	.00	.00	8.58	.31	41.9	.11	7.68	.2	.46	23.75	896.96	.67	365
70	5	75	3	.53	.22	20.64	240.4	.00	.00	7.44	.24	48.7	.06	6.64	.2	.56	16.10	836.13	1.77	324
72	5	165	2	.46	.21	29.03	196.0	.00	.00	7.89	.25	50.1	.06	7.25	.2	.51	14.11	814.53	.83	339
74	5	230	2	.42	.12	21.16	153.1	.00	.00	6.22	.26	45.4	.04	3.96	.1	.37	14.30	575.14	1.15	304
76	5	250	2	.53	.13	34.73	80.08	.00	.00	7.83	.15	49.1	.06	5.21	.1	.44	10.70	766.62	1.14	250
78	5	315	9	.48	.13	34.65	118.3	.00	.00	10.5	.12	47.1	.07	5.32	.1	.40	8.72	1077.8	.65	245
80	5	345	1	.42	.00	31.14	128.6	.00	.00	9.26	.11	42.7	.07	3.85	.1	.38	9.03	898.45	.76	285
82	5	370	1	.47	.12	22.81	106.8	42.54	.00	11.0	.15	44.1	.07	4.19	.1	.39	11.48	1011.0	.82	297
84	5	407	1	.53	.09	26.42	109.4	.00	.00	10.2	.13	47.1	.06	3.17	.1	.39	7.70	1057.5	.91	284
86	5	487	1	.31	.11	30.74	122.7	.00	.00	11.2	.13	45.4	.08	3.48	.1	.40	6.96	1103.9	1.04	272
88	5	523	3	.33	.09	22.76	109.0	.00	.00	11.2	.14	48.5	.07	2.64	.0	.39	7.86	1000.7	1.40	269

SMP	OC	POS	Q	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%	Mass
90	5	560	3	.41	.19	23.55	108.8	31.20	.00	9.84	.19	40.4	.05	2.56	.1	.35	18.15	821.29	3.89	307
92	5	593	1	.46	.16	24.50	119.4	.00	.00	9.37	.16	48.6	.07	4.53	.1	.45	9.86	1006.5	.91	319
94	5	620	1	.29	.13	23.51	94.79	33.36	.00	12.0	.15	46.9	.08	2.78	.0	.37	9.63	1123.7	1.64	293
96	5	649	1	.42	.14	16.82	127.7	45.15	.00	10.4	.17	43.8	.06	3.70	.1	.39	12.15	903.05	2.24	289
98	6	999	9	.49	.00	42.14	168.7	96.33	.00	25.3	.27	42.6	.12	4.50	.1	.40	24.60	2130.0	1.00	369
100	6	999	9	.27	.00	41.54	167.6	.00	.00	24.1	.31	47.2	.12	4.55	.0	.41	26.13	1968.2	.93	290
102	6	999	9	.50	.00	40.51	156.1	.00	.00	21.2	.29	43.1	.11	4.20	.0	.41	30.82	1866.4	1.17	357
104	6	999	9	.44	.00	27.77	158.6	57.56	.00	20.0	.23	44.3	.10	3.44	.0	.39	22.28	1766.7	.68	364
106	6	999	9	.60	.21	46.17	230.6	117.0	.00	22.2	.42	40.4	.12	7.07	.2	.50	43.34	1961.1	2.11	241
1	1	12	3	.30	.10	21.17	87.71	.00	.00	10.5	.21	48.0	.07	4.05	.0	.37	10.73	967.45	1.27	370
3	1	50	3	.43	.13	17.82	141.9	.00	.00	9.83	.15	39.2	.06	4.06	.0	.33	12.96	797.11	2.07	293
5	1	96	3	.50	.07	.00	83.86	.00	.90	10.2	.17	45.8	.07	2.78	.1	.33	10.20	970.29	.80	295
7	1	155	1	.46	.13	15.08	113.3	30.65	.00	9.21	.10	43.8	.06	3.80	.0	.34	12.35	805.27	1.92	381
9	1	215	2	.46	.10	.00	109.5	.00	.00	8.81	.13	45.8	.06	3.08	.0	.33	8.17	724.77	1.24	325
11	1	328	1	.39	.11	17.69	133.8	.00	.00	10.1	.16	56.0	.06	3.86	.1	.65	8.92	922.00	.99	287
13	1	380	1	.37	.17	38.48	111.7	.00	.00	7.93	.23	47.6	.06	3.23	.0	.37	15.46	817.18	2.32	255
15	1	418	2	.41	.13	.00	104.3	38.94	.00	6.30	.19	38.8	.05	2.71	.1	.34	10.25	735.18	2.51	381
17	1	440	1	.33	.15	16.11	113.1	.00	.00	9.75	.17	47.5	.07	2.88	.0	.36	7.72	933.88	.91	323
19	2	370	3	.89	.46	33.25	204.1	.00	.00	5.39	.28	39.0	.04	8.40	.1	.44	66.40	525.83	5.30	365
21	2	445	2	.58	.25	29.62	207.0	.00	.86	8.86	.26	43.1	.06	8.96	.2	.57	24.26	935.40	1.71	338
23	2	500	3	.38	.12	26.22	115.3	.00	.00	8.68	.16	42.2	.05	5.59	.1	.38	15.29	874.89	.82	386
25	2	580	1	.42	.14	27.82	135.0	.00	.00	8.04	.33	42.2	.06	3.58	.1	.37	23.25	951.04	1.03	312
27	2	695	3	.32	.17	.00	106.7	.00	.00	10.9	.27	41.0	.06	2.68	.0	.34	19.32	951.47	2.17	325
29	2	780	1	.33	.10	.00	97.28	.00	.00	8.92	.21	46.5	.07	2.76	.0	.34	9.59	982.83	.62	241
31	2	845	1	.30	.13	.00	96.25	.00	.00	9.86	.25	42.7	.06	2.52	.1	.34	14.28	962.79	.74	304
33	2	873	2	.33	.00	.00	124.2	.00	.00	10.3	.16	43.4	.07	3.12	.0	.36	10.96	1001.3	.93	282
35	3	276	3	.44	.25	27.76	136.4	41.97	.00	11.2	.18	38.5	.08	8.16	.1	.38	23.99	1191.0	3.66	375
37	3	310	3	.50	.16	23.67	110.8	35.65	.88	9.42	.18	45.9	.07	5.31	.1	.42	13.27	954.93	1.87	309
39	3	355	1	.45	.14	25.48	176.5	.00	.00	11.0	.23	44.4	.08	6.82	.1	.53	16.02	1163.9	.87	330
41	3	390	3	.47	.22	25.20	166.3	.00	.00	8.66	.22	41.9	.05	6.08	.2	.44	15.71	775.55	2.49	393
43	3	440	3	.39	.22	19.98	158.7	38.50	1.1	5.16	.20	43.2	.03	5.34	.1	.38	17.17	376.64	3.77	356
45	3	470	1	.48	.11	27.04	139.7	.00	.00	14.0	.19	47.7	.07	9.07	.1	.48	9.81	1319.5	.60	337
47	3	510	3	.48	.21	19.39	156.9	42.12	.00	9.31	.17	43.5	.05	5.33	.2	.43	15.58	921.85	2.14	300
49	3	550	2	.48	.27	23.12	134.1	41.18	.88	8.82	.20	39.6	.06	5.50	.0	.39	18.65	821.27	5.23	289
51	3	600	3	.46	.19	.00	82.11	.00	.51	10.5	.09	41.7	.07	3.35	.0	.35	12.48	1099.6	3.38	311
53	4	0	3	.95	.33	40.06	232.0	48.72	.00	11.0	.25	48.7	.07	10.5	.3	.59	41.43	1343.3	2.44	352
55	4	35	1	.64	.27	26.54	215.8	40.54	.00	15.6	.26	43.5	.11	8.97	.2	.53	20.84	1899.2	1.49	327
57	4	65	3	.61	.13	29.26	172.8	.00	.00	16.0	.19	40.2	.11	8.89	.1	.45	14.53	1863.5	1.26	293
59	4	90	3	.54	.11	24.44	171.9	46.34	.00	20.4	.16	47.6	.11	6.66	.1	.47	11.56	2139.8	.48	325
61	4	110	1	.43	.20	.00	86.41	.00	.00	17.1	.13	42.3	.11	5.47	.1	.38	14.83	1989.6	1.80	314
63	4	150	3	.49	.20	23.79	136.8	49.07	1.8	13.9	.19	44.0	.08	6.38	.1	.44	59.87	1476.9	1.97	346
65	4	0	8	.96	.88	82.07	614.7	.00	.00	.00	9.79	.00	.04	17.1	1.0	1.2	171.9	517.12	19.1	343
67	5	15	2	.46	.26	20.51	210.0	37.15	1.3	.00	.25	42.3	.02	6.59	.2	.45	16.45	126.33	3.80	321
69	5	59	9	.56	.17	34.12	224.3	.00	.00	3.44	.23	44.7	.03	7.45	.2	.52	15.15	289.95	1.16	266
71	5	91	3	.51	.20	17.34	248.6	.00	.89	3.41	.27	45.1	.03	5.82	.2	.52	17.85	314.12	2.37	376
73	5	195	1	.41	.14	.00	160.6	.00	.00	9.80	.16	52.2	.06	5.51	.1	.41	8.71	970.64	.52	350
75	5	240	2	.48	.22	.00	112.4	.00	.00	7.45	.25	47.8	.04	5.45	.1	.37	15.23	676.63	2.30	310
77	5	290	1	.63	.13	.00	.00	.00	.74	11.4	.20	46.7	.05	2.95	.0	.36	12.82	898.18	1.39	225
79	5	333	1	.45	.07	17.78	110.9	.00	.00	9.14	.10	42.4	.07	3.42	.0	.35	10.24	956.36	1.29	323
81	5	355	1	.51	.13	23.88	96.09	13.67	.00	10.4	.13	45.2	.06	2.82	.1	.37	8.34	954.60	.96	227
83	5	393	1	.51	.09	22.43	119.7	.00	.00	10.5	.38	44.2	.06	3.25	.0	.38	8.09	956.37	.95	220
85	5	450	1	.51	.11	.00	89.00	.00	.00	10.2	.17	46.0	.07	2.86	.0	.37	9.11	948.92	1.03	265
87	5	505	1	.39	.16	17.88	139.6	44.69	.00	9.21	.15	45.0	.07	3.15	.0	.36	10.49	947.37	1.41	284

SMP	OC	POS	Q	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K%	Al%	Mn	Cl	Ca%	Mass
89	5	543	1	.39	.13	.00	.00	37.16	.00	8.60	.16	40.9	.06	1.71	.0	.31	10.47	837.59	2.22	293
91	5	575	1	.41	.14	16.61	107.0	.00	.00	10.5	.17	49.6	.07	2.74	.1	.40	10.06	950.07	2.15	349
93	5	605	1	.50	.13	27.39	96.13	21.91	.00	10.5	.21	44.8	.07	4.02	.1	.41	10.78	975.67	1.60	309
95	5	643	1	.42	.15	.00	133.6	.00	.00	9.65	.18	43.5	.06	2.98	.0	.38	12.61	890.61	2.76	304
97	5	685	1	.39	.12	16.05	106.7	30.19	.00	8.89	.17	47.4	.05	4.20	.1	.41	9.63	763.80	.89	340
99	6	999	9	.51	.13	27.27	175.5	76.05	.00	20.8	.31	49.9	.11	4.68	.0	.40	26.46	1844.8	.90	247
101	6	999	9	.39	.11	25.68	161.7	61.80	.00	23.5	.25	47.6	.11	3.77	.1	.38	20.14	1865.4	.62	345
103	6	999	9	.49	.15	31.25	120.2	74.41	.00	20.1	.28	49.0	.10	4.35	.1	.43	26.32	1666.0	.86	329
105	6	999	9	.52	.16	30.20	160.6	63.78	1.2	26.2	.23	46.6	.12	4.84	.0	.41	22.09	139.44	.99	260
130	10	999	9	.75	.11	57.52	141.7	33.76	.00	8.40	.38	41.9	.05	4.95	.1	.40	19.90	883.88	1.24	252
131	10	999	9	.53	.12	70.51	186.4	.00	.70	9.11	.46	40.8	.04	6.31	.2	.45	31.43	840.85	1.40	232
132	10	999	9	.51	.15	.00	.00	.00	.00	14.5	.06	50.8	.06	2.84	.0	.36	8.41	1355.7	1.60	219
133	10	999	9	.64	.13	84.56	279.0	.00	.00	8.65	.48	45.8	.05	6.07	.2	.51	26.55	902.80	1.21	209
134	10	999	9	.42	.00	24.60	.00	34.64	.77	13.8	.05	44.9	.04	.00	.1	.26	9.71	1417.6	1.90	287
135	10	999	9	.34	.11	29.20	107.6	36.73	.68	15.6	.10	41.0	.07	2.15	.0	.31	7.61	1378.5	1.27	372
136	10	999	9	.48	.09	35.49	136.7	.00	.00	11.1	.04	47.8	.02	2.80	.2	.41	5.36	978.39	.28	308
137	10	999	9	.58	.09	28.31	140.2	.00	.00	14.7	.00	44.3	.05	2.32	.0	.37	4.25	1316.5	.10	282
138	10	999	9	.82	.00	60.51	179.1	.00	.00	11.3	.36	42.1	.04	3.96	.1	.39	16.98	787.44	.90	220
139	10	999	9	.23	.00	36.68	120.7	.00	.00	10.7	.24	42.4	.06	5.22	.1	.39	12.58	981.83	.63	318
140	8	999	9	.26	.08	.00	.00	.00	.00	8.84	.05	46.9	.04	1.26	.0	.26	8.19	794.67	1.38	342
141	8	999	9	.32	.00	138.0	95.46	.00	.43	5.02	.01	43.1	.02	2.64	.1	.34	1.42	480.63	.05	236
142	8	999	9	.31	.09	89.05	107.2	.00	.00	6.83	.02	44.7	.02	2.42	.1	.34	4.43	616.72	.28	282
143	8	999	9	.57	.11	78.96	162.4	23.38	.61	4.22	.05	48.4	.02	4.98	.1	.37	7.37	355.13	.53	286
144	8	999	9	.62	.19	31.45	167.7	.00	.00	10.1	.11	46.5	.03	2.81	.1	.42	14.63	863.08	1.21	276
145	8	999	9	.36	.17	26.33	134.4	40.04	.00	10.2	.17	47.3	.05	2.68	.1	.35	24.00	1020.0	1.84	335
146	8	999	9	1.4	.23	50.33	333.5	.00	.00	9.27	.05	52.1	.05	5.10	.1	.55	14.89	587.32	.46	207
147	8	999	9	.62	.10	35.78	126.7	53.08	.00	20.9	.00	41.9	.09	3.44	.0	.39	3.35	2012.0	.09	240
148	8	999	9	.48	.17	36.86	152.8	.00	.00	7.28	.11	42.4	.03	3.13	.1	.38	22.44	690.50	1.06	308
149	8	999	9	.49	.14	32.95	189.8	.00	.00	5.01	.00	43.5	.01	4.21	.1	.37	26.55	299.35	.24	299
150	9	999	9	.43	.07	19.07	150.0	.00	.00	7.22	.00	44.0	.04	4.29	.1	.36	4.38	680.39	.15	322
151	9	999	9	.68	.00	99.66	139.9	.00	.00	8.91	.08	47.0	.02	3.28	.1	.37	7.52	646.65	.37	260
152	9	999	9	.34	.00	70.50	186.7	.00	.44	6.44	.00	46.0	.02	2.73	.1	.40	2.61	582.21	.03	262
153	9	999	9	.48	.00	52.92	155.7	.00	.00	8.16	.00	44.5	.02	5.45	.1	.44	4.00	655.19	.10	272
154	9	999	9	.32	.00	138.0	95.46	.00	.43	5.02	.00	43.1	.02	2.64	.1	.34	1.42	480.63	.05	272
155	9	999	9	.36	.09	27.52	170.3	.00	.73	3.92	.00	47.3	.02	3.30	.1	.39	3.99	263.75	.04	257
156	9	999	9	.60	.00	148.9	168.7	.00	.00	6.24	.08	48.0	.02	3.87	.1	.45	9.94	593.18	1.03	225
157	9	999	9	.48	.12	90.15	127.0	34.79	.00	9.43	.07	44.8	.02	3.07	.1	.36	6.17	743.14	.36	273
158	9	999	9	.50	.10	31.03	202.9	.00	.68	4.11	.00	45.8	.01	3.41	.1	.38	3.24	413.22	.00	262
159	9	999	9	.64	.00	23.39	.00	.00	.00	7.03	.00	47.4	.04	1.41	.0	.28	44.22	820.65	.08	357
110	7	999	1	.52	.11	.00	107.8	.00	.00	11.3	.18	39.8	.07	2.47	.1	.29	10.76	1188.4	.74	324
111	7	999	1	.35	.18	.00	93.42	46.68	.73	10.3	.18	41.0	.07	1.79	.1	.22	15.34	1000.9	3.94	332
112	7	999	1	.60	.11	30.68	142.8	.00	.00	12.7	.23	40.6	.07	2.98	.1	.31	10.55	1013.1	.71	231
113	7	999	1	.32	.00	.00	128.7	42.82	.00	11.1	.16	42.3	.07	2.20	.0	.31	12.61	1121.9	2.63	193
114	7	999	1	.45	.14	32.33	93.65	.00	.00	12.1	.09	43.9	.06	2.10	.0	.32	8.47	966.85	1.67	277
115	7	999	1	.50	.13	21.20	111.9	.00	.00	12.8	.20	39.1	.04	2.88	.1	.28	12.89	966.13	.58	336
116	7	999	1	.45	.15	23.70	152.5	30.85	.00	.00	.17	40.0	.03	4.38	.2	.33	12.94	997.89	.61	304
117	7	999	1	.49	.12	20.76	.00	.00	.00	10.2	.14	40.5	.03	1.64	.1	.24	12.05	903.19	1.97	277
118	7	999	1	.36	.11	25.77	101.5	33.61	.00	10.3	.23	48.0	.06	2.29	.1	.38	11.75	1113.2	1.05	248
119	7	999	1	.50	.13	30.67	122.1	46.59	.00	12.1	.20	45.1	.05	3.38	.2	.38	11.22	1008.8	1.51	332
120	7	999	1	.39	.15	21.00	103.4	34.40	.00	12.5	.22	50.4	.08	3.42	.1	.36	14.91	1217.3	2.41	294
121	7	999	1	.57	.13	.00	125.5	33.44	.00	11.8	.28	41.1	.06	3.60	.1	.43	13.52	1129.6	.76	243
122	7	999	1	.36	.14	20.82	92.32	.00	.00	11.1	.21	45.2	.06	2.40	.1	.33	9.77	1182.3	.69	263
123	7	999	1	.57	.12	31.71	129.6	.00	.00	12.2	.24	44.9	.07	3.59	.1	.44	13.52	1161.7	.92	358

<u>SMP</u>	<u>OC</u>	<u>POS</u>	<u>Q</u>	<u>U</u>	<u>Dy</u>	<u>Ba</u>	<u>Ti</u>	<u>Sr</u>	<u>I</u>	<u>Br</u>	<u>Mg%</u>	<u>Si%</u>	<u>Na%</u>	<u>V</u>	<u>K%</u>	<u>Al%</u>	<u>Mn</u>	<u>Cl</u>	<u>Ca%</u>	<u>Mass</u>
124	7	999	1	.46	.10	19.11	139.4	.00	.00	10.9	.16	45.2	.07	2.55	.1	.32	11.02	924.67	1.52	345
125	7	999	1	.59	.15	33.70	147.1	.00	.00	14.3	.22	49.3	.07	3.79	.1	.40	12.42	1164.8	.86	294
107	1	150	8	1.2	.95	.00	.00	306.8	.00	.00	.45	.00	.02	5.52	.1	.22	81.59	254.25	36.2	310
108	1	150	8	1.2	.99	88.24	208.2	292.6	2.0	.00	.42	5.46	.02	8.76	.2	.29	84.40	269.45	35.4	349
109	1	150	8	1.3	.99	53.82	240.5	208.0	2.4	4.42	.63	11.1	.03	14.3	.3	.55	72.29	241.36	29.0	349
126	1	150	8	1.3	.81	.00	.00	218.8	.00	.00	.38	.00	.02	6.29	.0	.21	77.56	180.77	38.7	368
127	1	150	8	1.2	.88	100.8	.00	233.8	2.8	.00	.40	.00	.02	4.58	.0	.17	80.24	207.88	37.7	320
128	1	150	8	1.3	.97	.00	167.0	290.4	3.4	.00	.43	.00	.02	7.50	.2	.26	80.38	288.50	36.7	367
129	1	150	8	1.8	1.0	44.75	152.7	260.6	3.0	.00	.46	.00	.02	7.28	.2	.26	78.69	274.61	37.2	347

Appendix 5: General Sample Information

Sample: L indicates limestone; D indicates dolomite.

Outcrop Location

- | | |
|--------------------------------|---------------------------|
| 1.....East Amherst St. Roadcut | 6.....Oaks Corners Quarry |
| 2.....Glen Park Falls | 7.....Centerpointe Site |
| 3.....Goodrich Road Roadcut | 8.....Guenther Site |
| 4.....Akron Falls Park | 9.....French 3 Site |
| 5.....East Amherst St. Quarry | 10.....Henry Long Site |

Position refers to the vertical distance in centimeters above the starting point on the face of the landmark (often at the disconformity). At Outcrop 7, EAST refers to the eastern sampling area, and WCEN to the west central region of the site.

Accession, for the archaeological samples, refers to the Marian E. White Museum artifact accession numbers.

Quality refers to the quality estimate based on flaking properties and fineness of texture.

- 1.....fine-grained texture, good to excellent flaking properties
- 2.....medium-grained texture, more marginal flaking properties
- 3.....coarse or highly varied texture and inclusions, poor flaking properties

Colour is measured using the Geological Society of America's Rock Colour Chart. (mw indicates mottling; & indicates the presence of two equally dominant colours.)

Mass is in milligrams.

Outcrop	Sample	Position	Quality	Colour	Mass
1	001	12	3	N5 mw N7	370
	002	38		N4 mw 5YR 2/1 & N7	299
	003	50	3	N5 mw N7	293
	004	67	3	N5 mw N7	313
	005	96	3	N4 mw N7	295
	006	140	1	N3 mw 5B 7/1	314
	007	155	1	N3	381
	008	195	1	N4 mw 5B 7/1	279
	009	215	2	N4 & N6	325
	010	265	1	N4 mw 5B 7/1	310
	011	328	1	N4 mw 5B 7/1	287
	012	350	1	N4 mw N7	300
	013	380	1	N4 mw 5B 7/1	255
	014	400	1	N4 mw 5B 7/1	303
	015	418	2	N4 mw 5B 7/1	381
	016	440	1	N3 mw 5B 7/1	352
	017	440	1	N3 mw 5B 7/1	323
	107 L	150	-	-	310
	108 L	150	-	-	349
	109 L	150	-	-	349
	126 L	150	-	-	368
	127 L	150	-	-	320
	128 L	150	-	-	367
	129 L	150	-	-	347

Outcrop	Sample	Position	Quality	Colour	Mass
2	018 D	000			300
	019	370	3	N4 mw 5B 7/1	365
	020	410	3	N4 & N5 mw N7	364
	021	445	2	N5 mw 5YR 2/1 & N7	338
	022	460	1	N5 mw 5YR 2/1 & N7	382
	023	500	3	N4 mw 5B 7/1	386
	024	505	3	N5 mw 5B 7/1	354
	025	580	1	N4 mw N7	312
	026	620	3	N4 mw 5B 7/1	318
	027	695	3	N5 mw 5B 7/1	325
	028	775	1	N4 mw N7	312
	029	780	1	N4 mw N7	241
	030	815	3	N4 mw 5B 7/1	288
	031	845	1	N4 mw 5B 7/1	304
	032	873	2	N4 mw 5B 7/1	300
033	873	2	N4 mw 5B 7/1	282	
3	034	260	1	N3	381
	035	276	3	N4	375
	036	290	1	N4 mw 5B 7/1	355
	037	310	3	N4 mw 5B 7/1	309
	038	335	-	N4 mw 5B 7/1	381
	039	355	1	N4 mw 5B 7/1	330
	040	370	1	N4 mw N7	346
	041	390	3	N4 mw 5B 7/1	393
	042	410	1	N4 mw 5B 7/1	350
	043	440	3	N4 mw 5B 7/1	356
	044	460	1	N4 mw 5B 7/1	358
	045	470	1	N4 mw N7	337
	046	490	3	N4 mw 5B 7/1	326
	047	510	3	N4 mw N7	300
	048	530	3	N4 mw N7	290
	049	550	2	N3 & N5 mw 5B 7/1	289
	050	580	1	N3 & N5 mw 5B 7/1	305
	051	600	3	N4 & N6	311
052	623	3	N4 & N5 mw 5B 7/1	316	
4	053	0	3	N4	352
	054	20	2	N3 mw N7	328
	055	35	1	N3 mw N7	327
	056	50	3	N3	309
	057	65	3	N4	293
	058	70	2	N3	354
	059	90	3	N3 mw 5B 7/1	325
	060	100	1	N3 & N6	332
	061	110	1	N4 mw N7	314
	062	130	1	N4 mw N7	355
	063	150	3	N3 mw N7	346
	064	165	1	N4 mw N7	369
	065 D	0	-	-	343

Outcrop	Sample	Position	Quality	Colour	Mass
5	066	0	2	N4 mw N6	335
	067	15	2	N4 mw N6	321
	068	40	2	N6 & N4	365
	069	59	-	N3 mw N6	266
	070	75	3	N4 mw N7	324
	071	91	3	N3 mw N6	376
	072	165	2	N5 mw N6	339
	073	195	1	N5 mw N6	350
	074	230	2	N4 & N5 mw N8	304
	075	240	2	N4 & N5 mw N8	310
	076	250	2	N5 mw N7	250
	077	290	1	N3 mw N6	225
	078	315	-	N3 mw N6	245
	079	333	1	N4 mw N6	323
	080	345	1	N3 mw N6	285
	081	355	1	N4 mw N6	227
	082	370	1	N3 mw N6	297
	083	393	1	N3 & N4 mw N7	220
	084	407	1	N4 mw N6	284
	085	450	1	N3 & N4 mw N7	265
	086	487	1	N3 mw N6	272
	087	505	1	N3 & N4 mw N7	284
	088	523	3	N3 & N4 mw N7	269
	089	543	1	N3 & N4 mw N7	293
	090	560	3	N3 mw N6	307
	091	575	1	N3 mw N6	349
	092	593	1	N3 mw N6	319
	093	605	1	N3 mw N6	309
	094	620	1	N3 mw N6	293
	095	643	1	N3 mw N6	304
	096	649	1	N3 mw N6	289
097	685	1	N3 mw N6	340	
6	098	1370	-	N3	369
	099	1370	-	N4	247
	100	1370	-	N4	290
	101	1370	-	N3	345
	102	1370	-	N4	357
	103	1370	-	N3	329
	104	1370	-	N3	364
	105	350	-	N2	260
	106	350	-	N2	241

Outcrop	Sample	Position	Quality	Colour	Mass
7	110	EAST	1	N4 mw 5B 7/1	324
	111	EAST	1	N5	332
	112	EAST	1	N4 mw 5B 7/1	231
	113	EAST	1	N4 mw 5B 7/1	277
	115	EAST	1	N5	336
	116	EAST	1	N5	304
	117	EAST	1	N5	277
	118	WCEN	1	N4 mw 5B 7/1	248
	119	WCEN	1	N4 mw 5B 7/1	332
	120	WCEN	1	N4 mw 5B 7/1	294
	121	WCEN	1	N4 mw 5B 7/1	243
	122	WCEN	1	N4 mw 5B 7/1	263
	123	WCEN	1	N4 mw 5B 7/1	358
	124	WCEN	1	N4 mw 5B 7/1	345
	125	WCEN	1	N4 mw 5B 7/1	294

Outcrop	Sample	Accession	Mass
8	140	87.09 77910	342
	141	87.09 77897	236
	142	87.09 77904	282
	143	87.09 77901	286
	144	87.09 77898	276
	145	87.09 77895	335
	146	87.09 77895	207
	147	87.09 77862	240
	148	87.09 77896	308
	149	87.09 77896	299
9	150	87.31 80200	322
	151	87.31 80200	260
	152	87.31 80197	262
	153	87.31 80208	272
	154	87.31 80208	272
	155	87.31 80208	257
	156	87.31 80203	225
	157	87.31 80209	273
	158	87.31 80210	262
	159	87.31 80223	357
10	130	62.1 5520	252
	131	62.1 5520	232
	132	62.1 5520	219
	133	62.1 5520	209
	134	62.1 5520	287
	135	62.1 5520	372
	136	62.1 5520	308
	137	62.1 5520	282
	138	62.1 5520	220
	139	62.1 5520	318

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