THE CHEMICAL CHARACTERIZATION OF ONONDAGA CHERT FROM THE PEACE BRIDGE SITE (AfGr-9): IMPLICATIONS FOR THE SPATIAL MOVEMENT OF LATE ARCHAIC LITHICS IN SOUTHERN ONTARIO

BY

GEORGE R. CLARK

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF ARTS

Department of Anthropology
University of Manitoba
Winnipeg, Manitoba

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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FOREWORD

This thesis was not borne from any sort of long-term plan on my part. As with most things, it was completely serendipitous. I had just finished my first year of graduate school and was getting desperate for a viable thesis topic. Late that summer, during my first season of work with a consulting company, I found myself screening fill from an Iroquoian midden at the Holly site in Barrie. I happened to be screening for Ron Williamson, an icon in southern Ontario archaeology, and my course was set through a completely off-hand comment.. I had been speaking to him about the recently published site report of the Peace Bridge site in Fort Erie, an enormous site covering a surprising amount of the urban core of Fort Erie and long known as a hotspot for chert reduction activities. The recent investigations uncovered an unequivocally identified quarry area. Ron immediately suggested something that no one had ever attempted to do – to source the Onondaga chert deriving from the Peace Site. Onondaga chert is virtually everywhere in southern Ontario, mostly derived from glacial cobbles, and here was an identified quarry full of material covering all stages of lithic reduction. The temptation was far too great – to be offered a chance to understand the workings of lithic reduction in such a prolific site – I had to see it through.

Not only did this thesis topic greatly interest me, I felt that I was an ideal candidate for the job. I came to archaeology through the sciences – my undergraduate work was steeped in chemistry and geography. Thus, the methodological underpinnings of the archaeological sciences came easy to me and I was never put off by the prospect of a great deal of math. As well, I had always found myself interested not only in lithic technology, but also in the articulation of technology with society and how one is shaped by the other.

However, in terms of the lithics themselves, I was always intrigued by them. They always conjured up images of industry, ingenuity and reliance – these were more than just pieces of stone, they were a key necessity in the material world of the people who made them. I always knew that despite the gravity and silence that lithics initially seem to offer, that they would speak if spoken to – you just had to learn their language.

When the pragmatic questions in the study of lithics, their production, life history and distribution, are answered to some degree, a subsequent investigation of the ideological and social meanings that are instilled in these artifacts can be addressed. This holistic treatment of the nature of lithics and lithic technology can only shed light upon the economic and social spheres that these products passed though.

It is in this sprit, the nascent investigation of lithic distributions and their area of production, that this study is firmly based. It is offered as that first foothold in the ever broadening study of lithic production systems of which the first and foremost requirement is the identification of their origin and a technique to assign their provenance.

CHAPTER I: INTRODUCTION TO THE PROBLEM

Nobody believes the official spokesman... but everybody trusts an unidentified source. Ron Nesen (Congressional journalist, 1977)

I. Introduction – The problem

In order to address spatial distributions of cultural material on a regional scale, and more importantly, the underlying behavioral mechanisms behind the observed pattern, the archaeologist must first conduct two interrelated tasks: a) the source of the transported or exchanged materials must be identified and b) the observed spatial pattering of the material must be described. These tasks are mandatory when attempting to address the organization of either material movement or prehistoric exchange (Earle 1982). Inherent in these studies is the following: firstly, that some degree of archeologically visible material movement from source to use areas has occurred; secondly, that this movement can be determined with some degree of certainty; and thirdly, that the utilized source is still in existence. Beyond these methodological requirements is the pragmatic economic reality that a researcher will be hesitant to invest heavily in an instrumental research design on a source area that is of questionable importance. In this light, the identification of quarries and other procurement locales is paramount to exchange studies. However, once the effort is expended in comprehensively 'defining' a source a number of enticing research regimes are opened, not the least of which is an attempt at the reconstruction of the procurement and/or exchange systems in play at the source itself.

The Archaic of southern Ontario was a period of flourishing lithic production and distribution. In particular, the Late Archaic of southern Ontario offers evidence of spatially extensive movement of artifacts from source areas to other sites in the region that can be observed with a degree of rigor in the archaeological record. Although it is unlikely that this type of behavior was new to the Archaic, data from earlier times is sparse and does easily lend itself to such a study. The goal of this thesis will be to present a framework for the geochemical identification of raw material from quarry areas and to determine if the extent of movement of raw materials from these source areas to other sites in the larger region is observable. This will provide the opportunity to examine the development of early exchange networks, and any other study that rests upon quantifying material movement across space in southern Ontario and beyond.

II. Data

The Genesee Point (See Figure 1), an archaeologically identifiable form typical of the Broad Point Late Archaic found throughout southern Ontario and New York State, is usually produced on Onondaga chert. This chert type is derived from the Onondaga geological Formation found in southern Ontario and across northern New York State. Recent studies (Jarvis 1990 – see Figure 2) have shown that the eastern half of this formation was formed under conditions that have rendered it with a unique geochemical signature that allows for artifacts produced on this material to be statistically and geochemically identified as having originated from it. However, what was lacking was a comprehensive attempt to link this methodology to the remaining western portions of the formation and, in turn, to archaeological material produced from a known, prolific precontact quarry located on the formation itself. The Peace Bridge site (AfGr-9) fulfills these requirements (See Figure 3).

The Peace Bridge site (AfGr-9) in Fort Erie, Ontario, Canada has been established as a key procurement locality (quarry) for lithic raw material in the Niagara region

(Emerson and Noble 1966, Houghton 1909, Kenyon 1981, Williamson 1999, Williamson and MacDonald 1997). A quarry cut mined by precontact peoples was recently discovered through mitigative excavation at the site. This cut, and the site itself, is located adjacent to the Onondaga Formation. These factors render this site a prime candidate for the study of cultural material movement derived from the raw material available at this locale.

The Peace Bridge site was occupied intensively between the Late Archaic and Early Woodland periods (Emerson and Noble 1966, Houghton 1909, Kenyon 1981, Williamson 1999, Williamson and MacDonald 1997). At the site, pre-contact peoples living in band level societies quarried a vein of high quality Onondaga chert. Of particular note is the Late Archaic Genesee Period presence exhibited at the site, marked by a characteristic point form that has been evidenced in regional contexts (Ellis et al. 1990, MacDonald and Steiss 1997). This style of point is found over a wide geographic area in southern Ontario and New York State. It has been hypothesized that a significant portion of these points were produced on raw material from the Peace Bridge quarry. In short, this site contains all the necessary constituents for an idealized provenance analysis oriented toward the goal of examining material movement across space.

In this study, a comparison of raw material from both on-site and off-site contexts was conducted in order to test this hypothesis. Fragments from Genesee points from several localities across the region of southern Ontario will be included in the analysis.

III. Methods

The provenance methodology used in this study was conducted in three stages, in an attempt to identify a wider regional presence of Peace Bridge chert in each step. The first stage was to perform a provenance study using Induced Neutron Activation Analysis (INAA). A suite of statistical tests, namely descriptive statistics, bivariate plot examination and discriminant analysis, was performed in order to comprehensively define Peace Bridge Onondaga chert from the component quarry in terms of its trace elemental constituents. These results were compared to the trace elemental data derived by Jarvis (1990) on the easternmost portion of the Onondaga Formation in order to determine if the chemical pattering identified by Jarvis (1990) extends west into the Peace Bridge quarry. In order to further chemically delineate the Peace Bridge quarry, this same technique was performed on Onondaga Formation chert exposed in the town of Port Colborne, approximately 26km to the west of the Peace Bridge site (See Figure 2).

The second stage was to use this technique to assay and determine if culturally modified Late Archaic Genesee Period lithic material found in on-site contexts, namely the Late Archaic residential areas, of the Peace Bridge site can be ascribed to the component quarry.

The third and final stage was to use the above technique and results to assay culturally modified Late Archaic Genesee Period lithic material found in off-site, regional contexts in order to determine if they originated from the Peace Bridge quarry. The INAA facility employed for this study is located at McMaster University, Hamilton, Ontario.

IV. Theory and Hypotheses

Studies of material movement across space attempt to establish both the existence of prehistoric inter-regional contact and by specifying the mechanisms of this interaction (Earle and Ericson 1977). This movement need not cover any minimum distance, nor be limited by social or geographical boundaries. However, this movement is of crucial value in generating *spatial* aspects observed in the archaeological record. The spatial distribution of cultural materials in the archaeological record is the product of both the organizational structure driving the movement exchange and the geographical distribution of the artifacts themselves. In this light, the study of material movement can offer the investigator key behavioral insights of the people behind the observed distribution.

This conceptual framework allows for an investigator to formulate a number of hypotheses of the relationship between an artifact source, the resultant regional patterning of material made from that source and the mechanisms responsible. Hypotheses can be divided into two basic types: General and Specific (H.Greenfield, pers comm.). General hypotheses are those that relate to human behavior. Specific hypotheses are those that relate to the specific data and methods used in the research. This is a useful dichotomy because it allows for discussion of general theoretical issues, and their relationship to specific data and methodologies.

IVA. General (Behavioral) Hypotheses

It has been suggested that a great majority of the lithic material found on the Peace Bridge (AfGr-9) site, located in Fort Erie, Ontario originates from the local source, the component Onondaga chert quarry (Williamson and MacDonald 1997). However, evidence also points to the movement of some proportion of this lithic material off-site by precontact peoples (Emerson and Noble 1966, Williamson and MacDonald 1997). It is proposed that some portion of Late Archaic Genesee Period culturally modified lithic material found in regional (off-site) contexts can be identified as having originated from the Peace Bridge quarry. The key behavioral hypotheses are as follows:

(i) If culturally modified lithics from inter-site contexts can be sourced to the component quarry cut, then some degree of lithic reduction activities occurred on-site. The null hypotheses is that lithic material found on site is derived from sources other than the identified component quarry cut or the provenance methodology employed in this study is not applicable to the Peace Bridge quarry.

(ii) If culturally modified lithic material sourced to the Peace Bridge quarry is identified in regional contexts beyond the immediate surroundings of the Peace Bridge site, then this identified movement of culturally modified lithic material into off-site contexts must be explained in behavioral terms, including potential inter-band exchange, regional occupation areas (band territories) or through differential access to raw material source. The null hypothesis that that culturally modified lithic material is found only in local, on-site contexts

IVB. Specific (Research) Hypotheses:

The more specific hypothesis addressed in this study is that *culturally modified lithic material has moved off-site from the procurement or source area*. This will be addressed through a comparative analysis of pre-contact, culturally modified lithic material from both source areas and adjacent discard areas.

The core of this study will be the identification of lithic material displacement through space. In order to identify this type of spatial displacement comprehensively, the archaeologically utilized quarry must be identified and a chemical signature assigned.

V. Conclusion

The suite of evidence that is present at the Peace Bridge (AfGr-9) site allows for the undertaking of an exploratory research design aimed at examining the spatial movement of material. This locale incorporates a precontact quarry with substantial evidence of lithic reduction activity having taken place on site. This study will seek to provide a technique that can ascribe provenance to Onondaga chert derived from the

Peace Bridge quarry. In short, this site contains all the necessary constituents for an idealized provenance analysis towards the goal of examining material movement across space; an archaeologically identifiable artifact form that has been recognized in regional contexts produced on a regionally significant raw material source that is potentially chemically quantifiable.

CHAPTER II: THEORETICAL ISSUES - MODELS OF SPATIAL MOVEMENT AND IMPLICATIONS FOR EXCHANGE STUDIES

I. Introduction

Consciously or not, studies of artifact movement across space expand upon previous diffusion research by attempting to establish both the existence of prehistoric inter-regional contact and by specifying the mechanisms of this interaction (Earle and Ericson 1977). A great many of these studies focused on the role of exchange and its integration within local cultural systems and the role that exchange played in cultural change (Schortman and Urban 1987, Renfrew 1977, 1984). Exchange involves the 'mutual appropriative movement of goods between hands' (Polanyi 1957: 266). This 'movement', or change of location, need not cover any minimum distance, nor be limited by social or geographical boundaries. However, this movement is of crucial value in generating *spatial* aspects observed in the archaeological record. This movement or change in location is elemental to the concept of exchange. The spatial distribution of exchange commodities as observed in the archaeological record is the product of *both* the organizational structure driving the exchange and the geographical distribution of the artifacts themselves. The pragmatic archaeological reality in the study of exchange is that the materials of exchange themselves are often well represented as artifacts in the archaeological record. The intrinsic value ascribed to many exchanged materials (either exotic or utilitarian) by prehistoric cultures is often based upon the qualities of rarity, visual distinctiveness, or durability. This durability – especially in terms of lithics – is amendable to preservation in the archaeological record.

The notion that materials of exchange are driven by behavioral structures coupled with the fact that exchanged materials are often archaeologically visible, point towards the following understanding; that finds of the actual goods exchanged are the most concrete evidence that an archaeologist can hope to have for the determination of contact between cultural groups. However, this cannot be taken as a simple truth, as archaeologists must be mindful of mechanisms of equifinality in the archaeological record. A simple correlation from source A to find spot B does not necessarily equate to exchange between group X at the source and group Y at the find spot. A multitude of unseen and ephemeral social (i.e. direct vs. indirect raw material access, territoriality, exchange of raw vs. semi-finished vs. finished material), and functional (i.e. on-site vs. off-site use contexts, practical vs. prestige) variables influence and drive the observed spatial distribution that is not readily identifiable. The only solace to which students of emerging regional exchange systems can cling is that material exchange often incorporates a source and a destination across space, regardless of the interim behavior.

II. Exchange Theory

A. General exchange theory and Economic Anthropology

Many interpretations and analyses of exchange mechanisms have their roots in economic and structural anthropology, and a brief review of its relationship to these schools is of use here. Interest in exchange studies and the role of the individual in exchange were first studied by Marcel Mauss (1872-1950), the student and nephew of Durkheim, who was interested in the elementary structures behind the practice of giving gifts. Mauss believed that gift giving, or reciprocity, operated according to the elementary principle 'to give, to receive, and to repay' (Erickson and Murphy 1998). To him, reciprocity is an ingrained mental structure; a logic shared by all, which governed not only exchange, but also economics, social organization and kinship. This is in direct contrast to the economic anthropological notion that reciprocity was restricted to non-market economic transitions.

Claude Lévi-Strauss further studied this relationship between kinship and reciprocity (Lévi-Strauss 1969). His structural and ethnographic studies of the reciprocal exchange of women concluded (in simple terms) that kinship groups exchanging women as marriage partners create relationships among themselves and among the exchanged women. This relationship both mediates the groups and brings them closer together forming a balanced system overall, using both 'positive' relationship (that promote harmony) and 'negative' relationships (promoting hostility and antagonism) (Erickson and Murphy 1998).

Exchange studies were further fueled by the economic anthropological debate of the 1960's between economic 'formalists' and economic 'substantivists'. The Formalist school maintains that the traditional Western definition of economics, namely the 'allocation of scarce resources among unlimited wants' can also be applied to non-Western economies (Erickson and Murphy 1998). The archaeological implication is that the amount of an exchanged item found at a site is described mathematically as a function of distance from the source of the material and as a function of the size of the interacting centers (Hodder 1982). The underlying assumption is that the principles of minimal effort and maximum advantage govern exchange. The mathematical models (i.e. regression analysis and gravity models) are based on data from contemporary Western society and can be applied cross-culturally to all societies. Formalist economic anthropology is deductive, in which abstract variables are fitted to an empirical reality (Hodder 1982).

However, substantivists (i.e. George Dalton, Karl Polanyi and Marshall Sahlins) disagree. They maintain that the formalist approach is enthnocentric, and that capitalist conceptions do not apply to economies lacking markets and the social complexity of states (Erickson and Murphy 1998). Rather, people in cultures governed by kinship work to maximize their material advantages in the name of furthering themselves socially, the true economy behind every transaction. This school maintains that society itself is relatively static and self-supporting, aiming to preserve equilibrium with the environment (Hodder 1982). The fundamental difference with formalists is that non-market peoples cannot be interpreted in an economic materialist framework as any worthwhile analysis of such an exchange network must be emic in nature and utilize an inductive framework.

Sahlins (1972) provided additional concepts to the substantivist school by defining three types of reciprocity: a) *positive* reciprocity among close kin, in which exchange acts are motivated by generosity, altruism or the idealism of the gift, b) the less personal *balanced* reciprocity among those well known to each other, in which goods are exchange for material of equal value, and c) *negative* reciprocity, in which strangers of the socially distant attempt outdo each other for the upper-hand (Renfrew and Bahn 1991, Sahlins 1972).

However, some formalist analyses attempt to harbor substantivist ideals. Social-exchange theory holds that all social relations can be conceptualized as social exchanges, and can be studied using economic analyses (Rowlands 1980). Participants in an exchange act can be described as attempting to maximize status and symbolic ties, thus the exchange interaction is the exchange of material and nonmaterial goods between people with interdependent needs (Rowlands 1980). The end result is that economy produces wealth, not to obtain food or other necessities, but to obligate others and increase social power through the acquisition of both material and social wealth.

In contrast to the extremes presented by the formalist and substantivist schools of thought, Hodder believes that exchange must be studied within a social context and as part of a system of production (Hodder 1982). His belief is that the artifacts of exchange are not arbitrary; they are appropriate within a cultural, ideological and historical context. As these objects have meaning in specific cultural categories and not in others, any viable analysis of exchange systems must consider the way in which the symbolism of the artifact legitimates and articulates with the power base of interest groups (Hodder 1982). With this in mind, the development of the cultural value behind exchanged material will shed light upon the active construction of social strategies behind the manipulation of the symbolism and contextual significance of artifacts (Hodder 1982).

B. General models of exchange derived from ethnography

There exists a seemingly unsurpassable dilemma in exchange studies, as Hodder succinctly states: "it is simply impossible to test whether [precontact] artifacts moved from source to destination by exchange from person to person, or whether, on the other hand, individuals went directly to the source" (Hodder 1992: 124). As well, it is certainly conceivable that archaeological artifacts arrived at their destination through mechanisms wholly unrelated to any exchange system in place. Although ethnographic studies certainly show that material exchange could take place, and likely did in the past, it is difficult to observe this archaeologically. However, Hodder has conceded that, to his knowledge, "no one in the literature has suggested that prehistoric [precontact in Canadian Studies] exchange did not occur" (Hodder 1992:124). It is upon this unverifiable assumption that exchange studies rest upon. It is within this sobering context that all exchange studies must be placed.

Exchange studies have long formed an important focus of archaeological and anthropological investigations. Exchange is implicitly a more holistic term that embodies non-material transactions, such as ideas, persons, information etc., and recently many have rejected the term 'trade' as it often implicitly embodies western industrial economic ideals of commodification and profit. The foundation for this interest rests upon two lineages of intellectual endeavor that have been examined with increasing fervor since the early 1980's. The first is abstract and relatively substantiated; namely the recognition that exchange is central to the maintenance and adaptation of cultural systems (Earle and Ericson 1982, Hodder 1982, Renfrew 1984). The second is technical, as recent instrumental innovations have permitted more detailed quantitative studies of exchange (Earle and Ericson 1982). Exchange is at the heart *(au fond)* behind the spatial movement of material, which in turn is the underpinning of the more expansive investigation of social engines driving exchange itself.

However, the study of precontact exchange can offer more than just economic information. Post-processualism emphasizes the notion that material, and hence economic, considerations are intertwined with symbolic and social institutions - upon investigation, one can be defined by the other (Hodder 1992). In this light, the study of exchange offers a method of investigating the organization of society in both social and economic terms (Renfrew 1977, 1984). This is because exchange works to provide stability, bringing in energy (functional or symbolic) to the cultural system when it is needed.

If exchange is 'the mutual appropriative movement of goods between hands' (Polanyi 1957:266), then this 'movement', or change of location, need not cover any minimum distance, nor be limited by social or geographical boundaries. However, it is of crucial value in generating *spatial* aspects observed in the archaeological record. 'Between hands' implies a component of human interaction. Polanyi established three types or modes of exchange on the basis of human interaction, which were further built upon by other substantivists (Polanyi 1957, Renfrew 1984).

A. *Reciprocity* of reciprocal exchanges take place between individuals who inhabit identical social niches – i.e. their positions are symmetrical. Exchange takes place more or less as equals. [Note: See Sahlins (1972) and above for further concepts of reciprocity].

B. In *redistribution*, goods are sent to an organizing center, or at least are appropriated by it, and are then redistributed. Exchange in this mode can be much more sophisticated and complex, as opposed to a series of relatively unstructured reciprocal exchanges between individuals.

C. *Market exchange* implies both a specific central location where exchange transactions occur (the market place) and a type of social relationship where bargaining can take place. It involves a system of price making through negotiation.

All of these modes require some degree of external organization to regulate both procurement activities and social relations (Renfrew 1984, 1977). It is these three general modes that encompass the following models of exchange organization and the spatial distributions as observed in the archaeological record. This is fundamental – as the spatial distribution of exchanged commodities, as observed in the archaeological record, are the product of *both* the organizational structure and the geographical distribution of the artifacts of exchange themselves.

Many anthropologists hold the notion that 'exchange' is not limited to concrete or tangible goods; rather 'information' can also be considered a commodity. As well, exchange can encompass issues of emic cultural symbolic significance that exist beyond purely economic considerations. For example, goods exchanged as 'gifts' can take on significance beyond the material realm. The 'economy' of exchange – material or symbolic – can be seen as 'embedded' in the social matrix. Sociologists use the concept of 'exchange' to 'further describe all interpersonal contacts; viewing all social behavior as an exchange of goods, material as well as immaterial' (Renfrew 1984). Exchange of goods can be seen as 'reinforcing social relations, and material exchange gauges a single individuals relationship with others in their social environment. At a larger scale, it can shape the communities' relationship with its neighbors' (Renfrew 1984). The organizational principals that have guided it shape the archaeological observations of the distribution of exchanged materials, be it prestige or utilitarian. In this light, it is worthwhile to briefly survey the descriptive models of exchange and the manner that they can be analyzed as heuristic devices for understanding the mechanics of exchange.

C. Specific descriptive models of exchange

The operational structure of exchange, or 'the impact upon the [organizational] flow and distribution of goods, and hence upon the artifacts themselves 'is of primary importance (Renfrew 1977, 1984). Renfrew (1984) has synthesized various models of organization that affect, and can be identified through, the spatial distribution of artifacts (see Figure 4). These *descriptive* models of exchange are derived from artifact distributions that have been identified to a point-specific source (i.e. through chemical characterization); they can utilize absolute or relative abundance of a source-specific material at each site the distribution of these sites through space and time (Earle and Ericson 1977). Renfrew (1984) and others (Crumley 1979, Plog 1978) have offered further refinements of the above three major exchange systems that can be analyzed through the above graphic techniques.

1. ***Direct Access***: one group has direct access to another's resource. If a territory boundary exists, it is crossed with impunity. As well, no exchange transaction occurs between human agents

2. ***Home-base Reciprocity***: one group visits the home base of a neighbor and negotiates for an exchange of resources.

3. ***Boundary Reciprocity***: both groups meet at their common territory boundary for exchange purposes.

4. ***Down-the-line exchange***: a type of exchange whereby home base or boundary reciprocity is repeated successively between neighbors that practice negotiated exchange. Down-the-line exchange and can be represented mathematically on the basis of village spacing, distance from the edge of the supply zone, the proportion of goods at the edge of the supply zone and the proportion of commodities passed on by each village (Renfrew 1984, 1977). However, one must be aware of the following assumption, that the quantity recovered at any one location bears some regular, consistent relationship to the quantity passing through that location (see Figure 5).

5. ***Central Place Redistribution***: neighbors take their resources to a centralized location outside of their territorial boundary to exchange with another autonomous individual or group – no direct contact between groups practicing exchange takes place. One must note that central-places were likely the locale for the exchange of a multitude of materials. The proportion of one type of commodity, if higher and interpreted as more intensively exchanged, can be identified as a long distance exchange good as opposed to more ambient proportions of other goods that are widely and locally produced (Renfrew 1977, 1984) (see Figure 6).

6. ***Central Place Market Exchange***: neighbors take their resources to a central place outside of their territorial boundary and exchange *directly* with each other – there is not necessarily another active participant in the exchange.

7. ***Middleman Exchange***: autonomous individuals/groups shuttle between neighbors and exchange their respective goods - impartial territorial access is assumed. Point C on Figure 7 represents the boundary of the regions served by the participant middleman. In this light, and without the presence of a central place redistributive center, the fall-off of a commodity from a source is less rapid (Renfrew 1984, 1977)

8. ***Emissary Exchange:*** one neighbor sends a controlled emissary to their neighbors' location to conduct the exchange.

9. ***Colonial Enclave***: similar to emissary exchange, but a semi-permanent or permanent 'enclave' is established to conduct exchange.

10. ***Port of Exchange***: both neighbors send emissaries into neutral territory to establish a port of exchange.

11. ***Random Walk or Flight Models***: Biologists have modeled the manner in which a new species will infiltrate a new habitat by conducting a mathematical analysis of the distribution of the species from a point source. The archaeological analogy is that each period of ownership of an item of exchange is the counterpart of a single flight, and the exchange transaction is the termination of one flight and the initiation of another (Renfrew 1977). When a large number of transactions are conducted, a mathematically discernable pattern is produced. In short, this model holds that a small number of transactions will render the resultant artifact distribution closer to the source, or the center of dispersion. In turn, higher frequencies of transactions will result in a much larger dispersal area (Renfrew 1977). The 'random' title of the model refers to the direction of flight or transaction. This type of modeling illustrates that a 'large number of uncoordinated events will, in certain circumstances, produce a coherent, quantifiable fall-off curve' (Renfrew 1984, 1977).

12. ***Gravity Models***: This geographically derived model postulates that the amount of interaction between two cities (or a source and a city) is directly proportional to the number of people living in those cities and inversely proportional to the intervening distance (Crumley 1979, Plog 1978). This model has been used in exchange studies to model changes in the effective hinterland serviced by locales through space and time

D. Forms of analysis

These descriptive models can be analyzed using the following approaches: two-dimensional graphic analysis, synagraphic map analysis, nodal analysis, network analysis and systemic/simulation studies.

Graphic analysis, or 'fall-off curves' is the easiest and most direct method of modeling exchange. It seeks to 'represent the abundance of a raw material at a site as a function of the distance to the material's source; the general hypothesis here is that the amount of interaction between a source and site is determined by the cost of transporting the raw material' (Earle and Ericson 1977, Renfrew 1977, 1984). These variables, abundance (interaction) and transportation cost (distance), are plotted and the subsequent relationship is analyzed through regression analysis (Earle and Ericson 1977, Hodder and Orton 1977, Renfrew 1984, 1977) (See Figures 5-7 for examples of fall-off curves).

The next type of analysis is synagraphic map analysis, represents prehistoric exchange systems as artifact densities on a contour map in two-dimensional space (Earle and Ericson 1977). In this analysis, abundance of material is representative of interaction between the sites within the region and the source. The changes within the contour map show changes in the abundance through space. For example, a simple fall-off model would produce a series of concentric bands surrounding the source, with each band having successively less of a given source's material as distance increases from the source. Using this technique, Earle and Ericson (1977) has showed that archaeological data, stemming from obsidian systems in California, produced concentric banding, but not *circular* concentric banding. These spatial irregularities, when compared to the idealized model, reflect the effects of other variables, including alternative raw materials, location of trails and perhaps social boundaries (Earle and Ericson 1977). In short, synagraphic mapping is a simple and efficient technique to construct a first order approximation of spatial patterning and can be used in concert with characterization studies to isolate specific exchange systems and to analyze anomalies (Earle and Ericson 1977)

Network analysis is a descriptive and potentially explanatory technique used to analyze patterns of interaction. In this approach, sites are the 'nodes' of the network and exchange linkages are the 'interactions'. In short, this technique allows for the modeling of exchange interactions between sites rather than just between sites and sources. This 'network' is a series of elements linked by specified exchanges of goods, behavior and information (Plog 1977). The following variables must be considered to generate and compare network systems in order to fashion an accurate model; the range of material being exchanged, the quantity of goods being exchanged, the nature of items (homogenous vs. heterogeneous) being exchanged in the network, geographical or social breadth of network, temporal duration of the network, the directionality and symmetry of the exchange system, the degree of network centralization and the complexity of the network itself (Plog 1977).

Nodal analyses focus on exchange within the context of a single site, or the study of exchange on a small-scale. For example, DeGarmo (1977) has offered a methodology for analyzing exchange on the site level: the identification if intrasettlement groups, the analysis of production activities within each group and the documentation of possible group exchange (DeGarmo 1977). In another study, Singer and Ericson (1977), the production of a quarry site was analyzed, as it was possible to measure the total output of a quarry for an articulated exchange systems. This in turn led to a diachronic investigation of the fluctuations of an exchange item through time (Singer and Ericson 1977).

Systemic and simulation studies attempt to model the dynamic properties of exchange systems using emic values derived from ethnographic and ethnohisotrical evidence. Here, all events or changes are compared to, and seen to be a result of, the greater systemic entity, as the exchange subsystem does not work in isolation from the greater whole. Systems and simulation models have the potential to cope with unknown variables, are particularity suited to exchange analysis (Clarke 1972, Irwin-Williams 1977). For example, ethnographic studies have traditionally concentrated on interpersonal and ceremonial aspects of exchange within a community. The extension of this to a greater regional level is tenuous at best. Within this vein, a systemic model of the operation (dynamics) of egalitarian exchange can be studied through computer simulation. Elliot et al. (1978) attempted to simulate and experiment with the hypothetical processes that could have produced the surviving distributions of Neolithic axes in Britain. Knowing some of the raw material sources, a random walk process was used as it was assumed that the system of exchange involved the axes being transported over large distances. Although each individual exchange was not random, the overall exchange patterns can be conceptualized as a random process. In this model, axes from two or three sources were initiated on random walks and the final distribution was compared to archaeological data. It was found that the simulation identified some degree of competition between axes from different sources, and illuminated the most likely ranges of numbers and lengths of steps taken in moving from source to destination (Elliot et al. 1978). In this light, simulation studies can reveal a diachronic aspect of the investigation. However the following problems were noted: the model did not take into account differences in temporal utilization of the sources, nor did it assess the 'position' of other axes (Elliot et al. 1978).

Renfrew (1984) considers the above models to be a kind of evolutionary typology of organizational exchange structures. One can observe the evolution of social complexity from strict egalitarian access to the notion of property rights to mechanisms of exchange that incorporate exchange between more groups and over greater distances. As regional diversity increases, reciprocity begins to erode in favor of redistribution, as less face-to-face interaction occurs due to its decreased efficiency. In this light, more sophisticated exchange mechanisms mean that the notion of 'exchange' becomes 'less embedded, less integrally related to the social organization' (Renfrew 1977, 1984), and in turn will favor the growth of market exchange. The last three modes tend to be historically limited to exchange between state organized, high volume, distant neighbors (Renfrew 1977, 1984).

E. Potential analytical problems

Some of these quantitative models make various problematic assumptions. First, they assume that exchange is taking place from 'hand to hand in a homogenous population' and that no one individual or place is distinguished from any other (Renfrew 1984, 1977). However, this is often not the case as the exchange certain commodities, perhaps originating from distant sources, can have preferential treatment. The 'exotic' nature of its distant origin generates an exchange hierarchy. In turn, a hierarchy of settlement can coincide with this exchange activity. Suppliers from a distance bring their goods to a local meeting place, which, although 'down the line', serves as a central place. The commodity is then disseminated from the central place to the smaller localities in the sphere of its influence. In terms of effective supply, the central place is 'closer' to the source than the lower-order localities, even though it may be physically farther from the source. Archaeologically, this type of hierarchy is manifested by a higher frequency of the commodity than the population could possible need, as it is acting as a supply depot for its hinterland.

A second potential problem is that a larger population attracts a larger quantity of material, and need not result in any greater frequency of commodities. The abundance observed in the archaeological record may not reflect the quantities 'passing through' (Renfrew 1984,1977).

Thirdly, the conception of 'distance' might not be related to actual physical distance on the ground, there might be other 'measures' of distance in play, i.e. cognitive difference (Plog 1978).

However, other factors must be kept in mind when considering the organization of exchange. For example, absolute distance and available transport facilities (i.e. strict marine exchange) will not lend itself to down-the-line exchange as goods are carried *en masse* between specific destinations. As well, the nature of the commodity being exchanged may elicit a 'cultural cognitive response' that will affect the manner of its exchange (Renfrew 1977, 1984). For example, the abundance of the resource and its use (prestige or functional, free circulation or limited circulation between social classes) will determine its cultural worth and in turn its exchange organization. The nature of the resource itself could also affect the organizational structure of its use.

When examining archaeological exchange systems and spatial distributions, one must be aware of the following caveats: the first is that only *some* aspects of the trading network will survive in the archaeological record. For example, a trading network involving perishable goods coinciding with the movement of a more durable item, such as lithics, will be hard to detect and incorporate into a model. Secondly, the distributions recovered are directly correlated with *what is found* – for example, an exchange network which is seen to be truncated in a certain region may not be the result of the termination of exchange but a product of the lack of archaeological research in the area or lack or durable archaeological remains (Renfrew 1977, 1984, Irwin-Williams 1977, Hodder and Orton 1977). One *must* be aware of the limitations of the data set and the 'representiveness' of the archaeological record that one is working with. Thirdly, as Renfrew (1984) states: "a spatial distribution of finds never represents a situation at a single point in time. It represents a series of events over a definite time span; it is a palimpsest of activities" (Renfrew 1984). Hence, the archaeologist must be mindful of the tacit assumption that the observations are a result of diachronic activities, regardless of the chronological boundaries on the study that can be constructed. Fourth, it is likely that, depending upon the nature of the exchange network, the prescribed worth and the nature of the material of exchange, that more than one model of exchange is in operation in any given region or locale at the same time. Not only is the resultant archaeological distribution a palimpsest of events over time, it is a palimpsest of different modes of exchange working in concert. At this point in the study, it should be restated that the above treatment of exchange theories and modeling is offered to illuminate the *potential* analyses that can take place once a technique is in place to investigate relationship between artifact distribution and provenance – the aim of this study.

III. Exchange in hunter-gatherer society

Since the period under consideration is thought to be band-level hunting-gathering societies, a brief review of hunter-gather society and the nature of their exchange systems are offered.

A. A brief review of hunter-gatherer society

As the subject of this study, 'hunter-gatherers' are peoples who are reliant upon these procurement modes for subsistence; they are dependant upon the immediately useable products that the surrounding environment provides (Bohannan 1992). 'Mobile' hunter-gatherers are forced to follow or adjust their residential pattern when resources are subject to seasonal fluctuations (wildlife) or are migratory (large game); temporary shelters fill this residential need. It is therefore easy to understand that despite the high number of hunting and gathering societies in the past, the number of peoples involved in each of these 'band level' societies is small; no environment can support large populations solely on the basis of wildlife (Bohannan 1992).

Hunting-Gathering societies have in common one overarching anthropological attribute – an economy of the society and the economy of the component domestic groups are largely undifferentiated from one another (Bohannan 1992). In other words, the most basic domestic unit, the nuclear family, is both the engine of 'production' and the sole unit of consumption. One cannot be separated from the other. For this reason, hunter-gatherers have well-developed mechanisms for sharing available resources with other members of the community, as sharing and gift giving cement such communities together (Bohannan 1992).

Contemporary ethnographic observation of existing, although severely marginalized, hunter-gatherers societies illustrate that these peoples live in what is today defined as 'bands', which are small social groups of related individuals, usually consisting of fewer than 100 people. The only typical division of labor in a hunter-gatherer band is one based on gender, where women predominately gathered wild food, and men hunted. As well, men were responsible for fishing and were the primary participants in foreign affairs, including warfare and exchange. However, there is ideally little opposition to helping others, regardless of sex, with their subsistence or other assigned tasks. This is because work linked the individual directly to the group as a whole; as a consequence there was almost no differentiation of rank to set one person apart from other members of the group, or almost no social stratification (Bohannan 1992). Informal leadership, however, was not uncommon (Renfrew and Bahn 1991). Steward (1955) observed and defined two extreme types of bands based on kinship and marriage rules; the patrilocal band (exogamous and virilocal) and the composite band (which lacks explicit exogamic rules and marital residence customs). Most bands have marital rules that espouse aspects of both of these systems (Service 1971). Relationships among bands are typically informal; the individual maintain social and kinship ties with members of other bands, but the bands themselves are not organized collectively through any formal economic or political ties.

B. Ethnographic exchange and raw material procurement in hunter-gatherer societies

Regardless of the mechanism, goods and/or information are exchanged as a result of personal interactions. There exists a number of behaviors and types of relationships that would be expected to occur in hunting and gathering societies (either individually or in concert) that account for the movement of goods and the resultant archaeological patterning: obligatory sharing and gift giving founded on ties of real or ascribed kinship, fusion of settlement and subsistence patterns, the payment of bride wealth in conjunction with marriage rules, the establishment of personal trading partners, and the practice of redistributing goods as part of communal feasting or rituals (Sahlins 1972, Stewart 1994). Ethnographically, as stated previously, issues surrounding both exchange and direct access are rooted in notions of band territoriality. Any networks derived from these phenomena would generally be informal, with no precise beginning or end, web-like and interlinked in nature and maintained by the opportunistic actions of individuals. These networks would incorporate the needs, wants and preferences of an individual working within the system. In turn, individuals could influence what, and how much, moved through a given portion of the exchange system (Stewart 1994). However, it must be noted that holistic egalitarian relations are probably not a uniform characteristic of hunting and gathering relationships (Price and Brown 1985, Stewart 1994) and thus manipulation of exchange systems by individuals seeking status or desiring to forge specific alliances can be expected. In this light, the hoarding of exchange items and the occurrence in specialized contexts of exchanged goods reflects the potential for the manipulation of meaning in the eyes of the recipient; the symbolism of an object need not be derived solely from the nature of the exchange system through which it passed (Stewart 1994).

Exchange itself is not the sole reason for the existence of an exchange network, but rather it is a key cultural component aimed at promoting inter-group communications, reducing the potential for conflict or mitigating actual conflict, and establishing an individual's, family's or groups access to resources and hospitality beyond their home territories. In this light, exchanged artifacts are only the tip of a much larger 'iceberg' of items moving within an exchange system, which would also include foodstuffs, skins and other perishables. Some researchers argue than when a series of exchange networks are intertwined, the movement of both subsistence, or utilitarian, and 'exotic' products is insurance that the utilitarian needs of diverse individuals in the various linkages in the exchange system are served.

Here, it is worthwhile to paint a more detailed picture of the context of hunter-gatherer exchange. Renfrew (1974:103) states 'basic groups do not exist in isolation, but affiliate into larger groups, meeting together at periodic intervals'; nearly all human groups exhibit the gathering of people, some from very distant places, under circumstances which are hard-pressed to explain in purely economic terms, even though economic transactions surely took place in such contexts. These meetings can be conceptualized not purely as the meeting of groups, but rather as meetings of individuals who happen to be members of a number of different social groups or spheres. Such meetings are likely common among hunter-gatherers, where the 'smaller bands that constitute hunter-gatherer society meet together for talk, for ritual, for exchange, to prepare for or conduct the exchange of marriage partners, in short to conduct a very full range of human interactions' (Renfrew 1992: 9). In this light, the full range of interactions is more aptly characterized as one of 'communication' rather than of 'exchange', since the underlying motivation and functional role of the interactions may not primarily be the acquisition of material goods. For example, although such meetings may serve a functional need by providing knowledge of subsistence activities or even the exchange of marriage partners, they could also have included singing, dancing, the exchange of gifts, games or competition in a friendly environment and would have likely involved a series of rituals, both secular and religion. In this light, the exchange of goods could also be used as a pretext to legitimize the social and ritual activities that take place beyond purely function needs, as such gatherings serve as an affirmation of faith and shared worldview that is reinforced by the visible acceptance of a much wider social group (Renfrew 1992).

However, of key importance to this study is hunter-gatherer notions of territory and social boundaries since both exchange and the social permeability necessary for direct access a to raw material in another's territory can involve the crossing of a band's geographical boundary. Marxist anthropologists postulated that a stage of 'primitive communism' existed before the rise of the state and the division of society into social and economic classes, and the egalitarian lifestyle typical of hunter-gatherers supports this notion (Cashdan 1989). However, this sharing of resources does not presuppose that hunter-gatherers did not understand notions of personal property and land tenure. Material items, such as tools, clothing and ornaments, are owned by the individual for their own personal use, and most hunter-gatherer societies had in place some system of land tenure, usually communal, to control access to the land and its resources (Cashdan 1989). Most discussions concerning land 'ownership' among hunter-gatherers are framed using the ecological concept of 'territoriality'. Ethnographically, the diversity of land ownership systems is great. Turnbull (1965), in his study of the Mbuti, observed that each band within its territory was, to the largest extent possible, independent of its neighbors in terms of politics and economics. A 'territorial' extreme is that of the Vedda of Ceylon, where band territory is subdivided for individual band members, who can pass their property on to their children. Territorial boundaries were not clearly defined by natural features, but rather were marked by pictures, cut into tree trunks, of a man with a drawn bow. Territories were guarded and intruders might be shot, although the borders were so well known that quarrels over trespassing were rare (Seligmann and Seligmann 1911, Cashdan 1989). On the other end of the continuum, the Hadza of Tanzania had a very fluid system of land use, such that any individual may camp wherever they wishes without asking permission (Woodburn 1968, Cashdan 1989). A more universal pattern is that of the !Kung San, where band territories are associated with a core group of long-standing residents who are spoken of as the 'owners', and must be approached by outsiders for permission to visit. Here, 'owning' is not in the western sense of economics and property, but should be conceptualized as stewardship; they are the spokespeople representing the best interests of the band (Cashdan 1989). !Kung children can inherit access rights to the territory from each parent and have primary access to the territory in which they choose to settle. Territory boundaries are recognized by natural landmarks and are not marked or defended. Permission to access another band's territory is always sought after but rarely refused. Bands who do not want visitors to remain usually do not unequivocally refuse permission, but rather make the visitors feel unwelcome so that they will leave of their own accord (Cashdan 1989, Lee 1979).

It is important to note that the circumscription of territories is typically never to the detriment of any one band. Turnbull (1965) observed that the total territory is more than ample for the total population. In the case of the Mbuti, bands were arranged side-by-side in several vast circles, the center of each having such loose boundary definitions that it was effectively a no-man's land, in which anyone may hunt and where bands occasionally, albeit rarely, came into contact with each other (Turnbull 1965).

Ecological modeling has pointed out an inverse relationship between territory size and resource availability, typically band territories are smaller where resources are more abundant as not as much travel (or energy) is required to acquire the material needed. However, the degree of territoriality, or the extent to which a band is concerned about defending boundaries and excluding outsiders, can also be understood through the use of an ecological model. Here, ecologists argue that territorial defense (which incurs both time and energy costs) will only take place when it is economical to do so; when the benefits of exclusive access exceed the costs of defense (Cashdan 1989). It is only under conditions of competition for resource that benefits are gleaned from territorial defense, so in areas where resources are abundant one would expect to find little expression of territoriality (Cashdan 1989).

C. Archaeological studies of raw material procurement in hunter-gatherer society

Before more specific models of raw material procurement and use are presented, a brief review of hunter-gatherer land-use patterning is of benefit. The work of Binford (1980) constitutes one of the most ethnographically informed models of hunter-gatherer land use subsequent to his study of the Nunuimut and later more equatorial hunter-gatherers. His work attempted to characterize hunter-gatherers by the different strategies that were employed as they moved around in their exploitation range. Binford (1980) began by characterizing hunters and gatherers on the basis of their practiced mobility as either foragers or collectors. Mobility was further characterized as either residential or logistical. Residential mobility was typified by the movement of the entire group, or band, from one location to another. Logistical mobility involved the return iterant movement of task oriented individuals or small groups from a residential location to the specific task area, then back again. Foragers were characterized by high residential mobility with logistical mobility playing a small role; groups would move their residences or base camps from one location and collectively relocate at another spot; Binford conceptualized this trend as 'mapping' onto desired resources. In this mode, residential dispersal to improve resource exploitation would only occur if demanded by the nature of the resource. On the other hand, collectors are typified by making few residential moves with many logistical moves in order to exploit resources. This dichotomy of residential and exploitive organization is of conceptual value when focusing on a specific exploited resource and task site; the quarry.

Many studies, based in ethnographic research on hunter-gatherer quarry use, generally conclude that exploitation of quarry sites or raw material resources was fully integrated or "embedded" within the overall subsistence system (Binford 1979, Johnson 1984, Robertson and Williamson 2000). In short, rather than lithic procurement being the sole object of travel to a known source area, lithic procurement activities were likely to have been carried out in tandem with the exploitation of local faunal and plant resources. In his recent re-examination of Early Archaic models of settlement ranges and site types in the southeastern United States, Daniel Jr. (2001: 260) concludes that Early Archaic groups likely treated quarries 'like every other location, carrying on routine subsistence activities while undertaking stone procurement'. Archaic peoples 'employed an adaptive strategy that balanced the need for tool stone that was predictable, but limited in occurrence, with the more widely available but less predictable need for subsistence sources' (Daniel Jr. 2001:261). The end result was a settlement configuration that included access to high-quality knappable stone sources while concomitantly fulfilling subsistence needs (Daniel Jr. 2001).

One of the repercussions of this embedded pattern is that diverse arrays of activities, which are not directly linked to the quarrying of raw lithic material, were likely to have been carried out at the quarries or adjacent workshop sites (Robertson and Williamson 2000). In this light, a wide range of variation in the character of quarry-related activities may be found within these 'embedded' systems. An example of such diversity is Jamieson's (1979) study of the Slack-Caswell Site, where it was suggested that the pre-Iroquoian use of the quarry was restricted to the collection of Bois Blanc chert for immediate consumption by groups hunting deer in the surrounding area.

On the other end of the spectrum, some quarry sites are likely to have been the specific object of travel, and longer-term occupation, in order to obtain large quantities of the desired material; the exploitation of other resources in adjacent areas was of subsidiary importance (Johnson 1984, Robertson and Williamson 2000). This strategy has been defined by Ellis and Spence (1997) as 'direct-embedded' procurement. In this strategy, quarry sites can be expected to yield indications of more permanent habitation, as the manufacture finished tools or refined tool preforms was carried out in conjunction with hunting, fishing and plant collection (Robertson and Williamson 2000).

Also of relevance to this study is the issue of quarry access. Limited ethnographic evidence of the role of quarry sites in the hunter-gatherer economy suggests that quarries, in general, were considered to be open territory, and that little attempt was made to control these geographic locales (Ericson 1984). This model suggests that quarries appear to have be regarded as neutral territories which could be utilized by various autonomous, although perhaps related, regional groups. This notion is in keeping with the evidence for concepts of non-private ownership among hunter-gatherers (Robertson and Williamson 2000). Territories were typically defined on the basis of the use of paths that exists between specific resource locals or places, which collectively define and structure personal and social existence (Robertson 1997). Rather than delineating boundaries and claiming continuous geographic areas, hunter-gatherers tended to negotiate access to resources (i.e. the use of paths to get to specific places) with their immediate neighbors (Ingold 1986, Robertson and Williamson 2000). Although preferential rights may be bestowed upon a band's regular use of a specific area, it is rare that these rights will extend to exclusive control or "ownership". Rather, it is likely that efforts were made to avoid potential conflicts between different groups on such 'neutral' sites (Robertson and Williamson 2000). Such measures may include the payment of small gifts between groups or policies of avoidance (Ericson 1984, Robertson and Williamson 2000, Stewart 1987). In the case of avoidance, those seeking to replenish their supply of raw lithic materials would visit the quarry for only as long as was necessary for collection; the material would be subsequently reduced at workshop sites located in the surrounding hinterlands (Robertson and Williamson 2000). As well, another strategy for reducing potential conflict may have been minimizing the number of people charged with the task of obtaining chert (Robertson and Williamson 2000). Ethnographic and archaeological studies have suggested that task groups of only one or two individuals could, on a single trip to a quarry, satisfy their family annual requirements of raw materials (Robertson and Williamson 2000). Those chosen for this task would make this trip to the quarry, either to engage in primary reduction activities at the source or secondary reduction or preform manufacture at nearby workshops, may have been part-time 'specialists', in regards to their particular skill as flint knappers or for other reasons (Jamieson 1979, Robertson and Williamson 2000).

IV. Conclusion – implications for this study

The above discussion is offered as an overview of the prolific corpus of literature that exists for material movement across space and exchange. Exchange is a central concept in both anthropology and archaeology. Exchange as a concept relates not just to material transactions, but also embodies all interpersonal contacts and the exchange of ideas amongst participants. Of critical importance is that the exchange relationship is just as important as the material being exchanged. The ethnographic examples of exchange and resource procurement, the ethnographically derived mechanisms driving the movement of material in space, and the suite of potential distributional models and analyses lend weight to the proposed hypotheses previously addressed.

The Peace Bridge site encompasses many of the behaviors addressed, including material hoarding, the full suite of lithic reduction activities and, potentially, issues surrounding the access to lithic raw material sources. However, in this study, one has to be aware of the degree to which peoples living in the Late Archaic in the Niagara Peninsula *needed* chert on the most rudimentary scale; it was a critical component of their daily activities. In Algonquian and Iroquoian cosmology, the appearance of toolstone, or flint, has been ascribed sublime origins, being associated with the 'blood of the Gods' (Williamson and MacDonald 1998). With this in mind, exchange systems certainly did function to fulfill material need, and this should not be overlooked when addressing concurrent functions served by the system itself. The successful outcome of this study will provide a fundamental tool in addressing the concepts addressed in this discussion, namely the ability to describe material distributions across space; from source to discard; and provide the researcher with the means to compare material spatial distributions to potential behavioral models.

CHAPTER 3: METHODOLOGY AND TECHNIQUE

I. Introduction

A key conceptual distinction that needs to be illuminated from the onset of this chapter will be between method and technique. Method can be considered as the conceptual process by which an investigation is carried out (e.g. provenance studies). Technique relates to the actual physical process by the proposed method is undertaken (e.g. neutron activation analysis - H. Greenfield, pers. comm.). The following is a more detailed discussion of this distinction as it relates to this study.

The key component method of this analysis is provenance study. These can be easily summarized as the means by which a geographic source can be identified for raw materials through the comparison of material with known origins to those of unknown origins.

Many techniques to provenance artifacts exist, from simple macroscopic examination of color and texture, to microscopic examinations of exotic inclusions and thin-sectioning, to robust geochemical techniques, including mass spectroscopy, X-ray fluorescence and, of particular interest to this study, induced neutron activation analysis. The technique chosen depends upon a number of analytical and pragmatic constraints such as the nature of the material under study, economic and time considerations associated with a particular type analysis, accessibility and qualified personnel necessary for the chosen instrumental technique to name but a few.

II. Method – Provenance studies

Provenance, in geoarchaeological terms, is the geologic-geographic source of the raw material from which the artifact was made. That is, 'a specific geologic deposit – usually a quarry, mine, geologic formation, outcrop, or other coherent and bounded geological feature' (Rapp Jr. and Hill 1988). This method is at the heart of the study of spatial distributions as it provides the means to accurately describe a materials' distribution across space.

A large number of chemical, physical and biological parameters can be used to identify the sources of natural materials. Among these are the use of trace elements, isotopes, diagnostic minerals or assemblages, microfossils, and geophysical parameters (Rapp Jr. and Hill 1988). The underlying assumptions for provenance studies are: (i) that 'there is a demonstrable set of physical, chemical, or mineral characteristics in raw-material source deposits that is retained in the final artifact' (Rapp Jr. and Hill 1988) and (ii) the 'Provenance Postulate' which states that there is greater variation in chemical composition between sources than within them (Luedtke 1987, Jarvis 1988)

In the case of lithics, archaeologists have long attempted to discover geologic provenance using the most simple of methods – observations of colour, texture and other macroscopic properties. In one of the earliest studies using these methods, investigators in the mid-eighteenth century observed that two types of stone were used in the construction of Stonehenge – one local and one exotic. H.H. Thomas was able to trace the exotic material to the mountains of Wales through petrologic and petrographic analysis (Thomas 1923). However, this is a constrained method as an enormous amount of overlap in visual characteristics between different geological and lithic materials. Even the most basic property of colour can be the most misleading as it is affected by grain size, texture and inclusions (Klawiter 2000). In this light, macroscopic variation can often be misleading and inadequate when dealing with lithic material – including chert. Quite often on the basis of colour and appearance, cherts and artifacts are linked with inadequately studied but well-known quarries. This is especially the case of Onondaga chert, which is macroscopically homogenous across the entire formation (Jarvis 1990). This type of misclassification on chert is evidenced by Spielbaurer (1984) who found serious errors in visual-based sourcing classifications of what were thought to be three easily-recognizable, well-defined chert varieties in southern Illinois (Speilbauer 1984). His studies showed that traditional macroscopic analyses failed to account for the full range of observable variations as investigators are often limited by standards for colour comparison (i.e. the Musell Colour Charts) and the universal phenomena that artifacts are too small to reflect the full range of physical variation that exists in their parent source.

However, this is not to say that macroscopic analyses are futile, as they are used for non-quantitative studies. As well, macroscopic variation is a key component when a suite of analyses is conducted in order to identify a geologic source.

In this light, the potential for objective geochemical analyses based upon diagnostic chemical properties to provide an accurate and replicable means of sourcing geologic materials is significant. Researchers have noted this potential and in turn geochemical provenance techniques have grown increasingly popular and more accurate over time.

III. Technique – Induced Neutron Activation Analysis

There are various techniques used in provenance studies including multi-element physical techniques of atomic absorption spectrometry (AA), x-ray fluorescence spectrometry (XRF), inductively coupled plasma atomic absorption spectrometry (ICPAA), inductively coupled plasma mass spectroscopy (ICPMS), and induced neutron activation analysis (INAA). All of these instrumental techniques provide the researcher with the concentrations of constituent trace elements in some form. This is essential for constructing a geochemical 'fingerprint' of the material under study.

The general procedure for chemical characterization of a geological raw material is as follows:

1. Samples from the source of interest are chemically analyzed by the instrumental technique of choice and the resulting data are then statistically analyzed to determine homogeneity (variance) and grouping (means) of the source. Sampling procedure is critical at this step to ensure that all material variability is represented. The goal of this procedure, geochemical 'fingerprinting', is to isolate the characteristic element(s) of composition for comparative use.
2. Artifactual material is collected from an archaeological context, analyzed and compared to the geochemical 'fingerprint' established above for the material source. (Earle and Ericson 1977, Harbottle 1982, Luedtke 1992)

Although this is a useful conceptual procedure, it ignores a number of pragmatic realities, which plague the analyst. Firstly, with very few exceptions, it is almost impossible to unequivocally source anything (Harbottle 1982). What *is* attainable is the multivariate *characterization* of an object or assemblage of objects found under archaeological pretexts by mineralogical, thermoluminescence, density, hardness, chemical and other tests while simultaneously performing such tests upon the raw material source, if available, in order to disclose similarities (Harbottle 1982). In short, a

> 'careful job of chemical characterization, plus a little numerical taxonomy and some auxiliary archaeological and/or stylistic information, will often do something almost as useful: It will produce groupings of artifacts that make archaeological sense. This, rather than absolute proof of origin, will often necessarily be the goal' (Harbottle 1982:15).

The intention of using chemical characterization on archaeological materials is to construct a taxonomy that offers behaviorally relevant results. This is beneficial to the archaeologist, as the numerical and continuous nature of the chemical variables measured is perfectly suited for numerical taxonomy construction (Harbottle 1982).

This study will undertake an Induced Neutron Activation Analysis of the Peace Bridge quarry for a number of reasons. The analytical advantages offered by this technique are its high degree of sensitivity, precision and accuracy for many trace elements and its ability to analyze the whole sample, not just one particular surface as in other instrumental techniques. It also demands very little in terms of sample size from the researcher (50-200mg) (Henderson 2000) As well, this technique has a relative insensitivity to major matrix constituents and is capable of measuring 30-35 elements simultaneously in a small amount of time. This technique has also proven its utility in other provenance studies of chert (see Luedtke 1992 for comprehensive reference collection). In this particular study, the nature of the material source under study demands that the potential geochemical variation that exists be accounted for by the best means possible, which is attenuated by the pooling of results from previous studies of the material in question. In this light, the geochemical provenance study of the Onondaga Formation undertaken by Jarvis (1988, 1990) informed this investigation greatly, as the raw data gleaned from that analysis was pooled with the results found here. Jarvis (1988, 1990) was the first to illuminate the relative success of INAA this particular type of chert. The ability to pool results gleaned from his study to those derived from this investigation will only render the results more accurate and increase the likelihood of a successful outcome. As well, this accretion of results using this technique might potentially initiate a unified regional study technique for the provenance analysis of the Onondaga Formation.

Neutron Activation Analysis (INAA) has long been used as a technique for trace elemental analysis. Its origins date back to 1936, when Harvey and Levi discovered that inorganic samples containing certain rare earth elements became highly radioactive after exposure to a neutron source (Glasscock 2000). It was shortly realized that the measurement of the induced radioactivity could both identify and qualify elements present in the sample. Since then, INAA as a technique has increased both in popularity and in sensitivity. It has been used in the analysis of marine shells, cassiterite, flint and pottery (Glasscock 2000, Harbottle 1982, Luedtke 1992, Rapp Jr. et al. 1988). In fact, for many elements and applications, INAA offers sensitivities superior to those attainable by other methods – on the order of parts per billion or better (Glasscock 2000).

INAA, in short, exploits the fact that neutrons in an atomic reactor can combine with nuclei of many elements in the introduced sample to produce short-lived radioactive isotopes. In turn, these isotopes from the irradiated sample can be detected by the unique gamma radiation which they emit as they decay. The most common type of nuclear reaction used in INAA is the *neutron capture, gamma released* (n, gamma) reaction (see Figure 8). Here, a neutron interacts with the target nucleus and results in a compound nucleus that is in an 'excited state'. The excitation energy of the compound nucleus is due to the binding energy of the neutron with the nucleus (Glasscock 2000). The new compound nucleus will almost instantaneously de-excite or stabilize with the emission of one or more characteristic (or signature) gamma rays. However, in many cases this new compound will also yield a radioactive nucleus which also de-excites (or decays) by emission of one or more characteristic *delayed* gamma rays, but at a much slower rate according to the unique half-life of the radioactive nucleus (Glasscock 2000). A short time later, the sample is removed from the neutron bath and exposed to a detector. In INAA, this is usually the 'lithium-drifted germanium' detector (Glasscock 2000). This device operates on the following principal – gamma rays that pass through the counter produce electrical pulses whose size is directly proportional to the gamma ray energies. These pulses are in turn fed into a 'multi-channel analyzer' that sorts the pulses and produces an output reminiscent of an oscilloscope (see Figure 9). As radioactive isotopes have virtually the same energies, the detector groups all of these pulses into a 'channel'. These pulses do not render a single point as the design of the detector introduces a spread of a few percent. As well, a degree of ambient or background 'noise' is present throughout the process. The noise is subtracted from the count of interest by subtracting the number of counts from an adjacent energy band of the same width.

There are a number of other variables that affect the response of the sample to neutron bombardment –including the number of neutrons the sample is bombarded with, the atomic 'cross-section' of the target nuclei and the stability of the radioactive element produced by the neutron activation. In order to calculate the concentrations of elements in an unknown sample, the unknown is irradiated alongside a known standard (with similar constituents) and the two are measured using the same detector. Elemental concentrations are then calculated using a formula incorporating the degree to which the sample is exposed to radiation, the atomic density of the sample, decay constants for the isotopes detected, the elapsed decay time (Klawiter 2000). The ratio of calculated values between the standard and the unknown will then provide a quantitative number for the concentration of elements in the sample. Accuracy by these techniques usually ranges between 1 and 10 percent of the reported value. The use of common standards by different analytical laboratories permits the direct comparison of data obtained by different researchers at different institutions at different times (Glasscock 2000, Klawiter 2000). This is often defined as the 'comparator' method (Glasscock 2000). An example of this process can be made with sodium: Na^{23} interacts with an incident neutron, producing ^{24}Na (an unstable radionuclide). After a period of time, the ^{24}Na emits a Beta particle and a gamma ray of specific wavelength. After undergoing this decay, the nuclide now becomes ^{24}Mg. The emitted gamma-ray interacts with a detector, revealing the presence of sodium in the sample (Klawiter 2000).

The INAA method does have some limitations – namely an inability to detect lighter elements such as hydrogen, carbon, nitrogen, oxygen and silicon. However, it must be noted that INAA does have advantages over other previously mentioned techniques for multi-element analysis. Both AA and ICP require that samples be dissolved before introduction into the instruments – an addition that can potentially add to the problems of accuracy (Rapp Jr. and Hill 1988). XRF is at a disadvantage as it is susceptible to matrix and interference problems and lacks the sensitivity in the parts-per-billion range compared to INAA (Rapp Jr. and Hill 1988).

IV. Sampling and Sample Size in INAA studies

The intent behind the sample selection is to capture the extremes of chemical variation inherent within the chert source under study in order to represent these variations in the subsequent statistical treatment of the geochemcial trace elemental data (Hancock 2001). Most archaeological projects involving trace element analysis generally use a sample quantity that balances research goals with available funds. However, a brief discussion of sampling theory prior to the analysis is practical. In short, the necessary sample size increases with the variation present within the population and with the degree of certainty required from the sample (Luedtke and Meyers 1984). Table 1 illustrates the sample sizes associated with varying degrees of precision and variation at the 95%

confidence interval, where V is the mean of all the coefficients of variation for the individual elements.

The table can be used as follows: given a chert source with an average trace element variation of 0.3, if a sample of nine fragments were analyzed there would be a 95% chance that the resulting mean for most elements would be within 20% of the true population mean. Luedtke believes that this table should not be followed without question as it is based upon formula that assumes random sampling. As well, it assumes that the data will follow a normal distribution (Luedtke and Meyers 1984). Luedtke has noted that the values on this table changed very little when the 90% confidence level was used (Luedtke and Meyers 1984).

It is important to restate Harbottle's (1982) two main conceptual taxonomic principals that are of interest to this portion of the study:

1. The greater the content of information in the taxa of a classification and the more characters on which it is based, the better a given classification will be.
2. *A priori*, every character is of equal weight in creating natural taxa (Harbottle 1982)

These sampling concepts must be undertaken in concert with the potential variability and overall nature of the geological source under study. The continuous nature of the Onondaga Formation will force an investigator to rigorously sample outcrops of interest. Small-scale treatment (i.e. $n<20$) of trace elemental data is less likely to offer valuable resolution, as the nature of chemical variation across the entire escarpment is not well understood. However, in this research design, previous results (Jarvis, 1990) point to a high rate of success using INAA analysis of Onondaga cherts, and perhaps more importantly, the desired goal of chemically identifying comprehensively a single culturally utilized outcrop.

V. Sample Preparation in INAA

These samples are typically macroscopically documented (for example, lithics and ceramics are often visually described, photographed or drawn in plan and profile and color range is noted using a Munsell Color Chart), washed with distilled water. The samples are then sub-sampled or reduced in size in order to facilitate introduction into the atomic pile. This stage, in the case of lithics, often requires the removal of flakes from the objective sample using non-metallic implements (i.e. stone, antler etc. as metallic instruments can potentially introduce contaminates into the sample chamber). The sample is typically about 200mg and can be introduced into the reactor chamber in flake form. It is important to note that this reduction must be undertaken in a manner that will lessen introduction of contaminants into the sample container and result in flawed readings. The sample is then placed in a small, labeled plastic container for pneumatic introduction into the atomic pile. Samples are irradiated (in this study) at 5.0×10^{11} $n.cm^{-2}.s^{-1}$ for five minutes. Each sample is then counted for 5 minutes, after a delay time of ≈ 18 minutes (count 1). Each sample was then recounted for five minutes, after a delay of thirty-six minutes (count 2).

VI. Statistical Methods in INAA

The statistical technique employed should be capable of utilizing all trends in the trace elemental data. Past studies began with a limited examination of data trends through the examination of bivariate plots or bivariate plot analysis. However, the overall sensitivity of the technique forces one to consider that the trace elements detected might not necessarily be of use in provenance of the material itself, and in this light bivariate plots, although informative, are of limited value when generating a chemical fingerprint for the material under study. To utilize the analyzed suite of elements to their full potential, multivariate statistics have been employed. Jarvis (1990) has pointed to a number of multivariate approaches that have been explored by archaeologists, including cluster analysis, similarity coefficients and pattern recognition. As well, other potential analyses include Analysis of Variance, Correspondence Analysis, Canonical Correlation Analysis, Stepwise Discriminant Analysis, and Principal Component Analysis (Klawiter 2000). However, the most recommended method is discriminant analysis (Jarvis 1990, Harbottle1982, Luedtke 1979) as it allows for the assignment of unknown samples to defined groups generated from known samples.

Discriminant analysis transforms trends in multivariate variables into a more easily examined single variable (Jarvis 1990). Sample data from known groups are used to develop a discriminant function that maximizes the differences between these samples through the comparison of variation between and within those groups. Samples of unknown membership can then be assigned possible group membership based upon their similarity to established groups (Jarvis 1990). For example, a researcher may have geochemical data that defines the range of geochemical constituents for two chert formations. One could then use discriminant analysis to create a discriminate rule from the geochemical data set to statistically delineate the two chert formations from each other, creating a geochemically based statistical 'fingerprint'. The drawbacks for this method are the idealized necessity for distinctly separate, non-overlapping geochemical data sets for the derivation of the discriminant rules, and the necessity of knowing beforehand that the unknown samples belong to one of the two defined groups, and not some unknown third possibility (Klawiter 2000). As well, an accurate discriminant analysis (that does not misclassify samples) requires that the variables in each group have multivariate normal distributions and for all covariances to be equal. Jarvis (1990) presents a simplified three-variable case that can be used to illustrate these necessary conditions:

> "If the data of each [three variable] group are mentally pictured as occupying a three-dimensional space, with each elemental concentration defining a dimension, a multivariate normally distributed group would form a cloud which would become increasingly dense toward its center and any cross section made through it would show a normal distribution of values. If all of these groups' clouds had the same dimensions, their variances would also be equal' (Jarvis 1990: 10)

If these conditions can be met, then discriminant analysis provides a powerful tool for geochemical provenance studies

VII. Conclusions

The above discussion illuminates the chosen method and technique that will be used in this study. Not only is induced neutron activation analysis a powerful instrumental analytical tool in provenance studies, the subsequent statistical framework that identifies material to source is of significant utility when the underlying principals are understood. This geochemical provenance technique, although proven to have success, can be disastrous without an underlying interpretive strategy of geochemical provenance studies and an understanding of the statistical arguments involved. Renfrew (1991) points out one of the lease successful characterization projects in recent years that involved the analysis of thousands of copper and bronze objects from the Early Bronze Age of Europe. These objects were studied using optical emission spectroscopy and were classed into groups based upon their composition without recognizing that very different source areas might produce copper with a similar trace elemental signature. Furthermore, changes in the trace elemental composition during smelting were not accounted for. From the standpoint of geochemical provenance, the identified groups were more or less meaningless (Renfrew 1991). In this light, a thorough understanding of the material and context under review is critical for a successful provenance analysis.

CHAPTER IV: THE STUDY AREA

I. Introduction

Before any provenance analysis is undertaken, the researcher must be informed of the regional and site specific trends typical for the raw material in question and its use through time. This is necessary as the samples utilized and their contexts must be of both methodological and archaeological significance, otherwise the resultant provenance construct will have limited applicability to this and further studies. The following is offered as a summary of Late Archaic culture-history and exchange of the Great Lakes region.

II. Late Archaic Culture History

A. Great Lakes Late Archaic

By about 3500 B.C., most of the Great Lakes supported a regional ecology and vegetation familiar today, despite the high degree of climatic and crustal fluctuations in the wake of glacial ice (Ellis et al. 1990, Mason 1981). This regionally diverse cultural adaptation to the changing environment is thought to have been accomplished without any major loss of existing social institutions and practices (Mason 1981).

The first shift seen in the Great Lakes Late Archaic was a significant population increase. Secondly, as a consequence, the frequency of Late Archaic sites vastly outnumbers all known sites of the previous, and exponentially longer, Paleo-Indian time span (Ellis et al. 1990, Mason 1981). Great Lakes Late Archaic sites tend to be deeper, larger and richer in debris than their antecedents, as well as exhibiting an unseen complexity in structure (Ellis et al. 1990, Mason 1981). Cemeteries suddenly appear, although they do not completely replace isolated graves within living or abandoned camp grounds that was an accepted burial practice previous to the Late Archaic. Mason (1981) points out that "once cultural systems were potentially or effectively able to accommodate the changing physical world to the social and cultural pressures of increasing population, that very success probably rebounded to potentiate, if not stimulate, further supplementing [of the] the population" (Mason 1981). In this light, a broader, and therefore more easily adaptable, subsistence base than that of the Paleo-Indians, 'culminated in and characterized the Late Archaic period' (Mason 1981).

Generally, the Late Archaic way of life was varied, flexible, and sustainable as subsistence strategies rested on a diverse array of food sources - big game, small game, fish, shellfish, reptiles, waterfowl, ground-running and tree-roosting birds, and vegetable resources (Mason 1981). The breadth and variability of these culturally recognized food sources helped buffer against seasonal failure of one or even several of them.

This shift to a procurement of a wider array of food sources, both on a local and regional level, likely forced special attention to the seasonally abundant resources. In this light, fish, which were generally not important throughout the Great Lakes region in previous times, appear to have been a significant food source (Mason 1981). As well, a new emphasis on plants is indicated by the consistent recovery of charred floral remains on Great Lakes Late Archaic sites, as well as the recovery of milling and nutting stones necessary for their processing (Mason 1981). The degree of plant use points to more than just a trivial utilization of plants, as the 'processing of plant foods requires more than a passing acquaintance with local plant associations, soils, water sources, microclimates and all of the other subtle interacting factors which encourage or inhibit plant growth' (Mason 1981). In contrast, highly mobile hunters have much less need of such information. The acquisition and utilization of this degree of intimate horticultural knowledge lends itself much more easily to a people that are more sedentary and less mobile. As well, the combined trends of a growing population and the displacement of the coniferous forest by food-rich deciduous forest in large tracts of the Great Lakes must have been responsible in some part for the intensification of interest in plants (Mason 1981).

It has also been suggested that in the Late Archaic period, with the post-glacial re-attainment of high water lake levels, a viable fishing industry would have existed. Fishing gear underwent inventive and expansive development at about this time, and fish bones in camp middens show an explosive increase (Ellis et al. 1990, Mason 1981).

This 'wider provisioning of the larder' (Mason 1981: 145), especially in its heavier reliance on fish and plants, enhanced the big-game hunting focus observed in Middle Archaic times. However, it must be noted that in southern Ontario, this trend of utilizing a broader array of food sources has been evidenced as far back as the Middle Archaic, and that this 'shift' in procurement strategy was not a watershed moment of the Late Archaic, but rather was a culmination of a previously employed, albeit to a lesser degree, subsistence strategy. The result was a more balanced exploitation of overlapping food resources, their combined capacities fulfilling the subsistence requirements of more people than ever before. In this manner the 'quintessential Archaic way of life' was a 'process of settling in to the challenges and opportunities' of the changing and rich environment (Mason 1981). This intensification was local in character, as regionally or locally based subsistence patterns did not allow for the same sort of relatively homogenous pan-North American culture as evolved in the Paleo-Indian period. This is because the reduced mobility and heightened dependence on locally producible flora and fauna demanded the emergence of more variable, and therefore regional, cultural complexes. One of the most far reaching ramifications of the new mode of life was its 'eventual value as a kind of pre-adaptation to the much later development of agriculture; although never planned or predetermined, it was simply a consequence of a more intimate knowledge of local terrain with its various soils and plant' (Mason 1981).

The Great Lakes Late Archaic populations more astute understanding and use of their environment was not limited to that of subsistence, it also involved the mineral world as well. Non-flint materials such as granites, gabbros, basalts, gneisses and sandstones provided major new sources of raw material for tool production, as the techniques of pecking, grinding and polishing rose to a level of significance never before observed in the archaeological record (Mason 1981). Of importance here is the variety of observed milling stones thought to process vegetable foods, and heavy woodworking tools to help support the more sedentary use of the evolving Great Lakes forests. In this light, artifacts often took on a regional or local cast, especially in stylistic attributes.

B. Southern Ontario Archaic: Chronology and Definition

In many parts of northeastern North America, the 7000-year long Archaic stage is often inadequately documented, and Ontario is no exception (Ellis et al. 1990). With this in mind, many researchers have avoided using cultural-historical constructs such as 'tradition' and 'phase' as the paucity of archaeological evidence from this time make such distinctions arguable at best (Ellis et al. 1990). As well, the Archaic is a period of great change and the evidence at hand is often not enough to demonstrate cultural continuity or discontinuity. Taxonomic terms, especially when covering such diverse archaeological cultures over a temporal span like the Archaic, often fail to accurately model all regions at all times. In this light, taxonomic definitions will be offered with specific reference to the study area, although it must be noted that these age ranges are not universal. In the Great Lakes region, the introduction of ceramics occurred around 2800 to 2900 B.P. (Spence et al. 1990), offering a *terminus post quem*, albeit somewhat arbitrarily, for the Archaic. However, the beginnings are harder to identify with assurance as Archaic and Late Archaic traits did not appear all at once, they appeared gradually. In this light, Ellis et al. (1990) have chosen to begin the Archaic with the introduction of notched points, as these are the least disputed chronological marker of the Archaic in southern Ontario (See Figure 10). The earliest observation of these in the archeological record is approximately 10 000 B.P. Thus, the Archaic manifestation as chronologically defined in southern Ontario is labeled as 10 000 B.P to 2800 B.P. This period was further refined into Early, Middle and Late subdivisions (Ellis et al. 1990). Unfortunately, some discrepancies exist between researchers as to where these divisions can be drawn. These variations reflect that notion that simplistic temporal divisions of a region as diverse as the Northeast will inevitably render large inconsistencies in localized area, and in turn not reflect the cultural continuum through time that existed (Ellis et al. 1990). In southern Ontario, Ellis et al. (1990) have defined temporal divisions that seem to correspond to the major changes as observed in the archaeological record. For the purposes of this study, their definitions will be utilized: the Early/Middle boundary is drawn at 8000 B.P. and the Middle/Late juncture at 4500 B.P. (See Figure 10)(Ellis et al. 1990).

Archaic peoples in southern Ontario are thought to have utilized a hunter-gatherer economy with social and economic underpinnings that were characterized by openness and flexibility. The consequence of this type of social permeability was the erosion of identifiable cultural and 'ethnic' boundaries, in which case 'traditions' and 'phases', which by definition must have encompassed a number of local bands, may not exist in any discrete or identifiable form (Ellis et al. 1990). As well, the lack of a relatively comprehensive culture-historical framework has impeded the progress of contemporary theoretical frameworks in the region – the paucity of data is seemingly once again to blame. In this light, temporal, regional and cultural distinctions are used with the understanding that they are neither rigid nor exclusive.

'Archaic' as a term, which has held many function and temporal meanings since its first application, is of limited use as a focal taxonomic unit; the great variability observed throughout the Archaic erodes its utility. Taxonomic divisions use artifacts as time markers, or 'index fossils', serve to partition temporal variation into convenient and meaningful subunits that correspond to time, space and/or function (Morrow 1999). However, variation in form and provincialism in typology mask "underlying interregional continuities and lead us [archaeologists] into thinking of past cultural boundaries that never really existed" (Morrow 1999: 221). This being said, most investigators today conceptualize the archaic in two basic ways – in assemblage content (material culture associated with Archaic sites) and inferred subsistence practices/economies (Ellis et al. 1990). Ellis et al. (1990), in their widely accepted summary of the Archaic in southern Ontario, describe the following characteristics of the Archaic in southern Ontario:

- an increase in the number of formal tool characteristics seen for the first time: heavy groudstone tools (i.e. axes, celts, chisels, adzes, gouges, bayonets, stone plummets and bannerstones).
- points with notched or stemmed haft elements
- notched pebbles used as netsinkers for fishing
- items used in the processing of plant foods

- the widening of raw material choice for stone tool manufacture, including the use of material with generally poorer flaking characteristics (i.e. quartzite, slate and greywacke) and a concurrent, increased reliance on more localized stone resources (including the use of secondary deposits such as glacial till and river beds) with a marked decreased in the use of more exotic raw materials derived from distant sources
- a generalized increase in the use of heavier, less portable tools than observed in the antecedent Paleo-Indian times (i.e. wood working tools such as axes and gouges)
- A flaked stone tool kit based whose nature is seemingly more expedient – items typically lack extensive flaking (either shaping or resharpening) as seen during the Paleo-Indian
- a decrease in observed workmanship of flaked-stone industries (as compared to Paleo-Indian)
- the manufacture and use of bone tools – with a particular emphasis on items used for fishing activities
- an absence of smoking pipes as observed in subsequent Woodland times
- the appearance of the use of native copper
- a pronounced regional variability in both assemblage composition and settlement patterning characteristics (when compared to relatively homogenous Paleo-Indian manifestations as seen over large geographic area)
- a marked increase in the number and variety of sites

The inferred subsistence practices gleaned from the above material differences further discern the Archaic from the Paleo-Indian. The Archaic has been ideally described as a lifeway prior to the institutionalized use of horticulture and ceramic technology, whose subsistence procurement strategy was based on hunting and gathering; it is a time subsequent to the Paleo-Indian colonization of diverse environmental zones pursuing now extinct large game; a time when groups 'settled in' and became more familiar with local resources (Ellis et al. 1990). This more thorough and intensive use of local resources, resulting in an overall increase in subsistence efficiency, is a significant transition in southern Ontario subsistence economy. This change is marked by an appearance of specialized resource procurement and processing tools absent in earlier contexts (Ellis et al. 1990). This more intensive and extensive use of local resources combined with a greater focus on less mobile resources is thought to have engendered the following in southern Ontario:

- Population increases (as observed in a larger number of sites and an increase in the size of sites)
- Reduction is size of inhabited 'territories' (as observed in the decreasing use of 'exotic' materials)
- Longer occupations and seasonally occupied sites (as observed by larger sites, less portable toolkits, a appearance of sites with several component burials) and consequently, a reduction in residential moves during a seasonal round
- Increasing regional variability as local resources vary across space, compelling groups to employ differing social formations and technologies in order for these resources to be fully exploited (Ellis et al. 1990)

C. The Late Archaic in Southern Ontario

In terms of the overall Archaic in southern Ontario, the Late Archaic is the most well known. A number of Late Archaic sites are known and are well preserved, and many have been excavated. The visibility of the Late Archaic in archeological contexts is thought to represent both the increase in population towards the end of the Archaic (more sites to be found) and the adoption of modern Great Lakes levels after 4500 B.P. (Ellis et al. 1990, Mason 1981). A great many early and middle Archaic sites were likely destroyed through post-glacial water levels in the Great Lakes (Ellis et al. 1990), and the Peace Bridge Site is no exception.

Robert Funk (1983) had previously identified three successive complexes existing in Late Archaic of southern Ontario for the ca.4500-3000 B.P. period, which he has termed the 'Lamoka' (early), Satchell (middle) and Inverhuron (Late). This tripartite division has been maintained, but subsequently renamed by Ellis et al. (1990) after projectile points that characterize these three periods – the Narrow Point (early), Broad Point (middle) and Small Point (late) complexes (see Figure 11). Sites belonging to the

Narrow Point (4500-3800 B.P.) complex are typically defined by stemmed or broadly side-notched points, which are often coarsely flaked, and are typically twice as long as they are wide. Researchers have alluded to a southerly distribution of Narrow Point sites (Ellis et al. 1990). Snow (1980) has identified the Narrow Point (which he has labeled as Mast Forest Archaic) as an adaptation to nut or mast producing forests (Snow 1980). This is evidenced by stone mullers, pestles and pitted stones suggesting the processing of plant foods, and nuts, in particular (Ellis et al. 1990).

D. Broad Point Archaic (4500-3500 B.P.)

Large broad-bladed stemmed points (Broad Points) became widely distributed throughout Eastern North America during the Late Archaic (4500-3500 B.P.). (Ellis et al. 1990, Robertson et al. 1997). 'Broad Points' range from Maine to Florida. The range of these points is so widespread that it is extremely unlikely that it is the result of a single tradition (Ellis et al. 1990) . If any common historical connection is argued, it is that the technology originated from the American southwest, where the use of Broad Points was well established by 4500 B.P (Ellis et al. 1990, Turnbaugh 1975). Others have attributed the spread of the Broad Point tradition to diffusion and adaptation on the part of local populations, as some researchers have found evidence in certain areas of 'traditional' narrow point forms continued to be used alongside Broad Points (Dincauze 1975, Ellis et al. 1990; Robertson et al. 1997). Witthoft (1953) initially suggested a core area for these peoples as encompassing the Chesapeake, the Potomac, the lower Delaware and the Rappahannock River systems based on the artifactual associations he observed between Broad Points and soapstone vessels (Burgar 1985, Witthoft 1953). Other researchers have suggested that the sudden appearance of Broad Point in the northeast was the result of migration northward from Florida along the eastern coast (Burgar 1985, Turnbaugh 1975, Ellis et al. 1990, Robertson et al. 1997). This hypothesis was rejected by Cook (1976) as this 'super technology' would have led to a population increase that is not found during the Broad Point Archaic and in turn, out-migration (characteristic of band-level societies) would have prevented the development of a social system which led to more complex societies on the coast (Burgar 1985, Cook 1976). Furthermore, Burger (1985), Cook (1976) and Kenyon (1980) have suggested that the overall site pattern in the southwest and mid-Atlantic differ enough that migration is not indicated. However, most researchers accept a southeast maritime origin for the Broad Point form. Cook (1976) has pointed out that the Broad Point tradition may not reflect an archaeological culture, but rather a horizon (artifact types found over a wide area in a relatively brief period of time indicative of rapid adaptation) or a separate archaeological complex utilized by the same peoples. In this light, the similarity between southern and northern Broad Point styles and a corroborating chronology of radiocarbon date cannot be discounted (Burgar 1985, Cook 1976). Although the mechanism is not known (i.e. migration or diffusion of traits) the data seem to support a southeast origin for the Broad Point.

The core area of Broad Point sites is the area extending along the Atlantic coast from Pennsylvania and New Jersey, northwards to southern New Brunswick and inland to upstate New York. The sites in this area belong to the Susquehanna (or 'Broadspear') tradition, and the area is one of the most intensively studied for broad point sites in the northeast (Ellis et al. 1990, Funk 1983, Snow 1980). In this region, variations of point forms resulted in a taxonomic nightmare – variations on the same theme resulted in a multitude of labels across regions (i.e. Snook Kill on New York, Lehigh in Pennsylvania) for the earliest Broad Point forms that had slightly contracting stems (Ellis et al. 1990). However, as a word of caution, one must refrain from equating variations in point forms as representing precontact cultures or ethnic identities, thus reading more from the artifact than is warranted. Morrow (1999) believes that variation in projectile point styles might just as well "reflect degrees of social distance rather than being signatures of ethnic affiliation. [Variations in tool form] ...can be reflective of social mechanisms acting on a much higher level than that of the local ethnic group" (Morrow 1999: 222). Hoffman (1985) has argued that "types" of stemmed southeastern points are in fact variations from the reworking of the same basic form (Hoffman 1985, Morrow 1999). Other factors potentially leading to artifact variation are the type and quality of raw material utilized.

In this context, and central to this study, is a related point type – the straight stemmed Genesee (see Figure 1 and 11). This type was first defined for New York (Ritchie 1971) and characteristic of what Funk (1976) has labeled the 'Batten Kill' phase (Ellis et al. 1990, Funk 1983, Ritchie 1971). Radiocarbon dates (from New York, Pennsylvania and New England) have suggested a date of ca. 3800 B.P. for these various Broad Point stemmed forms (Ellis et al. 1990). The subsequent dominant forms include a wide-bladed, notched point, the Perkiomen (3600 B.P.), in use during the Susquehanna tradition. After 3600BP, the Susquehanna Broad, a point with a narrower blade and expanding stem, became the typical point form (Ellis et al. 1990). Other associations inherent with the Susquehanna tradition in the mid-Atlantic region include the use of soapstone vessels, banner stones, grooved axes and the presence of cremation cemeteries, often associated with a variety of grave goods, especially caches of points and preforms (Ellis et al. 1990).

Broad Point settlements appear to have been oriented towards larger rivers in areas that provided access to both large river systems and upland areas that were rich in game (Robertson et al. 1997, Ellis et al. 1990). It is thought that these upland sites may be functionally specialized, representing seasonal processing camps. This is similar to the pattern found in the Genesee River of western New York, where nine sites have been documented on valley slopes and two have been found in upland locales (Robertson et al. 1997). However, large multi-component sites found in Ontario have produced material ranging from Paleo-Indian to Middle Woodland horizons (Robertson et al. 1997). Again, this more intensive occupation pattern and long-term re-use of certain locales is paralleled in New York.

In Ontario, little is directly known about Broad Point settlement patterning. Distributional evidence suggest that Broad Point sites in Ontario tend to be associated with areas of rolling or varied topography, with major sites located along major river systems (Ellis et al. 1990). In southwestern Ontario, such sites are often within easy access of sand plains, which once supported oak-hickory forests (Ellis et al. 1990, Kenyon 1981). Roberts (1985) study of south central Ontario indicates that Broad Point sites, when compared to those proceeding Archaic complexes, tend to be situated on larger water-courses, closer to water sources, and on sand plains or moraines (Ellis et al. 1990, Roberts 1985).

When distributional evidence is combined with excavated floral and faunal material, there exists a strong suggestion that Broad Point sites in Ontario represent a series of populations focused on upland resources, especially mast forest, which would have been rich in game animals such as deer. In this light, large points may be the most archaeologically visible element in a specialized deer hunting technology, possibly involving the use of thrusting spears in combination with deer drives. This upland orientation contrasts against the lakeshore emphasis seen in the subsequent Small Point Archaic (Ellis et al. 1990).

However, other researchers have offered another interpretation for this evidence, as some investigators regard 'broadpoints' not as projectile points but as specialized knives. In this light, the upland orientation of Broad Point sites might represent functionally (or perhaps seasonally) specific processing camps. Thus, the Broad Point complex may not be a distinctive archaeological 'culture', but rather a tool kit that is an element in some other complex (Ellis et al. 1990). This argument has been countered with the following evidence - throughout the northeast, Broad Point sites tend to be found as 'pure' components with similar radiocarbon dates. As well despite an upland and riverine emphasis, in Ontario, Broad Point sites may be found both in interior locales as well as lakeshore environs (Ellis et al. 1990).

Although Ontario evidence for Broad Point burial patterns is somewhat limited, some parallels can be drawn from New York State. Along the Mid-Atlantic Coast, Broad Point using people buried their dead in massed cremations, often with a rich accompaniment of grave goods inclosing caches of points, preforms and ground stone tools (Dincauze 1968, Ellis et al. 1990). This cremation-caching burial mode, as evidenced at the Peace Bridge site, extends into the Great Lakes Area (Ritchie 1969, Ellis et al. 1990, Robertson 1997).

Subsequent archaeological sequences to the Broad Point display a marked trend towards smaller, narrower points in northeastern North America; this new period has been labeled the Small point Archaic (3500-3000 B.P.) (Ellis et al. 1990). This shift to smaller points is seemingly more than stylistic, and potentially implies a significant modification in weapons technology and hunting techniques. It has been suggested that this change is concurrent with the introduction of the bow and arrow (Ellis et al. 1990). Small Point sites appear with more frequency, indicative of an ever-increasing population. In terms of settlement pattering, it has been argued that there were two major settlement types: a) lakeshore environments utilizing broad-spectrum subsistence procurement strategy occupied spring through fall with b) interior fall and winter camps presumably focused on deer and possibly the collection of fruit (Ellis et al. 1990). Particular to the Small Point Archaic is the appearance of true cemeteries.

E. The Genesee Point (2000 B.C. – 1500 B.C.)

The Genesee Point type will be of primary interest to this study, as it is the most ubiquitous Broad Point formal tool found at the Peace Bridge site (AfGr-9 – see Figure 1) and beyond, it is one of the most prominent icons of formal tool technology found in southern Ontario during the Late Archaic. Of note in this analysis is the wide geographical distribution of the Genesee projectile point; within the Broad Point traditions of the northeast, Genesee Points are found in large numbers throughout Vermont, central and western New York, southern Ontario, Eastern Michigan, much of Pennsylvania, northern Ohio and eastern Indiana (Robertson et al. 1997, Ellis et al. 1990). However, the highest concentrations of the Genesee point appear in Ontario and New York (Robertson et al. 1997). In fact, in southern Ontario, it has been argued that the Genesee point is the most common and widely distributed Broad Point type (Robertson et al. 1997, Ellis et al. 1990). In the Grand River drainage and the Niagara Peninsula of

Southern Ontario, as well as western New York, Onondaga chert was almost invariably used in their production, suggesting that local populations in these areas had direct or indirect access, either to the primary outcrops of Onondaga chert that occur along the Niagara Escarpment or to the finished or semi-finished products of craftsmen living in closer proximity to the Onondaga sources (Robertson et al. 1997).

Distinctive of Genesee and other Broad Point forms is their manufacturing or reduction sequence (See Figure 12). For these types, a suitable piece of raw material is edged and thinned to form an ovate or triangular preform. After a subsequent further thinning, a five-sided or pentagonal preform is produced approximating the size of the finished point (Ellis et al. 1990: 12). These readily identifiable pentagonal bifaces have been called 'corner-removed points' or 'Susquehanna knives', but have since been categorized by their true function of that as a preform for Genesee and other Broad Point types (Dincauze 1975, Ellis et al. 1990). In fact, in Fort Erie, the Peace Bridge site (formerly the Surma site), situated on an outcrop of Onondaga chert, has evidence of complete reduction sequences represented by ovate/triangular preforms, pentagonal preforms and finished Genesee points; it has been identified as a production center (Emerson and Noble 1966, Kenyon 1981). Many local sequences in eastern North America have Broad Points dating to sometime between 4500-3500 BP, but of note is the Genesee component of the Davison site, which has been radiocarbon dated to ca. 3780BP (Ellis et al. 1990). The Peace Bridge site offered two dates for features thought to have been associated with Genesee period use: 3580 B.P. (calibrated to 2120-1750 B.C.) and 3740 B.P. (calibrated to 1930-1630 B.C.) (Robertson et al. 1997).

Broad Points are often the largest 'projectile points' used anytime from the Paleo-Indian time onwards. These wide-stemmed, wide bladed and robust bifaces have been interpreted by some investigators to have been unlikely used as viable projectile points, and in turn have suggested that Broad Points were in actuality knives (Cook 1976, Dunn 1984, Ellis et al. 1990, Stothers 1983). It is likely that some of these bifaces were used as knives, while others, which show distinctive tip impact fractures, were used as projectile points (Ellis et al. 1990).

However, Genesee points were not the only Broad Point types found in the Ontario Broad Point Archaic. Here is a brief summary of each, in order to better understand the variability as illustrated in form during the Late Archaic Broad Point:

Perkiomen & Susquehanna Broad: These points are made from pentagonal preforms and are best known in New York and Pennsylvania with related forms occurring in New England (Dincauze 1975, Ellis et al. 1990; Ritchie 1971). On Perkiomen preforms, the diagonal corner is notched, typically leaving the original perform visible in the finished point, which may have distinctive 'pointed' shoulders above the notches (Ellis et al. 1990). The Susquehanna point is relatively narrower but also made of a pentagonal preform, finished by flaking a V-shaped notch to produce a hafting element (Ellis et al. 1990). Although these points are not common throughout Ontario, they have been identified in the Niagara peninsula. No production sites for these types have been identified in Ontario, but elsewhere in the northeast Perkiomen is dated to about 3650-3550 BP and Susquehanna to ca. 3550-3200 BP (Ellis et al. 1990).

Adder Orchard: This southwestern Ontario point type differs from the Genesee point in that the blade is more slender, with the maximum width occurring above the shoulder (Ellis et al. 1990). This point form has been manufactured on a variety of raw materials - including Kettle Point chert, Onondaga chert and on coarse-grained metasediment lithics. Some researchers have suggested that the Adder Orchard point developed from the Genesee as a 'western' variant in southwestern Ontario and southeastern Michigan (Fisher 1997, Kenyon 1983). In Ontario, Adder Orchard points have been radiocarbon dated to approximately 3850 B.P. (Ellis et al. 1990).

Other Broad Point tools and tool-kits: it must be noted that Genesee points were often reworked into other tool forms, the most popular forms being drills and end scrapers. In extreme southwestern Ontario, Broad Point sites included lanceolate bifaces made from coarse-grained lithics. The tips of these bifaces, and some of the stemmed points, have a distinctive rounding use wear, possibly from hide-working (Ellis et al. 1990).

On Broad Point sites east of the Great Lakes (i.e. the Atlantic phase in Massachusetts), tool kits often included large, typically bifacially worked end scrapers with trianguloid to ovoid outline shapes (Dincauze 1976, Ellis et al. 1990). Similar forms have been reported in multi-component sites containing Broad Point occupations (i.e. Peace Bridge site in Fort Erie)(Ellis et al. 1990, Emerson and Noble 1966). In this light, it is possible that reworked end-scrapers and other reworked tools were also part of the Broad Point toolkit in Ontario (Ellis et al. 1990). However, identifying the remainder of the Ontario Broad Point toolkit is much more elusive. Other Broad Point sites have yielded chipped stone end scrapers and bipolar pieces, as well as chopper-like tools (Ellis et al. 1990). Aside from a few finds, ground stone tools do not seem to be common on

Ontario Broad Point sites. As well, banner stones have been found to have Broad Point associations, as evidenced at the Peace Bridge Site (Williamson and MacDonald 1997).

III. Late Archaic Exchange

A. Introduction

In the Late Archaic, as described above, the overall trend towards a more intensive exploitation of resources and the concurrent evidence of more sedentary strategies and more robust mortuary ceremonialism point to the notion of a more cohesive, less mobile band level society that would have been more susceptible to fluctuations in resources and other unpredictable phenomena which could potentially have a greater detriment to a more sedentary people. However, sedentarism requires social integrative mechanisms to ensure some level of social insurance; reciprocity, such as exchange, would likely have been in play as it has been shown that hunter-gatherers have well developed mechanisms for sharing available resources with other members of the community (Bohannan 1992). In this light, the following is offered as a brief discussion of Late Archaic models of exchange.

B. Southern Ontario Late Archaic Broad Point Exchange

In the Middle Atlantic (New York, Virginia, Maryland, Delaware, New Jersey, Pennsylvania, West Virginia and North Carolina) as well as the Niagara Peninsula in Ontario, extensive exchange networks are first visible during the Late Archaic period (after 2500 B.C.). In his pan-regional study of the distribution of rhyolite artifacts, Stewart (1994) identified two major types or systems of coexisting exchange use from the Late Archaic to Late Woodland times: "broad-based networks" and "focused networks".

Broad-based networks: This mode of exchange is characterized by hand-to-hand, down-the-line exchange forming weblike relationships common through out the region. Utilitarian artifacts and ornaments are the typical constituents and are circulated through a series of personalized relationships. In broad-based exchange, the percentage of a given material exhibits a gradual fall-off pattern within 30 to 50 miles of a source, followed by dramatic decline in frequency, although artifacts may continue to be found 200 to 3000 miles from a source. The fall-off patterns on the more distant ends of artifact distribution are not always symmetric decreases. These distributions are a fingerprint of both the distinctive territories of groups or bands that can procure a material directly, and exchange tools and implements of the same material (Stewart 1994). Broad-based exchange networks are extensive and were likely not restricted to formalized relations between a limited number of groups. The nature and quantity of exchanged items, and the timing of exchange, seem to be dependent on the particular needs or motivations of the parties involved and are not dictated by the nature of the exchange system itself. The exchange system is not strictly directional in that goods from a raw material source do not seem to be produced specifically for exchange with a distant, but well-defined area, group, or trading partner.

Stewart (1994) believes that exchanged material originating in the Middle-Atlantic region was most likely destined for broad-based exchange. Exchanged items typically included finished projectile points and bifacial preforms (used as utilitarian objects) which were resharpened, and eventually discarded in general contexts at sites. Given the presumed nature and intent of broad-based exchange, it is probable that transactions took place year-round and at a variety of settlement types.

However, concentrations of exchange goods in locales of rich food resources could be an indirect reflection of the *types* of transactions taking place and not because these items were sought as expressions of status (Stewart 1994). The exchange goods coming into these areas may have been exchanged for foodstuffs, or in the least served as guarantees of access to productive habitats by individuals or groups who were not members of the local territory or region during times of shortages in their own home territories. Thus, the large amounts of archaeologically visible material within such a circumscribed zone could be a result of the high numbers of outsiders attempting to establish rights of access through exchange transactions rather than a product of insiders seeking exchange items to use within a complex social milieu (Stewart 1994).

Hoarding in Broad-Based Exchange: Broad-based networks are manipulated periodically by some groups. Stewart (1994) argues that, from his study of the distribution of rhyolite and argillite artifacts, there existed areas well-removed from sources of material that show unusually high percentages of artifacts with respect to the expectations of down-the-line exchange. Highly desired materials are gathered through the broad-base exchange systems and these goods can be 'hoarded' within specific or settlement territories. Directional exchange can be rejected as an alternative explanation to hoarding since it implies the existence and formal linkage of central places or gateway communities that serve as the locus of exchange activities, or the involvement of groups or families who have preferential access to goods (Stewart 1994). In his study, no such sites or communities were identified, "even near sources of material where production of exchange goods would have been managed for directional exchange with distant partners" (Stewart 1994: 79). The documented volume and distribution of exchanged artifacts throughout the region argues against the existence of groups with preferential access to specific sources of material or production centers as the geographic extent of natural sources would have precluded the control of any resources by a particular group.

Focused Exchange: Often, there is evidence of patchy, discontinuous distributions of artifacts made from exotic materials, which can result in a similar distribution to that of a hoarded material that was drawn off a broad-based exchange network (Stewart 1994). The movement of these items involves relatively few contacts, not the series of interlocked, down-the-line exchange associated with broad-based systems. It seems unlikely that formalized exchange relations existed with cultures near source areas since the production and receipt of exchange goods is so sporadic and discontinuous. Instead, Stewart (1994) proposes that the more likely scenario is that individuals, small groups or entrepreneurs traveled outside of their home regions on sporadic trading missions, 'insinuating themselves into the broad-based networks of other areas to obtain the goods they eventually transported back home'(Stewart 1994). This type of patterning is identified as focused exchange – typically involving goods found outside the home region. It likely co-existed with broad-based exchange (although they do not appear to be interdependent) and may have been more seasonally oriented than broad-based exchange (at least in later times) as groups would likely have been more sedentary when crops would have been planted and trading expeditions would be reaching others in relatively obvious, well-known locations (Stewart 1994). As well, this type of movement would be less taxing in the summer then over the cold winter months.

The initiation of widespread, broadly based, down-the-line exchange in the Middle Atlantic region is credited most specifically to the period postdating 2500/2000

BC deposits associated with the Late Archaic Frontenac and Brewerton phases originally defined in New York, and with a variety of phases and complexes associated with the broad-bladed/broad-spear and fishtail projectile/biface types often groped under Transitional or Terminal Archaic (Stewart 1994). Evidence of broad-based and focused exchange systems appear concurrently alongside a number of other regional phenomena. Across regions, marked territoriality, and possibly ethnic diversity, is evident in the regionalization of artifact styles and the suites of lithic materials that are exploited in specific places (Ellis et al. 1990, Stewart 1994). The following summary by Stewart (1994) point to these concurrent phenomena:

- A shrinking of exploitative territories as compared to the preceding Middle Archaic Times
- Short-term, consistent reuse of a variety of site types (which is inferred from the size and depositional intensity of archaeological deposits) and the regularization of settlement and subsistence patterns
- Expressions of territoriality
- Dramatic population growth

Custer (1984) postulates that environmental change, in conjunction with the factors noted above, resulted in a realignment in the distribution and availability of resources that had traditionally been exploited by aboriginal groups, the end result being a spatial reorientation of groups and exploitative territories (Custer 1984). In turn, with more people coming into more frequent contact with each other, they have to cope with the full range of subsequent social problems. These conditions have been linked to the flourishing of exchange and exchange as social relations and opportunities that are inherent in the exchange of material goods provide a margin of economic and political security or insurance in times of uncertainty (Custer 1984).

IV. Broad-Point Archaic Raw Material Procurement – Direct Access

Ellis and Spence (1997), in their distributional study of Small Point Archaic raw material variation and lithic technology organization in southwestern Ontario, have identified a number of raw material procurement trends, which potentially extend back into the Broad Point Archaic as these trends likely originated during or before the Broad Point. Moreover, these trends are potentially part of a pan-Archaic procurement strategy. The following conclusions of interest to this study are (Ellis and Spence 1997):

- Lithic procurement was episodic – raw materials were procured in quantity in brief episodes for and used for a considerable period of time
- Groups generally took advantage of location during the round of normal settlement moves in order to replenish exhausted tool kits made on one material with locally available different material
- Although groups seem to have generally taken advantage of specific resources in their general vicinity, it does not mean that procurement was "embedded" (see previous discussion)
- Reoccupied sites tend to exhibit regularities in the raw material type and use, suggesting very repetitive rather the more flexible land use patterns
- Accepting that points and preforms are on certain materials due to the fact that they were procured from earlier visited sources, that in comparison to other artifact types, preforms were over produced relative to normal demands when these sources were exploited
- Some evidence exists that biface preform production occurred when a particular source was exploited, most often near the source
- Serial biface reduction was the most commonly employed means of manufacturing points

Subsequent to the Small Point Archaic in southwestern Ontario, the Early Woodland Meadowood Phase (c.a. 2800-2300 B.P.), shows evidence of biface preforms being produced in abundance near chert sources for transportation elsewhere (Ellis and Spence 1997). In conjunction, there appears to be a clear focus on Onondaga chert. Evidence suggests that, in this case, this focus on a specific raw material type is not strictly technological in nature, but instead may be a product of ceremonial and/or social factors (Ellis and Spence 1997). The transportation of this valued raw material in a prereduced (preform) state reduced the chance of breakage during travel and reduced the material that is transported and subsequently removed as waste (Ellis and Spence 1997).

Of particular interest to this study is the subsequent importance of both Onondaga chert and quarry locations in periods after the Broad Point. The Peace Bridge site, of central focus to this study, played an important role as a Meadowood Period raw material source.

Conclusion

This review of the study area's culture-history illuminates the observed trends in demography, territory exploitation, raw material resource procurement exploitation and a generalized increase in sedentarism. These trends are essential for the construction of a research design for a provenance study as these trends have spatial repercussions that can potentially be quantified and observed. To illustrate: Burgar (1985), in his detailed study of the distribution and formal variation of the Genesee point in Ontario, indicated a number of regional variants that may be associated with band hunting ranges or territories. It follows then that if material sourced to the Peace Bridge site is discovered in off-site contexts, in topography indicative of a potentially adjacent exploited territory or watersheds, then an informed provenance study could potentially distinguish inter-bad (regional or long-distance) exchange. However, before questions such as these can be posited, a more detail review of the data, namely the Onondaga geological formation and the Peace Bridge Site is required.

CHAPTER V: DATA – THE ONONDAGA GEOLOGICAL FORMATION AND THE PEACE BRIDGE SITE

I. Introduction

Artifactual material produced on Onondaga chert dominate the lithic assemblage not only the Peace Bridge site, but also precontact artifact assemblages throughout southern Ontario and New York State. Onondaga chert is a highly accessible source material with many outcrops occurring throughout both regions. One of these outcrops is located at the Peace Bridge site, located in Fort Erie, Ontario. Unfortunately, this major chert resource is for all practical purposes visibly homogenous. The different outcrops cannot be distinguished with any degree of certainty on the basis of macroscopic analysis. However, they are geochemically distinguishable as will be discussed below.

It must be noted here that although many investigators have, over the years, acknowledged that artifacts manufactured from Onondaga chert are derived from the Onondaga Formation, any further refinement of the actual outcrop utilized is not mentioned. This source is treated either a point source, or a more ephemeral regional source area, forming in essence a regional 'folk' category that is of little use when more focused spatial investigations are proposed. In short, investigators are understandably reluctant to refine their provenance to more specific outcrops without addressing the daunting task of a regional provenance study of the formation itself.

Previous chapters have illuminated the theory and methods behind the study of material movement. This chapter will detail the geological formation under analysis and offer a comprehensive review of the site under investigation.

II. The Onondaga Formation – a geological perspective

An understanding of the Onondaga Escarpment, a dominant southern Ontario geological formation, is necessary when discussing lithic procurement strategies and provenance studies in southern Ontario (See Figures 2 and 13-15). Onondaga chert occurs in the Onondaga Limestone, a Middle Devonian formation that underlies the southern half of New York State, parts of southwestern Ontario and northern Pennsylvania (Jarvis 1990). This formation, at its maximum height in Clarence, New York to the east, diminishes in height westward through the Buffalo area to Ridgeway and Port Colborne, Ontario. From Port Colborne westward to Hagersville, Ontario, the escarpment is low, and to some degree, discontinuous, being buried in many places by Pleistocene and Holocene deposits (Parkins 1977). This escarpment influences the local hydrology by preventing drainage southward into Lake Erie (MacDonald and Cooper 1997). The constituent sediments of the Onondaga Formation are derived from a reef complex deposited in a warm, shallow, normal marine environment (Parkins 1977). Rocks typical of reef, interreef, and lagoonal facies are abundant throughout the Formation. The bulk of the chert is confined to the finely crystalline lagoonal sediments with minor amounts in the interreef facies (Parkins 1977).

This formation is divided into four members: Edgecliff, Clarence, Seneca and Moorehouse, with the transition between each member ranging from sharp to variable depending on location and constituent members (see Figure 15). The following is a brief description of each, from the lowest to the highest member.

Edgecliff: This is the basal member of the formation. It is medio-crystalline and bioclastic, massive crinoidal and coralline, light to medium gray limestone (Parkins 1977:

15). The average height is 2.4m to 6.1m. The easternmost part of the formation is lacking in chert, however the west does exhibit evidence of densely bedded chert and poorly defined chert nodules in the upper-half of the member. At Peace Bridge, a densely bedded strata of chert from this member underlies much of the southern portion of the site itself (von Bitter, pers comm.2003).

Clarence: This member lies stratigraphically above the Edgecliff member. The constituent material is finely crystalline, medium to massive bedded, medium to dark gray colored cherty limestones (Parkins 1977). This unit is 12m to 14m meters thick. The most significant characteristic of this member is the abundance of light to medium gray mottled chert – it constitutes between 40%-70% of the whole member. This chert occurs in bedded, nodular and lenticular masses. The member is composed of cryptocrystalline quartz with minor amounts of coarsely crystalline chalcedony infilling the megafossils and cracks (Parkins 1977).

Moorehouse: This is the next member. It is a medio-crystalline and bioclastic, massive bedded medium gray limestone. The average thickness is 12m to 15m. Medium gray and brownish gray cherts are present in this unit, but comprise only 5-20% of the entire member. As well, chert is more abundant at the base of the Moorehouse member and rapidly becomes scarce as one goes higher (Parkins 1977).

Seneca: This is the highest member of the Formation. It is a medio-crystalline, medium to massive bedded, medium gray limestone. This member is, on average, 2m thick and is completely devoid of chert (Parkins 1977). Separating the Seneca and Moorehouse member is the Tioga Bentonite, a 15cm thick stratum of clay minerals, possibly a result of Middle Devonian volcanoes in Virginia (Jarvis 1988, Parkins 1977).

Throughout the formation, the primary components of the Onondaga Formation are the Clarence, Edgecliff and Moorehouse members (Parkins 1977, Jarvis 1988). The Seneca and a significant portion of the Clarence member were lost to glacial action. This trend is similarly applicable to the easternmost portions of the formation.

As stated above, chert is predominantly found in the Clarence and Moorehouse members. However, at the southern limit of the Peace Bridge site, the exposed chert quarry belongs to the Edgecliff member, as is evidences from the dark black to dark gray cherts characteristic of this member (von Bitter pers. comm.). The Clarence member outcrops extensively on most of the north shore of Lake Erie. As well, this member underlies the northern portion of the Peace Bridge site, and is exposed along the Niagara River waterfront southward to Lake Erie and beyond (MacDonald 1997).

A. Onondaga Chert, Chert Formation and Geochemistry

Chert is a sedimentary rock made up primarily of microcrystalline quartz (SiO_2). It is generally hydrous and consists of complexly joined quartz grains 1 to 50 microns in diameter (Knauth 1994). There are several, much debated hypotheses that describe the formation of chert, which is beyond the scope of this study. However, in carbonate sediments (such as the Onondaga Formation) cherts are thought to be the result of the replacement of carbonate (calcite or dolomite) sediments with siliceous material, as evidenced by the replacement of remnant voids and sedimentary structures in the silicified cherts (Klawiter 2000, Kneath 1994). This form of geochemical replacement typically occurs in small (<30cm) nodules that occur in distinct bedding horizons in the host carbonate rock (Klawiter 2000).

In the attempt to better define the process of silification, research has shown that the solubility of carbonate increases with decreasing pH, which is in contrast to the trend observed for silica. In this light, silicification of carbonate can occur when diagenetic (all of the physical, chemical and biological changes that a sediment undergoes after the grains are deposited and during the process of 'becoming' a rock, but before it is metamorphosed or weathered) alterations occur in pore spaces that have a high and decreasing pH (Klawiter 2000, Kneath 1994). Although no specific consensus has come to light concerning the mechanisms for this replacement, it has been illustrated that regardless of the mechanism, silicification occurs during diagenesis, before compaction and (in the case of dolomites) after the inception of dolomitization (Klawiter 2000, Kneath 1994). Since the silicification process in the nodules is complete, cherts are commonly 95% or more SiO_2 and typically contain only a few other elements.

Given this cursory review of the peterogenic history of carbonate cherts, it can be seen that there are several possible sources and alterations to the trace elements found in chert itself. Among many vectors, a proportion of the elements could possible derive from the deposited sediments that form the matrix of the chert itself, having been inherited from "upstream" weathered and eroded source rocks. The elements within these sediments may have been removed or enriched within the aqueous environment either during transport or deposition (Klawiter 2000, Kneath 1994). Further alterations can occur during digenesis of the sediments, as well as through subsequent alteration during exposure and weathering. As well, despite the potential for the replacement of all carbonate during the silica replacement process, impurities in the carbonate may be inherited by the chert (Klawiter 2000, Kneath 1994).

Many cherts form by the replacement of carbonate rocks such as chalk, limestone and dolomite. In turn, carbonate minerals are common contaminants in chert, to the degree that unreplaced patches of these minerals are often visible (Luedtke 1992). As well, many carbonate cherts contain the fossils of carbonate secreting organisms, some of which have been replaced by silica but others of which still retain part of their original aragonite or calcite shells (Luedtke 1992). Calcium, carbon and oxygen are all present in most carbonate minerals, and magnesium is an essential component of dolomite. Magnesium, manganese, iron and strontium commonly substitute for the calcium in carbonates, whereas sodium, barium, the rare earth elements commonly covary with carbonates in some cherts. In general, calcium, magnesium, and strontium can be considered the best indicators of the carbonate content of cherts (Luedtke 1992).

Also of importance here is a brief discussion of glacial clays, which form a significant component of the sediments that form the matrix of Onondaga chert. Clays are found virtually in all cherts (Luedtke 1992). Clays are a highly diverse family of minerals, which can be described chemically as hydrous aluminum silicates, most of which have a platey or sheetlike structure (Luedtke 1992). The bonds between the ions in this structure are relatively weak and loose, permitting a great deal of substitution, making clays highly variable in composition. As well, the high surface area of clays allow for the absorption of many other ions on their slightly charged surfaces (Luedtke 1992). Thus, a chert with a high clay content will generally have high proportions of many elements (Luedtke 1992). All clays contain aluminum, silicon, hydrogen and oxygen. Montmorillonite, a common glacial clay, also contains magnesium and iron. Illite, another common clay, is a source of potassium. Common substitutions are manganese and zirconium in montmorillonite and barium for potassium in illite (Luedtke 1992). When interpreting elemental data for cherts, it is usually safe to assume that virtually all of the aluminum is present in the form of clays, and that potassium, titanium, vanadium, chromium, rubidium, and cesium are also associated almost exclusively with clays (Luedtke 1992). However, many other elements can be attributed to clays to a lesser degree.

Another concern for this study is the affect of weathering on geochemical signatures on chert and chert artifacts. In general, weathering can oxidize or reduce minerals on the surface of cherts, and groundwater may then dissolve some elements and carry them away. Groundwater may also deposit other elements in porous or weathered rinds of chert nodules or artifacts (Luedtke 1992). However, different cherts will weather differently and some minerals are more susceptible to weathering than others (Luedtke 1992). Specifically, sodium, magnesium, calcium, uranium and rubidium are easily mobilized during weathering and diagenesis due to their more soluble and reactive nature (Klawiter 2000, Kneath 1994). These types of alterations must be taken into account when geochemically quantifying any chert source.

In short, the trace geochemical content of chert is a combination of chemical signatures inherited during the process of transport, deposition, diagenesis and alteration (Klawiter 2000, Kneath 1994). However, a single geological formation is unlikely to have a homogenous trace elemental content throughout the formation, especially if the formation covers a large geographic area, as the processes illuminated above will likely have been at work in differing degrees. As well, there will be both vertical and horizontal variations in elemental concentrations throughout a formation. For instance, the basin in which sediments were deposited might have included a number of micro environments of varying chemistry, the sources of sediment being fed to the basin may have changed over time, or postdepositional and diagenetic processes may not have acted homogenously throughout the geological body (Klawiter 2000, Kneath 1994). However, it is these processes that also render one portion of a geological formation different from another, lending to the premise that it is possible to distinguish varying geochemical signatures within a single geological formation.

Onondaga chert can be conceived of as a generalized carbonate chert (Luedtke 1992). This section data of Onondaga chert illustrates that dolomite rhombs and calcite inclusions are the most common impurities found. In compassion to other types of cherts, Onondaga chert is high in carbonate and salt-related elements, such as sodium, bromine, calcium, strontium, and magnesium (Luedtke 1992). However, is can be generalized as having an average content for elements associated with clays, metals and other detritus (aluminum, potassium, cesium, rubidium, iron, cobalt, chromium, zinc, titanium, vanadium, the rare earth elements, barium, thorium, hafnium, scandium) and it is relatively low for antimony, manganese and uranium (Luedtke 1992).

III. The Peace Bridge Site (AfGr-9)

A. Location and physiography

The Peace Bridge (AfGr-9) site is located in the town of Fort Erie, Ontario, Canada (see Figure 3). The site, characterized by a buried black soil layer that will be addressed later, extends west from the Niagara River for approximately 400m and north from the Peace Bridge, a key Canada-U.S. border crossing, for approximately 600m. It encompasses an area of approximately 24 hectares, or 60 acres (Williamson 1997).

Evidence from other adjacent excavations suggests that this distinctive soil stratum extends southwards, and has been found 2.6 km farther south along the Lake Erie coast. Adjacent to the site is the Niagara River, a wide, swift-flowing river with an average depth of 12m and an average current of seven knots, or 13km/h (MacDonald and Cooper 1997).

The Lake Erie coast assumed its contemporary form approximately 2000 years ago (MacDonald and Cooper 1997). Its physiography is characterized by sand-deposited ridges and dunes, cobble and sand beaches, shelved limestone pavements, sand spits, tombolos, as well as bars and backshore basins. As well, marshes would have been a prevalent occurrence prior to European settlement.

The general climate of southern Ontario since c.6000BP can be characterized as having warm summers, cold winters and high precipitation levels (MacDonald and Cooper 1997). This region is thought to have been deglaciated at c.10 500 B.P. with a subsequent warming trend between c.10 500 B.P. and 10,000 B.P. as glacial lake levels receded. The periods between c. 9600 B.P. and 8000 B.P. witnessed an apparent climatic reversal with winters becoming longer and more severe and summers warmer and drier than in pervious times. From 8000 B.P. to 6000 B.P. the regional climate became more moderate, as lake levels rose and mean annual temperature and precipitation increased (MacDonald and Cooper 1997).

In the vicinity of the Peace Bridge site, two major environmental zones can be identified. The first are upland areas with moderate to thick till cover correlated with a closed-canopy mixed forest dominated by maple and beech with lesser amounts of red oak and white pine (MacDonald and Cooper 1997). The second zone was typified by riparian area with active erosion and depositional processes which were correlated with open and closed-canopy mixed forest dominated by red oak, sugar maple and American beech, with lesser amounts of a wide variety of deciduous tree species (MacDonald and Cooper 1997).

B. History of research

Archaeological investigations have been conducted in the Fort Erie region as far back as the late 1800's and early 1900's. While the father of Canadian archeology, David Boyle, visited the area in 1887, it is not certain if he actually visited the site (Killan 1983, Williamson et al. 1997). The first directed research in the region was undertaken by Fredrick Houghton of the Buffalo Society of Natural Sciences (Houghton 1909, Williamson et al. 1997). His studies identified two small, precontact Neutral villages, a quarry site and a "continuous occurrence of cultural debris extending along the bank of the Niagara River" (Houghton 1909:320, Williamson et al. 1997). Houghton was also seemingly impressed with the quality and abundance of chert on the beach at Fort Erie, observing that "the shore at Fort Erie on this [Onondaga] outcrop is strewn with chips, flakes, blocks and half-formed implements, the waste of aboriginal quarrying and manufacture" (Houghton 1909:337-339, Williamson et al. 1997).

In the 1960's, excavations in this locale resulted in the documentation of the Orchid (AfGr-1) and Surma (AfGr-2) sites (Emerson and Noble 1966), which are now known to be components of the overall Peace Bridge site (see Figure 16). The Orchid component exhibited artifactual material from the Terminal Archaic to Late Woodland time. As well, this site contained a fourteenth century Iroquoian ossuary that contained the remains of a minimum of 300 individuals, together with a series of Middle to Late

Woodland transition and seventeenth century interments (Robertson and Williamson 2000). The Surma component revealed artifactual material spanning Middle Archaic to Late Woodland times, including one of the largest Genesee projectile point concentrations found up to that date. As well, the Surma component exhibited evidence of a significant transitional Woodland period cemetery (Emerson and Noble 1966).

In 1992, Archaeological Services Inc. (ASI), a private cultural resource management firm, documented the Walnut (AfGr-7) site. This site contained diagnostic material spanning thousands of years of occupation, from the Late Archaic to the Late Woodland. As well, two primary burials were documented on the site, likely associated with the Transitional Woodland period (Williamson et al. 1997). Since 1992, ASI has been mitigating the adverse effects of urban and commercial redevelopment in the vicinity of the Peace Bridge in the town of Fort Erie. The principal agents are the Buffalo and Fort Erie Public Works Bridge Authority and the Public Works Department of the Town of Fort Erie. This work has encompassed all stages typical in consulting archaeology, from monitoring to excavation. This site has exhibited a rich archaeological presence despite the surrounding urban activity. In the 1994-996 field seasons alone, over 300 000 artifacts were recovered. As well, over 600 sub-surface archaeological features were identified, of which 384 were excavated (Robertson et al. 1997). The nature of these deposits will be further examined below.

C. Archaeological remains

The principal constituent and marker of these archaeological deposits is a buried black organic soil layer, which contains evidence of approximately three thousand years of prehistoric occupation. This soil stratum has been coined a 'paleosol', as it is the preserved remnant of a relic A-horizon or topsoil layer in use between the Late Archaic (c. 4000 B.C.) to Late Woodland (c. 1600 A.D) before being buried by natural and artificial processes (Williamson 1997). This paleosol can be conceived of as a palimpsest of this time period. It would appear that this area was intensively occupied over the course of approximately 4000 years, beginning with the recession of high waters associated with the Nipissing Transgression (c. 3800 B.P.) (Robertson et al. 1997). It is likely that earlier occupations were scoured away by elevated water levels, although a Early Archaic point was recently found on the site (R.Williamson, pers.comm.).

D. Temporal and spatial components of site

Here, it must be stated that the excavations undertaken at the site are mitigative in nature; the site has only been excavated in small areas that are often disjointed. This is because the excavations are dictated by the nature of the impending development and not by the archaeological remains themselves. In this light, conclusions and interpretations are based upon the relatively small portion that has been excavated and are not comprehensive. As development in the town of Fort Erie is in a constant state of flux, so are the excavations of the site that are ongoing in nature.

(i) Artifictual material and settlement patterning

This site, as stated above, has been intensively, but not continuously occupied over a period of at least 4000 years. The following is a summary of the artifactual findings and settlement data associated with each time period during the 1994-1996 excavations.

The Late Archaic Occupation: Genesee points, associated tools and preforms compromise the vast majority of diagnostic lithic tools recovered from the site

(Robertson et al. 1997). These tools were recovered from both the paleosol and from subsurface features that frequently contain material from later period as well. This overall pattern of recovery demonstrates that Late Archaic period tool manufacturer's working at the site casually littered the area with discarded tools and preforms (Robertson et al. 1997). As well, debitage analysis from two Genesee features suggests that bifacial blanks were brought to areas near these features where they were thinned, suggesting different activity areas were delineated. Plant and faunal remains, and diagnostic subsistence tools suggest an annual subsistence cycle involving small interior fall and winter hunting camps, which were situated to harvest nuts and animals attracted to mast-producing forest, and larger spring and summer settlements among the littoral marshes, river mouths and lakeshores in order to exploit aquatic resources (Robertson et al. 1997). Two AMS dates on carbonized nutshells from Genesee features produced returns in the ranges of 3580 B.P. (2120-1750 B.C.) and 3470 B.P. (1930-1620 B.C.). As well, the first evidence of Broad Point cremation-caching tradition burials, in the form of Genesee burial found at the site. In terms of occupation, at least four Late Archaic feature concentrations were encountered at the site during the 1994-1996 excavations that may tentatively represent the remains of Late Archaic structural floors (Robertson et al. 1997).

Early Woodland Occupation: Material evidence, including Meadowood lithic tools characteristic of this time period, and Vinette 1 pottery, notable as the first form of ceramic. Also of note was the discovery of a cache of 29 complete or fragmentary Meadowood preforms and a primary interment of an adult with grave goods (Robertson et al. 1997).

Transitional Woodland Occupation: Portions of two transitional Middle to Late Woodland period house structures were evidenced only a few meters inland from the former shoreline of the Niagara River; the faunal remains recovered from these features suggest that processing of fish was a major activity in this location. A complete Middle Woodland undecorated ceramic vessel was recovered from the vicinity of one of the houses. Radiocarbon dating of charred food residue from the complete vessel returned an age of 1330 B.P. (A.D. 625-862) (Robertson et al. 1997). The lithic material from this time period suggests more prevailing use of unprepared, expedient cores rather than prepared bifacial cores.

Late Woodland Occupation: Despite the prolific evidence of Late Woodland occupation exhibited at the Surma and Orchid components, the 1994-1996 excavations produced limited evidence of this time period. However, Late Woodland occupation has recently been documented on the site, through the documentation of post-moulds representative of a Middle to Late Iroquoian longhouse.

(ii) Mortuary Evidence

The Peace Bridge site includes a significant mortuary component. Twenty of the features found between 1994 and 1996 represent burial deposits. ASI investigations evidenced the first finds of Broad Point tradition burials in Ontario. These cremations are closely comparable to the Late Archaic "Susquehanna" mortuary complex of the Mid-Atlantic coastal region, in that they are represented by deep basin pits in which the fill consists of basal layers of fired soil and/or highly organic black soils (Robertson and Williamson 2000, Snow 1980). Red ochre was also seen to accompany some of the cremations. As well, formal tools or biface preforms (often broken or burnt) and substantial quantities of burnt and unburnt animal bone accompany many of the Peace Bridge cremations.

As well, these excavations resulted in the discovery of many additional transitional Woodland burials beyond the significant finds of the Surma and Orchid components. Of particular note was the primary interment of an adult whose accompanying grave goods included a Middlesex/Adena (Woodland) complex blocked-end stone tube pipe made from Ohio limestone and a finely made T-shaped drill manufactured from Onondaga chert.

(iii) The Peace Bridge Quarry

During the 1998-1999 field seasons, a trench, approximately one-meter wide and some 86 meters long, was excavated previous to the construction of a water/sewer line (see Figures 17-20). This trench, following the removal of all imported fill, was hand-excavated in one-meter units. The stratigraphic profiles along the entire trench revealed the presence of an upper and lower paleosol. The excavations exposed two subsurface chert strata. At the base of the exposed Edgecliff member scarp was a slightly uneven limestone pavement. Close examination of the 40-50cm high layers of interbedded chert and limestone on the face of the scarp revealed a number of negative flake scars on the chert layers. The subhorizontal limestone pavement was also covered by a debris layer of chert debitage and cobbles. These findings suggest that this area was a primary mining location from which raw material was obtained. This hypothesis is supported by Professor Peter von Bitter, Department of Paleobiology, Royal Ontario Museum and

Department of Geology, University of Toronto, who has inspected the feature (Williamson 1999). Williamson (1999) has stated that:

> "Although the numbers of bifaces and formal tools on the top of the bedrock ledge averaged perhaps two or three per one-meter square, the first eight meters east of the scarp face yielded not only a greater number of decortation flakes and primary thinning flakes, but also no less that 70 bifaces, one Genesee projectile point, two net sinkers and six hammer stones. Clearly, this was an area of intensive core-reduction and tool making. In addition, tens of thousands of pieces of debitage were recovered from each one-meter square."(Williamson 1999)

It is likely that precontact peoples 'removed a sizable, unmodified piece from the face and turned around to test it as a potential core', resulting in a greater number of decortication flakes and primary thinning flakes in the quarry cut itself (Williamson 1999).

Although it is likely that quarrying activities occurred at the site, the only diagnostic artifact associated with the trench that exposed the quarry cut was a Late Archaic Genesee point. Although this artifact suggests a Late Archaic utilization of the quarry cut, the palimpsest nature of the trench fill may be the result of Late Archaic occupations or the mixing of remains from this and later occupations from the nearby settlement. Stratigraphically, the settlement area and the quarry are connected by a paleosol, which includes artifacts from essentially every period at the site. It is an undifferentiated sheet midden. The preserved features were found beneath the paleosol, cut into the sterile subsoil. Unfortunately, the nature of the majority of the artifacts found in the quarry (water sewer trench) fill and the sheet midden characterizing the entire site (both settlement area and quarry) itself is temporally undiagnostic (to a specific occupation) in nature. Thus, no direct Late Archaic (or other temporally) diagnostic stratigraphic link exists between the quarry and the adjacent settlement areas. Future excavations of the areas between the quarry cut and other settlement areas may provide more evidence as to the nature of the relationship between these two areas.

F. Late Archaic Exchange and raw material procurement at the Peace Bridge Site (AfGr-9)

Data from the Peace Bridge site suggest that Late Archaic peoples in the southeastern Niagara Peninsula employed a broad, adaptable subsistence base (Robertson et al. 1997). Their annual subsistence cycle utilized small interior fall and winter hunting camps, which were situated to harvest nuts and animals attracted to mast-producing forest, and larger spring and summer settlements along the Niagara River in order to exploit aquatic resources (Robertson et al. 1997). The ubiquity and frequency of net sinkers among the Peace Bridge assemblages, and indeed in other Niagara River site assemblages, point to the importance of fishing as a primary subsistence activity. In this light, lithic raw material procurement and tool production appear to have been carried out in conjunction with the activities necessary in a more permanent habitation (Robertson et al. 1997).

The intense precontact presence apparent through the wide range of activities carried out at this locale alludes to the possibility that some social groups may have had a greater residential permanence with this locale (Robertson et al. 1997). If one can assume that these 'resident' groups asserted some degree of territorial control over the quarry and other resources in the immediate vicinity, then the site can be potentially considered as "a central manufacturing and distribution center of finished tools, which along with preforms and perhaps unmodified raw material, were subsequently circulated inland to other communities" (Robertson et al. 1997: 507).

No definitive evidence, other than a seemingly overabundance of Late Archaic formal tools, can be identified as relating to Late Archaic exchange at the site. However, the presence of Meadowood bifaces and a Meadowood cache found at the site is of interest. These artifacts date to the Early Woodland period (ca. 900 – 400 B.C.) subsequent to the Late Archaic (Spence et al. 1990). However, the cultural continuum reflected at the site suggests the formation or initiation of Meadowood exchange system components many have occurred during the preceding Late Archaic. Meadowood exchange behavior is evidenced by the broad distribution of Meadowood bifaces throughout southern Ontario, which

> "together with the macro-regional uniformity of the Meadowood biface suggests some wide-ranging interaction between discrete regional populations, perhaps in the form of distributed assemblages manufactured by a limited number of master knappers, [was occurring] and that production was occurring well beyond the individual needs of the knapper or local band members" (Robertson et al. 1997:508).

Granger (1978) suggested that Meadowood exchange networks primarily functioned on an economic level (Granger 1978, Robertson et al. 1997). However, he did suggest that the exchange network led to a 'core of religiosity' where local circumstances and local decisions regarding the degree of economic surpluses to be 'retired at socially integrating ceremonies', or caches (Granger 1978, Robertson et al. 1997). Meadowood bifaces have also been viewed as a kind of 'peace fare' for maintaining exchange systems for the bands outside of the core exploitation area (Granger 1978, Robertson et al. 1997).

In this vein, evidence from the Small Point (Terminal) Archaic (3500-3000 B.P.) and the Glacial Kame mortuary complex (ca. 3000 – 2800) is also of interest. Hunter-gatherer bands throughout southern Ontario participating in the Glacial Kame mortuary complex were

> "linked though a widespread exchange network that brought marine shell artifacts from the Atlantic coast of the United States, copper goods from the Lake Superior region, and galena from sources in northeastern New York State, eastern Ontario and the headwaters of the Mississippi" (Ellis 1990:118)

The relevance of these observations is the notion that these trends may have been operating in some nascent form during the Broad Point Late Archaic. Although no earlier tradition has yet to be identified, grassroots participation in regional exchange networks must have been the norm if the ensuing well-structured, far-flung and institutionalized exchange networks are to be explained.

IV. The chipped stone industry of Peace Bridge

The vast amounts of chert tools and debitage that have been recovered from the Peace Bridge Site (AfGr-9) combined with the wide time span that is represented and a three thousand year tradition of burial, point to an overall sense of permanence associated with this locale (See Figure 21). Here, pre-contact peoples had access to accessible outcrops of high quality chert, a rich concentration of aquatic resources and one of the most significant congregating areas for migratory waterfowl in the province (MacDonald and Cooper 1997).

The chert reduction industry present on site, while dominated by bifacial reduction of prepared cores from the Late Archaic to Early Woodland time, changed to an industry reliant upon the expedient use of unprepared cores during the subsequent Transitional and Late Woodland times (Stewart 1997). This is in keeping with a shift seen throughout most of eastern North America, and is thought to correlate with increasingly sedentary settlement patterns (Parry and Kelly 1987, Robertson and Williamson 2000).

Other significant finds encountered during these excavations were a cache of Meadowood preforms. Of note here is the significance and complexity of caching behavior itself; researchers have identified the nature of the cache to often be related to commemorating the sacred origins of raw materials themselves, or as votive offerings that may illuminate the undercurrent of historical and social associations with a specific place (Robertson and Williamson 2000, Williamson 1996).

Within the Peace Bridge site itself, Genesee points and associated tools and performs compromise the vast majority of the diagnostic tools recovered from the Peace Bridge site. In fact, the 1994-1996 site summary suggests that 'this overall pattern of [lithic] recovery vividly demonstrates the fact that the Late Archaic period tool-makers working at the site casually littered the area with discarded tools and performs' (Robertson et al. 1997).

It is important for those unfamiliar with the Peace Bridge site to come to terms with the sheer amount of lithic material present within the paleosol and subterranean features (Figures 21 and 22). This is a key to understanding the importance of further studies on the intrinsic lithic economy. As suggested by Robertson et al., 'given the exceptionally large number of finished Genesee points recovered from … approximately 5% of the site [which was excavated] [evidence] strongly suggests …that a Late Archaic distribution network linked the southeastern peninsula and the north shore of Lake Ontario' (Robertson et al. 1997:508). To further this understanding, a brief summary of the lithic analysis from the 1994-1996 field seasons is offered.

A. Formal Tools

In terms of lithics, the 1994-1996 excavations recovered a total of 394 formal tools: 308 fragments were assigned cultural affiliation and 385 fragments were of Onondaga chert (MacDonald and Steiss 1997). Eleven taxonomic groups were identified, and the overwhelming majority was assigned to the Late Archaic Broad Point. It is interesting to note that Genesee material is spatially ubiquitous throughout the site in both paleosol and features. As well, later period features produced Genesee material that was either accidentally or purposefully included in the feature fill.

B. Bifaces and Debitage

The 1994-1996 field seasons produced 1515 biface fragments of which 1494 were made of Onondaga chert. In terms of debitage, in spite of a conservative sub-sampling strategy to cope with the prolific amount of material present on the site, hundreds of kilograms of chert debitage was recovered, the great majority (over 99%) of which was of Onondaga chert (MacDonald and Steiss 1997). Primary reduction flakes in the habitation/workshop areas were almost absent. By far the most common flake forms were secondary knapping flakes with a relatively small, but consistent fraction of secondary retouch flakes (MacDonald and Steiss 1997). In general, the debitage assemblage in the settlement areas of the site suggest that the manufacture of bifacial preforms from prepared blanks was the primary lithic reduction activity during the Late Archaic (MacDonald and Steiss 1997).

The relatively marginal quarry area exhibited a markedly higher percentage of primary flakes. As well, there is some evidence which points to the production of finished bifacial tools (MacDonald and Steiss 1997). The overall impression one has of the lithic assemblage from the 1994-1996 field season is that:

> '[The results suggest that] the early stages of stone tool manufacture, involving such activities as decortication, testing of cores, primary core reduction, and the removal of large flake nuclei, were carried out right at the chert outcrop, with rough flakes brought back to the habitation area for further working. Additional primary thinning and secondary knapping (biface thinning) were the undertaken to produce bifacial performs'. (MacDonald and Steiss 1997: 348 – 351).

It is expected that the analyses of the material from the mining area, which is currently underway, will yield a higher proportion of primary reduction debitage.

V. Sample description

The importance of sampling and the implications of poor sampling technique are well known to archeologists; many promising studies have been hampered by utilizing sampling techniques that were not planned in concert with the aims of the study and the underlying assumptions of the sampling methodology. The success of provenance studies rests upon a sampling technique that incorporates as much of the observed visible and geographic variation as possible into the subsequent research regime. To counter his extraordinary susceptibility to poor sampling, a well-thought out strategy must be utilized. The following is a description of the location and nature of samples used in this study. A summary of these descriptions is offered in Appendix 2.

A. Discussion of samples from the quarry

In an idealized study, samples removed systematically and directly from the face of the exposed quarry cut would have been used to geochemically define raw material from the quarry. Unfortunately, the trench which exposed the quarry cut has long since been backfilled. To add insult to injury, no samples were removed from the face itself when originally exposed in order to conserve its integrity. Given these restraints, the next best solution was to sample culturally modified material that was found on the surface of the limestone pavement at the base of the quarry cut (i.e. rejected pieces or thinning flakes) and material recovered from the fill directly above the quarry cut. In this light, samples were selected from units 12-13, which displayed the highest density of mining and reduction waste (Williamson 1999). It is argued that any potential lateral movement of individual lithic artifacts during the interval between mining and discovery is overshadowed by the variation of the raw material itself over the same spatial distance. In geochemical terms these materials would come from essentially the same spot with little or no loss in provenance resolution.

Culturally modified (debitage and biface) lithic samples were removed from units 12 and 13 of the water/sewer trench where the quarry cut was found (Figure 23) Specifically n=3 samples were removed from the subsilt layer (the fill directly above the limestone pavement), n=17 from the lower paleosol and n=17 from the upper paleosol for a total of 36 samples. These samples were retrieved from soil (or fill) strata specific volume samples, where all material found in one quadrant was kept for analysis. In order to encompass the entire range of potential geochemical variation, the entire volumetric sample (typically consisting of many kilograms of material) was visually inspected and samples were chosen which reflected the entire range of color and texture variation present. In this light, samples which exhibited cortex, weathering, banding and mottling were incorporated into this study, as this chert was of archaeological significance. As well, one of the larger bifaces were further reduced in order to incorporate the geochemical changes associated with weathering. The samples selected from the limsestone scarp face were collectively labeled PB1 through PB36. As well, a core derived from Unit 13 was reduced in order to provide singular samples in which cortex (B.0013a), weathered (B.0013b) and unweathered (B.0013c - interior) portions were isolated in order to provide a cursory examination of the effect of weathering on cherts derived from the Peace Bridge quarry. As well, the chemical variation throughout the weathered and unweathered portions of a solitary archaeological core could potentially illuminate trace elemental mobility these cherts. These macroscopic descriptions are summarized in Appendix 2.

B. Discussion of samples from on-site Genesee deposits

The material samples for comparative analysis to the source, or quarry cut, are derived from what has been identified as Feature 73 (Figure 24) found in area 4 of the east truck pad portion of the site (Figure 25). This feature exhibits artifactual evidence of both Genesee points and preforms. It is dominated by biface thinning debitage, suggesting that bifacial blanks were brought to the area near this feature where they were thinned (Robertson et al. 1997). This undisturbed Genesee period feature is ideal for the examination of the relationship between on-site quarry and lithic reduction activities. Samples (n=3) were removed from the debitage present in this feature for analysis.

C. Off site sample locations

a. <u>Outcrops and archaeological samples to the west (Port Colborne)</u>

The success of this study relies on the ability to distinguish between the Peace Bridge outcrop and other outcrops to the east and west of the site. Approximately 26km to the west of the Peace Bridge site, near the town of Port Colborne, lies the Ansari Site (AfGt-27), which contained material ascribed to a multi-component Onondaga chert workshop (ASI 2002). The site exhibits pre-contact material from the Middle and Late Archaic, Early (and possibly Middle) Woodland, and Middle Iroquoian periods.

Several (n=3) samples were removed from a sub-surface feature that contained fill that exhibited evidence of flint-knapping activities that were oriented towards producing refined bifaces or projectile point blanks ((ASI) 2002). Two Genesee projectile point tips were also found in this feature ((ASI) 2002). These samples were incorporated into the study as they were likely procured from the nearby beach on the north shore of Lake Erie, and in turn are reflective of the pre-contact utilization of chert from this area. This beach is casually littered with chert cobbles eroded out of the Onondaga Formation. A chert cobble was removed from this beach and incorporated into this study as a cursory exploration of the relationship between samples derived from the Ansari site and the nearby beach source area. Despite the unknown association between this cobble and its constituent member of origin in the Onondaga Formation, this cobble was reduced in order to provide singular samples in which weathered (P1-2) and unweathered (P3-5 - interior) portions were isolated in order to provide an understanding of the effect of weathering on cherts derived from this portion of the Onondaga Formation.

These samples will be statistically pooled and be comparatively utilized as a measure of the geochemical variation that is observed on the westernmost portion of the Onondaga Formation.

b. <u>Archaeological samples to the north</u>

One of the goals of this study was the identification of material derived from the Peace Bridge site in off-site locales. With this goal in mind, Genesee projectile points and point fragments were sought from off-site contexts to test this comparative aspect. In this light, this analysis was able to take advantage of the extensive ASI collections. An examination of the collections database identified four candidate sites that provided off-site samples for analysis. The following is a brief description of each site (See Figure 26):

AiGx-197 (n=1): This site, approximately 2km northeast of the town of Waterdown, in the Township of Flamborough, Ontario, was identified in the summer of 1996 during an archaeological assessment. The site, located on gently rolling terrain, was comprised of an Onondaga chert lithic scatter covering an area of approximately 400 square meters. A controlled surface collection of the site yielded a Late Archaic Genesee point missing only its tip ((ASI) 1996). This point was sampled for INAA by using a pressure flaking technique. Samples were removed from at least three locales from around the circumference of the point and pooled into one sample container. This pooling of multiple samples from isolated removal zones more accurately reflects the variation observed in the tool itself and is thereby better reflected in the subsequent results.

Greenwood (AlGv-148) site (n=2): The Greenwood site, located in the city of Vaughan, Ontario, is situated on low-relief terrain and was comprised of a 900 square-metre lithic scatter. A controlled surface collection resulted in the recovery of 29 Onondaga chert artefacts, of which two were Genesee projectile point bases ((ASI) 1995). These point bases were sampled in the same manner as above.

AlGv-177 (n=1): This site, located in the City of Vaughan, Ontario, was identified in the summer of 2000 during the course of an archaeological assessment. This site consists of 2 isolated surface finds, a biface and the lower portion of a Genesee point manufactured from Onondaga chert ((ASI) 2001). This point base was sampled in the same manner as above.

Morningstar (AjGw-113) site (n=1): This site, located in the city of Mississauga, Ontario, was identified during an archaeological assessment in the summer of 1988. The site consists of a single isolated surface find of a Genesee point. This point was samples in the same manner as above.

c. Archaeological samples to the south

Although Genesee and other Broad Point Late Archaic material has been found south of the Great Lakes, none have been incorporated into this present study. The logic behind this was twofold; firstly, the nature of this investigation is exploratory in nature and not comprehensive. In this light, a successful outcome would simply be the identification of material moving off of the Peace Bridge site, regardless of direction. In this light, the most easily obtained samples that were reflective of a large region were derived from assemblages where a great majority of work had been done. Namely, collections derived through the archaeological assessment of planned development in the 'golden horseshoe' area of Ontario on the shores of Lake Ontario. These samples were not only viable candidates, they were easy to acquire for this study. The second reason is logistical; samples derived from international contexts were not only laden with increased bureaucratic responsibilities over curation and potential destructiveness, they often crosscut regional culture-historical boundaries and, in turn, are products of a Great Lakes taxonomic quagmire (Williamson 1999). In this light, a decreased familiarity with the regional labels and collections could have been a potential detriment to this study and were in turn avoided. However, any further comprehensive distributional studies would be remiss if they did not incorporate material from contexts south of the Peace Bridge site

d. Previously published comparative data (outcrops to the east)

A key investigation that informs this study is the analysis by Hugh Jarvis (1990). Jarvis sought to establish the feasibility of conducting a large-scale trace elemental chemical characterization of Onondaga Chert. Seemingly frustrated with the tendency to assign a point source to artifacts stemming from a continuous formation based on visual identification, Jarvis designed a research strategy that attempted to characterize Onondaga chert samples from the easternmost outcrops along the escarpment using INAA.

Ten (later pooled to seven) outcrops were sampled from western New York State (Figure 27). Sixteen elements were measured: uranium, dysprosium, barium, titanium, strontium, iodine, bromine, magnesium, silicon, sodium, vanadium, potassium, aluminum, manganese, chlorine and calcium. Concentrations by mass were reduced from the raw gamma ray counts using in house standards and the comparator method. It must be noted that of the elements measured, strontium and iodine fell outside detection limits in half of the cases and were removed from analysis.

This technique illuminated a general increase in elemental concentrations moving eastward across the escarpment. The most expressive elements were bromine, chlorine and sodium as evidenced by a strong linear relationship among these elements in a scatter-gram analysis. The results engendered the interpretation that a facies shift (or a change in a sedimentary formation) occurred across the escarpment due to differing environmental conditions during the time of deposition.

Next, Jarvis attempted to test the results against archaeological samples. Specifically, he attempted to source archaeological samples through chemical characterization. Ten reduction flakes from three western New York sites were analyzed in the same manner as the geological samples. The results showed a comparable level of chlorine and bromine, but sodium counts were reduced due to what was believed to be chemical leaching.

Bivariate plot analysis revealed a seemingly low resolution clustering between source and artifact. However, Jarvis desired a more holistic analysis of the data. After accounting for sample size variation and variance inequality, Jarvis applied discriminant analysis, which uses sample data from known groups to develop a discriminant function which maximizes the differences between samples by comparing the variation between and within groups. This technique attained an overall classification success rate (or correlation between source and artifact) of 85% using data gathered through this method. In other words, Jarvis tested the resultant discriminate function by attempting to assign membership of known samples (the samples used to generate the discriminant function itself) to the known sources. The resultant statistical function assigned the sample to the correct source 85% of the time. The most discriminating elements were uranium, bromine, magnesium, sodium, vanadium, potassium, aluminum, manganese, and chlorine.

In short, Jarvis concluded that INAA can be successfully used to characterize Onondaga chert through systematic sampling as variation in a suite of elements can be observed across the escarpment. He was able to demonstrate that outcrops in the New York State portion of the Onondaga formation are geochemically distinguishable over relatively short distances. As well, Jarvis was able to use this technique to assign archaeological artifacts these geochemically identified outcrops with a significant degree of success (Jarvis 1990).

However, the investigation conducted by Jarvis (1988, 1990) failed to investigate the geochemcial relationship between the different stratigraphic members of the Onondaga Formation itself. Although vertical geochemical variation was incorporated into the dataset through the sampling of all exposed members at the outcrop locations, the final results bring into question whether the 'facies shift' identified by Jarvis (1988, 1990) is in actuality a geochemical difference between strata along the Onondaga Formation. Only a geochemical profile which incorporates a high degree of resolution between the differing members of the Onondaga Formation will rule out the stratigraphic geochemical differences and illustrate whether the observed geochemcial trend is spatial in nature.

As well, it can be seen that the several of key elements that Jarvis (1988, 1990) used to describe the geochemical gradient are also among the most mobile and are themselves subject to alteration and contamination through chemical enrichment and leaching through weathering. For example, many of the correlation trends can potentially be explained through carbonate salts or clay contamination. In this light, one must question the relationship between the observed geochemical gradient and the mobility of the very elements that are used to describe it.

VI. Conclusion

The work of Jarvis (1990) is a key to the success of this investigation, as his study exhibits that this technique was successful on the New York State portion of the Onondaga Formation. By logical extension, this technique should be of utility in the southern Ontario portion of the formations as well.

The identified facies shift, if found to continue into the Ontario portion of the formation, should render chert outcrops geochemically distinguishable from one another. In this light, data derived by Jarvis (1990) from adjacent outcrops to the east (New York) and west (Port Colborne) of the Peace Bridge site will be introduced into this study in order to facilitate greater resolution between the Peace Bridge chert outcrop and other adjacent chert outcrops.

CHAPTER VI: DATA ANALYSIS

I. Introduction

Provenance studies typically employ a number of statistical and descriptive techniques in order to expose potential patterning in geochemical data. These techniques include scattergram analysis, univariate analysis of variance, correspondence analysis, correlation analysis, discriminant analysis and principle component analysis. This provenance study will employ the methodology defined by Jarvis (1988, 1990), as the pooling of results from both analyses will easily lend themselves to a more holistic analysis of the Onondaga Formation. As well, the techniques utilized by Jarvis (1988, 1990) exhibited a degree of success that this study hopes to attain. However, despite the limited scope of this investigation, it should be noted here that any future analysis of this data would be well served by a broader statistical analysis regime that there is little room for here.

The raw data from an Induced Neutron Activation Analysis (INAA) sample, in the form of raw gamma ray counts derived by the gamma ray detector, is usually converted into elemental concentrations (usually parts per million) using the following equation (1):

$$\textbf{Concentration (ppm)} = \frac{\text{peak counts} - \text{background counts}}{P \times F \times e^{-dT(\ln 2/t)} \times M \times kw} \qquad \textbf{Equation 1}$$

Where P is the relative distance between the sample and the detector; F is a constant created from the in-house standards, dT is the delay time between sample irradiation and gamma ray counting, t is the isotopic half-life; M is the sample mass in mg and kw is a measure of the reactor power level (Jarvis 1988, R. Hancock, pers. comm.).

The concentration data for this study is listed in Appendix I. In each sample, the magnesium concentrations are not corrected for aluminum interferences. Although this is likely trivial in the analysis of cherts, it is of importance when characterizing the standards (R. Hancock, pers. comm). Appendix I is more easily understood with the knowledge of the conversion of ppm to percentage constituents (10 000ppm = 1%) and the understanding that data with the prefix 'less-than symbol (>)' denote that the determined concentration is the highest estimated amount (68% confidence limit) of element that could be present and not measurable. In other words, the signature of that element could not be distinguished from the ambient background count despite the observation of a 'peak' in that particular elements' gamma ray range. For all practical purposes, these concentrations amount to zero, as they cannot be quantified.

During this analysis, the Onondaga cherts utilized were sampled using pressure-flaking flake-removal techniques to remove roughly 200 mg with non-metallic instruments that could potentially contaminate the sample. These chert samples were introduced into the atomic pile and analyzed for 18 different detectable elements - U (Uranium), Dy (Dysprosium), Ba (Barium), Ti (Titanium), Sr (Strontium), I (Iodine), Br (Bromine), Mg (Magnesium), Si (Silicon), Na (Sodium), V (Vanadium), K (Potassium), Al (Aluminum), Mn (Manganese), Cl (Chlorine), Ca (Calcium), Co (Cobalt) and Cu (Copper).

Here, an examination of the analytical precision and accuracy of the dataset will provide a useful backdrop to the following discussion. Table 2 illustrates the 68% confidence level estimates of the analytical precision of the measurement expressed as a relative percentage for three of the sample studies in this analysis (F73-1, OS-1 and OS-

5). These measurements are based on the size of each gamma-ray peak relative to the background on which it sits (R. Hancock pers. comm.). Based upon these relative percentages, the quality of the data can be sorted into the following arbitrary categories of accuracy and precision (R.Hancock pers.comm.):

Excellent (<3%): aluminum, calcium, chlorine, manganese and sodium
Good (<10%): bromine, calcium, potassium, magnesium, silicon and vanadium
Poor (<20%): barium, potassium and magnesium
*Unacceptabl*e (>20%): barium, copper, cobalt, iodine and strontium

It must be noted here that in the different samples, there exists some variability between these classifications (for example barium, calcium, potassium and magnesium can be ascribe to more than one precision group) as these elements offered differing gamma-ray peak values relative to their background measurements. Generally, the higher the concentration of an element relative to its background count, the more accurate the resulting measurement (R.Hancock, pers.comm.). In this light, only elements which fall within the <10% category will be used for the subsequent statistical analysis.

II. Discussion of Data

In all, 56 samples were analyzed, including 39 archaeological samples from the Peace Bridge quarry cut, 4 archaeological samples from the multi-component Onondaga chert workshop at the Ansari site (AfGt-27), 5 modern samples from the chert cobble laden beach at Port Colborne, 3 archaeological samples from a Genesee feature (Feature 73) in the East Truck Pad at the Peace Bridge site and 5 archaeological samples derived from Genesee points found from sites on the north shore of Lake Ontario.

Not surprisingly, and in keeping with Jarvis (1988, 1990), the most common element in these samples was silicon, averaging 45% (NOTE: all percent figures shown are weight percent and are not to be confused with atomic percent - See Table 3 and

Appendix I). It can be noted that chert itself is silicon dioxide, which is 46% silicon when pure (Jarvis 1988, 1990). The next most abundant element is calcium, which ranged from less than 1% to 3% typically, with an extreme outlier of 27% derived from the modern Port Colborne cobble. Aluminum, chlorine, magnesium, sodium, titanium and potassium are minor elements (less than 1%) and the remaining elements are all at trace levels (less than 0.01%).

Of the 18 different elements analyzed in these samples, 7 elements (dysprosium, barium, titanium, strontium, iodine, cobalt and copper) frequently rendered a concentration that was below the detection limit of the apparatus. In these cases where an element might be present but is not detected, the instrument attempts to calculate the maximum amount of the element that might be present relative to background noise, and is illustrated by the use of the 'less-than' prefix before the final concentration value. The upper limits of this detection range varied from sample to sample depending upon the level of background static. The inherent uncertainty of these calculated values, although of substantive use in a holistic understanding of the chert constituents, would be detrimental to the ensuing statistical analysis planned for this study. In this light, these particular elements were removed from multivariate statistical consideration but were included in the substantive descriptive discussions. However, it should be noted that elements that sporadically fell below the detection limit (e.g. potassium, uranium and bromine) were included in the following analysis, with the concentrations from those specific cases removed. All statistical analyses were undertaken using SPSS v.10.

Tables 4 and 5 illustrate the mean concentrations for all elements (and the mean potential maximum concentration for elements that fell below detection limits) by outcrop (i.e. the Peace Bridge outcrop and Port Colborne) in Ontario. Although these numbers seem highly variable upon first inspection, some general trends appear when compared to the data derived by Jarvis (1988 – see Jarvis (1988) Appendix 4: INAA data). Jarvis (1988) identified a phenomena know as a 'facies shift' in the Onondaga Formation. In short, under certain environments of deposition, the geochemisty of a sedimentary formation is not homogenous, and forms a geochemical gradient that reflects differences in the depositional environment of the sediment (Jarvis 1988). In this light, Jarvis (1988, 1990) identified a geochemical gradient where the easternmost portions of the Onondaga Formation were 'dirtier' in terms of trace elements – the eastern most outcrops that were studied had, on average, the highest values of uranium, dysprosium, titanium, Vanadium, potassium, aluminum, magnesium and chlorine. However, due to the sampling strategy employed by Jarvis (1988, 1990) no geochemical correlation between the members of the Onondaga Formation can be ascribed.

Upon inspection, the data from the Peace Bridge quarry cut and from Port Colborne seem to be in keeping with the 'cleaner' trend to the west. The Peace Bridge samples (when compared to descriptive statistics sorted by chert outcrop in Jarvis (1988, 1990 – Appendix 4)) have the lowest mean values for uranium, titanium, bromine, sodium, magnesium, calcium and chlorine. The remaining elements had values that were also comparatively low and in keeping with the geochemical gradient identified by Jarvis (1988, 1990). The exceptions were silicon, which averaged very high compared to all of the other outcrops, and iodine, which exhibited the highest values of all of the compared outcrops, and silicon. This is a significant observation in itself, as silicon will increase as a constituent component if other elements are missing. In other words, the increase in the amount of silicon lends evidence to the high level of purity and quality of the chert stemming from the Peace Bridge outcrop.

However, these descriptions must be used cautiously, as the Peace Bridge data is likely only representative of chert from the Edgecliff, or lowermost member of the Onondaga Formation, which is likely the exposed chert at the Peace Bridge quarry. However, the data provided by Jarvis (1988, 1990) is a pooled representative of all of the exposed members of the formation vertically at the locale of sampling. Jarvis (1988, 1990) used this sampling strategy in an attempt to control for intra-source variation by using a vertical series of samples from each locus.

i. Geochemical Mobility of Trace Elements

An understanding of the potential mobility of trace elements of the chert under investigation is key to understanding the value of the subsequent results. This study sought to investigate the potential for geochemical weathering in Onondaga chert, regardless of source member, through the reduction of both archaeological and modern chert cobbles into weathered (B.0013a and P1-2) and unweathered (B.0013b/c and P3-5) samples, which were then analyzed (see Appendix 1). The results point to a significant degree of geochemical mobility in Onondaga chert. Specifically, vanadium, potassium, aluminum, manganese and magnesium showed significantly higher concentrations in the weathered samples than in their unweathered counterparts. Given this evidence, it would appear that Onondaga chert is prone to chemical enrichment and contamination of these elements. Conversely, bromine, sodium and chlorine exhibit higher concentrations in the unweathered samples as compared to their weathered counterparts. In this light, the reactive nature of these elements allows for their leaching from Onondaga chert with relative ease. However, calcium exhibited evidence of both trends. Specifically, calcium was found to render higher concentrations in the weathered samples form the Port Colborne (P1-2) cobble, yet displayed higher concentrations in the unweathered samples derived from the Peace Bridge cobble (.0013b-c). This dichotomy of observations points not only to the differential mobility of calcium in Onondaga chert, but also to the likelihood of differing enrichment (i.e. contaminant sources) and leaching mechanisms in play in the vicinities of Peace Bridge and Port Colborne.

In short, (of the measurable elements) bromine, sodium, vanadium, potassium, aluminum, magnesium, calcium, manganese and chlorine were found to exhibit a significant degree of mobility in Onondaga chert. Typically, grain-size, porosity and water content determine the degree to which cherts can be altered by weathering. As all cherts contain water, the more porous a chert is determines the ease with which it can exchange water through capillary action with the surrounding environment (Luedtke 1992). Onondaga chert has been observed to be a fine to medium grained chert (Luedtke 1992). It must be noted that water itself is chemically active can carry dissolved matter such as acids, bases or humic substances which can interact chemically with the chert. The movement of water in and out of chert can cause oxidation and hydration, dissolution and leaching, precipitation, and chemical and mechanical disaggregation, especially of the nonsilica minerals (Luedtke 1992).

Of note here is that regardless of the mechanism, both archaeological and modern Onondaga cherts are highly susceptible to chemical weathering and enrichment in a broad suite of elements. This degree of variability between weathered and unweathered samples in this study renders comprehensive results much more elusive. In this light, the following statistical discussions must be place against the backdrop of this enormous geochemical variability.

ii. Normality of Dataset

Many statistical methods have certain requirements or assumptions of the input data set. Discriminate analysis assumes that the data adhere to a multivariate normal distribution, which inherently requires that each individual variable have a univariate normal distribution. The normal distribution is a symmetrical smooth bell-shaped curve defined by a particular equation; one feature of it is that the two 'tails' of the curve extend infinitely in either direction without reaching the horizontal axis. This curve illustrates the notion that regardless of a particular mean and standard deviation a normal curve may have, there will be a constant proportion of the area under the curve, or a constant proportion of the cases in a frequency distribution of this from, between the mean and a given distance from the mean, expressed in standard deviation units (Shennan 1997).

Klawiter (2000) expressed an interesting notion, when undertaking a similar provenance analysis of the Prairie du Chein formation, a broad spanning continuous formation found in the midwestern United States. His studies suggested that it was highly unlikely that the entire sample dataset that was assembled be tested for normality as a single body, as this would only be valid if the entire data set were a representation of a random selection from a single homogenous source (Klawiter 2000). However, as the nature of the formation under study was undertaken with an aim to determine if portions of the whole formation are distinguishable from each other, the overall data set may not at all be close to multivariate normal, and ironically enough, it would be helpful to the study if it is not so (Klawiter 2000). As can be seen from the raw data tables (Appendix I and Tables 3-6, the skewness (a measure of the symmetry of the sample distribution) values tend to be toward the high end, as can be seen from the positive values (except chlorine and silicon which are skewed towards lower values). This is not unusual for trace element data; in fact it seems to be the norm (Luedtke 1984, Klawiter 2000).

Researchers have often been forced to transform the data to make the distributions appear more normal (Shennan 1997). A common transformation technique has been to use the logarithmic scaling of the data, or to convert the data to log *x* (here log to base 10 was used) values. The comparison of the skewness values of the untransformed and the log (10) transformed reduced data set is illustrated in Table 6. Here, the skewness values generated are for the most part closer to the value 0 (an ideal normal curve, regardless of the +/- sign) and closer resemble a normal curve. In this light, these log (10) transformations will be used in the subsequent analyses.

III. Bivariate Plot Analysis

The first step in a graphical analysis is to determine which elements correlate, or are strongly related. A Pearson's Correlations coefficients table was constructed to determine which elements correlated amongst the outcrops of discussion. This pooling is necessary in order to observed correlates between the outcrops in order to discern them from one another. In this light, the Peace Bridge and Port Colborne samples from the Ontario portion of the escarpment were pooled with data derived by Jarvis (1988). His examination identified and sampled the outcrops that were labeled as the East Amherst road cut, the East Amherst quarry, Williamsville and Centerpointe (See Jarvis (1988, 1990) and Figure 27). These were selected due to their proximity to the Peace Bridge site

– put simply, these outcrops are the next easterly 'down-the-line' outcrops that will comparatively clarify the distinct geochemical signature for the Peace Bridge quarry. The remaining outcrops from the Jarvis (1988, 1990) examination were not used as the potential for the geochemical distinction of outcrops east of the Peace Bridge site was already been illustrated – to do so again here would be repetition.

It should be noted that outliers are typical for large data sets such as these and are usually attributed to an error in the analytical process such as sample contamination or a foreign mineral inclusion in the sample itself. These samples were removed from the analysis. The total number of samples analyzed using this technique is large (n=129). Here, it must be noted that elements that fell below detection limits or were not measured in all of the samples due to disparities in the INAA analysis (copper, cobalt, dysprosium, uranium, barium, titanium, strontium and iodine) were removed from this analysis. The following ten elements were studied: bromine, magnesium, silicon, sodium, vanadium, potassium, aluminum, manganese, chlorine and calcium.

Table 7 illustrates the results. Bearing in mind that a prefect positive correlation will render a result of r=1.0, a number of strong, if not ideal, correlations arise. In keeping with the data gleaned by Jarvis (1988), the table illustrates two groups of intercorrelated elements. The first group is compromised of bromine, sodium and chlorine with r>.700 (P (one-tailed) significant at 0.01 level). However, this study also found a strong correlation (r=. 720) between calcium and magnesium. The second group illustrates weaker correlations between more elements. Here, magnesium, bromine, vanadium, magnesium, potassium, aluminum, manganese, chlorine, silicon and manganese correlated with r-values between 0.2 and 0.4.

Five scatter-plots exhibit the potential for separating outcrops along the Onondaga Formation: calcium vs. magnesium (r=0.720), bromine vs. sodium (r=0.779), chlorine vs. sodium (r=0.717), chlorine vs. bromine (r=0.701) (See Figures 28-31). Following Jarvis (1988, 1990), the plot of bromine vs. sodium (Figure 29) illustrates with some clarity the facies shift that has been previously identified seems to continue into the southern Ontario portion of the Onondaga Formation. The Peace Bridge samples cluster at lower levels the next eastern outcrop at East Amherst. As well, the samples from Port Colborne appear to cluster at slightly higher sodium levels than the Peace Bridge samples. The plot of calcium vs. magnesium (r=0.720) (Figure 28) also illustrates this separation between the Peace Bridge and East Amherst samples, although more overlap can be perceived. The plot of chlorine vs. sodium (r=0.717) (Figure 31) illustrates some promising clustering between Centerpointe, East Amherst and Peace Bridge, as well as some potential separation between Port Colborne (with slightly elevated concentrations of both) as compared to Peace Bridge. The plot of chlorine vs. bromine (r=0.701)(Figure 30) clearly illustrates the separation between Centerpointe (upper left), East Amherst and Peace Bridge.

These scatter-plots offer some insight into the nature of the easternmost portion of the Onondaga Formation and its potential for geochemical fingerprinting. These plots not only confirm the findings of Jarvis (1988, 1990), but also allude to the continuation of the facies shift identified by his work into southern Ontario. This facies shift is a key element in distinguishing outcrops along a continuous geological formation. However, any provenance analysis that rests its findings on one or two elements is questionable at best.

In this light, a more efficient and objective use of the data would be to undertake the use of multivariate statistics in order to utilize as much of the trace element data as possible. One of the most common and recommended methods is discriminate analysis (Jarvis 1990, Luedtke 1979, Harbottle 1982).

IV. Discriminate Analysis

As discussed previously (see Chapter 3), discriminant analysis transforms trends in multiple variables into a more easily examined single variable. This technique uses sample data from known groups to develop a discriminate function that maximizes the differences between those samples by comparing the variation between and within those groups (Jarvis 1990). Once these functions have been defined for each group, unknowns can then be assigned membership based upon similarity to the previously defined groups.

However, for this type of analysis to be rendered accurate (i.e. a low misclassification rate) the variables in each group should have multivariate normal distributions and all group covariance matrices should be equal. As discussed previously in this chapter, the data has been transformed using a log (10) transformation to render the distributions, as a whole, more normal. All of the variables, upon transformation, had skewness values of less than 2.5 (see Table 6), which are reasonable values for samples sizes of this size (Jarvis 1990). Regarding the condition of equal covariance matrices, SPSS provides Box's multivariate *M* statistic to test for covariance equality. In simple terms, this function sums all the differences between the different variances and provides an F-statistic, which can be interpreted as a probability that the group covariances are equal (Jarvis 1990). This analysis rendered a Box *M* value of 310.9 with an F-value of 2.862 (84 and 3140 degrees of freedom). This is a significant ($P<0.001$) and is indicative of equal covariance matrices. Jarvis (1990) notes that Box's M can be heavily influenced towards a lower value during the analysis of differing, small samples sizes (Jarvis 1990). Another measure of the perceived equality of covariance matrices that SPSS provides a Log Determinant value, which is a proportional measure of the volume of each multivariate ellipsoid that is defined by each group in multivariate space (see Table 8). Conceptually, the three-dimensional cloud conceived of for each group in Chapter 3 is, in this case, actually a six-dimensional ellipsoid as shown by the "rank" value in Table 8. Since each group is defined by a six-sided ellipsoid, the assumption of equal covariance would mean that each ellipsoid have roughly the same volume. The Log Determinant value, a relative measure of the volume of each ellipsoid, illustrates that in this case there does not seem to be any great disparity in ellipsoid values (as they are seemingly close together). Again, this alludes to equality in the covariance matrices. As both Box's M and the Log Determinant value both point equal covariance, then the differing samples sizes may not be that detrimental to the results and that this condition can be assumed to be met with a degree of certainty for this dataset.

The discriminant analysis undertaken was stepwise discriminate analysis, where each variable is added to the discriminant function during each step in order to further refine the final discriminant function. In this analysis, the following six elements were found to be the most useful in separating the various outcrops: bromine, chlorine, silicon, vanadium, sodium and magnesium. Conceptually, the discriminate function (for example using Fischer's linear discriminate functions as a template) defining each group can be idealized as (2):

$$A\ (\text{bromine}) + B\ (\text{chlorine}) + C\ (\text{silicon}) + D\ (\text{vanadium}) + E\ (\text{sodium}) + F\ (\text{magnesium}) + G \qquad \textbf{Equation 2}$$

Where *A, B, C, D, E* and *F* are constants generated by the discriminate process

Table 9 illustrates the discriminate results using Wilk's Lambda as the discriminator. Wilk's lambda is a measure of the distance separating the means or centroids of the ellipses formed in multivariate space by the discriminate function. Table 9 illustrates both original and cross-validated cases. Here, the original classified cases are the same cases (or samples) used to generate the discriminant function itself. This typically generates an overly optimistic estimate of the success of the classification. In this light, it is better to use one sample to compute the classification functions and another sample drawn from the same population to estimate the proportion classified. This process is called cross-validation and produces unbiased results. Put simply, each case is classified into a group according to the classification functions computed from all the data except the case being classified.

V. Results

i) All Geological Samples

The overall classification success (cross-validated) is very high at 72.6%. In comparison, five groups with samples added randomly would have a success rate of 20%. Specifically, the Peace Bridge samples had a success rate of 76.9%. The highest success rate was that of the Williamsville outcrop at 85.7%, with East Amherst having an overall success rate of 81.3% (both defined by Jarvis (1988, 1990)). However, the two other outcrops had a success rate that was somewhat disappointing – Williamsville at a 40%

success rate and the Port Colborne samples at 37.5%. In fact, the discriminant function defined by these samples misclassified 50% of the Port Colborne samples to the Peace Bridge outcrop, suggesting a significant degree of overlap geochemically. A deeper examination into the intermediate steps generated by SPSS during the discriminate building confirms this. SPSS generates a pairwise group comparison issuing *F*-statistics that describe which groups are most alike or different. Table 10 summarizes these results. Using these measures, the two most distant (or different) groups defined by the function are East Amherst and Peace Bridge with the highest Pairwise F-Statistic (42.261). Peace Bridge is also significantly different from Centerpointe (26.695) and Williamsville (16.954), which is not surprising, being farther way along the formation. Surprisingly, East Amherst is also markedly distant from the Port Colborne samples. However, a measure of the high misclassification rate of Port Colborne samples as originating from Peace Bridge is the F-statistic for the two groups, which is the lowest, identified at 4.727.

These distances can also be visualized (albeit in a curtailed manner) visually using a bivariate plot of the group centroids defined by the first two functions (defined as t the canonical discriminant functions) generated by the discriminate process. (See Figure 32) Typically, these first two functions account for the lion's share of the separation between all the defined groups. For example, if a sample had a first canonical variable (the horizontal axis) greater than zero and a second canonical variable (vertical axis) greater than one, it would likely belong to the group classified as three, or East Amherst. This map illustrates how the first two canonical variables (based upon bromine and sodium) clearly separated Ontario samples from outcrops eastwards along the formation as can be seen from the horizontal separation between the two loose clusters. However, this plot also illustrates the diffuse nature of the Port Colborne samples.

These results are promising in a number of ways. Firstly, the conclusions drawn by Jarvis (1988, 1990) would seem to be validated. Jarvis (1988, 1990) identified a facies shift in the Onondaga Formation that can be identified geochemically and be successfully utilized for the geochemical provenance of chert. These results illustrate that this facies shift extends into southern Ontario and that the quarry cut identified at the Peace Bridge site can be geochemically 'fingerprinted' as a result, with an overall success rate of 72.6%. This discriminant analysis illustrated that the two most distant (or different) groups defined by the discriminant function the East Amherst outcrop and the Peace Bridge quarry cut, which had the highest Pairwise F-Statistic (42.261). As well, the Peace Bridge outcrop can be distinguished from other outcrops to the east along the Formation, as Jarvis (1988, 1990) previously identified. However, the lack of stratigraphic control (or defined membership to specific Onondaga Formation members), this data might merely be illuminating changes in the vertical aspect of the Formation, as opposed to the spatial (or horizontal) aspects. Without a geochemcial profile among the members of the Formation itself, no concrete results can be stated, despite the potential for a degree of geochemical homogeneity between the differing members of the Formation itself

In order to classify the archaeological samples, the discriminate process was repeated with the addition of the archaeological (or unknown) samples, increasing the sample size to 137. These samples were classified as belonging to Peace Bridge (n=1), Port Colborne (n=4) and East Amherst (n=3). SPSS provides a casewise summary for each ungrouped sample that provides a probability (identified as posterior probability) that the samples belong to the groups as identified by the discriminate function. It also provides a probability for the next likely groups for membership with a corresponding probability. These results are summarized in Table 11.

Three samples were removed from the undiagnostic debitage of feature 73 from the Peace Bridge site itself. This feature was sampled in an attempt to ascertain if local (on-site) cherts were used for lithic production. The results of the discriminate analysis show that one of the samples belongs to the East Amherst outcrop (with a probability of 77.2%) with Port Colborne as the likely second candidate with a probability of 7.4%. The other two samples were classified to the Peace Bridge outcrop, with a likelihood of 40.2%. The second potential outcrop of membership is Port Colborne, with the respective probabilities of 39.6% and 33.5%. These results will be discussed in shortly.

ii) Iterations of Dataset – Port Colborne and Peace Bridge Pooled

In order to examine the shortcomings of the Port Colborne samples, a number of iterations were preformed on the dataset using discriminate analysis. In the first case, the entire dataset was re-processed with the Port Colborne samples pooled in together with the Peace Bridge samples. In other words, the discriminate function ascribed both of the Peace Bridge and Port Colborne data sets as stemming form the same origin, both stratigraphically and spatially. As the first analysis alluded to a high degree of overlap between the Peace Bridge and Port Colborne samples, this type of pooling could potentially render the remaining groups with stronger, more robust discriminate functions. Interestingly enough, this pooled did result in a stronger discrimination between Peace Bridge and the remaining outcrops. Table 12 shows that the pairwise group comparison between Peace Bridge and East Amherst. In this case, the value offered is 52.324, which is a higher degree of separation than achieved in the previous analysis. Table 13 summarizes the overall classification success (cross-validated) of this iteration, which was generally more successful than previously at 77.4%. In terms of assigning membership to the unknown cases, Table 14 illustrates the results from his analysis.

In this case, all of the archaeological samples were assigned to Peace Bridge or East Amherst with a much higher probability that the previous case. The samples from feature 73 were again assigned to both East Amherst (n=2) and Peace Bridge (n=1) with higher posterior probabilities in the group of highest membership. However, all of the off-site projectile point samples were re-assigned to either Peace Bridge (n=4) or East Amherst (n=1) with higher posterior probabilities in every case.

iii) Iterations of Dataset – Port Colborne and Peace Bridge only

As a last example, one more discriminate analysis was performed solely upon the Peace Bridge and Port Colborne sample. The strategy for this iteration was to see if the trends inherent in these two sample sets alone might shed some light upon the future potential for the separation of these outcrops in future studies given a larger dataset for the Port Colborne outcrop. Table 15 illustrates the results of this analysis. The overall success rate of the classification of only the Peace Bridge and Port Colborne outcrops is 85.1%. This is mildly surprising, as the pairwise group comparison F-statistic for these two groups is only 14.650, a comparatively small amount relative to the previous analyses. However, even given this relatively small degree of separation, all of the off-site samples (se Table 16) were assigned to the Peace Bridge outcrop. The lowest probability in these assignments was 77%, identified for the sample removed from the Greenwood (AlGv-148) site.

Discussion

These iterations illustrate both the sensitivity of the discriminant procedure and its shortcomings. The disadvantage of discriminant analysis is its requirement to assign unknown samples to the most similar sample group for which it has data. In essence, it cannot draw a 'line-in the-sand' where it can reject unknowns into an unknown group assignment. However, these iterations allude to a number of points which are of significance for future studies. When the Port Colborne samples were pooled with the Peace Bridge sample, the resulting analysis showed a strengthened separation between the Peace Bridge and East Amherst outcrops. Despite the intuitive notion that pooled samples would result in stronger discriminate function, the results of pooling undeniably illustrate a higher success rate for the resulting discriminant function. As well, the singular study of only the Peace Bridge and Port Colborne samples illustrate the potential for separation (given the 85% success rate during cross-validation) despite the comparatively low pairwise group statistic measure. However, these results must be taken as speculation only, as the small sample size of the Port Colborne samples is likely under-representative of the outcrop as a whole. As well, although the modern samples used for this study are representative of the archaeological chert source area in Port Colborne, in terms of geological provenience these samples remain unassigned to a specific member of the Onondaga Formation. In this light, the potential for separation described above may account for stratigraphic differences and not spatial differences. In tandem, these results point to the notion that the inclusion of the Port Colborne samples weakened the overall discriminant potential for all outcrops; its pooling with Peace Bridge strengthened the separation of Peace Bridge samples from those to its next closet neighbor to the east. Fortunately, these results also illustrate the potential for the separation of the Peace Bridge and Port Colborne outcrops, as can be seen from the success of the rate of classification of this iteration.

VI. Conclusion

i. Provenance Analysis and the Onondaga Formation

This statistical treatment offered a number of observations, although comprehensive results were elusive. First and foremost, it must be pointed out the all of the elemental variables used for both the bivariate plot and discriminate analysis, ironically, were the most mobile elements susceptible to chemical enrichment and leaching through weathering. In this light, all of the above geochemical analysis must be contemplated with the firm understanding that the very elements used to 'fingerprint' cherts along the Onondaga Formation have to potential to be altered over time. Despite this sobering thought, at first glance, the data point to a previously identified facies shift that extends west along the Onondaga Formation past the Peace Bridge site. Ideally, it would seem that the extension of this phenomenon would provide a geochemical signature to the outcrop at the Peace Bridge site, allowing for its provenance (or separation from other outcrops to the east) using geochemical techniques. However, the vertical geochemical relationship between different members of the Onondaga Formation could not be addressed within the scope of this study, and therefore these results must be observed with skepticism. The analysis of the Port Colborne samples illustrated that this western outcrop, if represented accurately, has some degree of overlap with the Peace

Bridge samples. As well, pairwise group comparison showed that there is little difference between the Peace Bridge and Port Colborne samples. However, this does not necessarily mean that Port Colborne is geochemically undistinguishable. As the investigation of Port Colborne was undertaken at such a small scale, there exist a number of factors can be responsible for this amount of overlap. Most salient is the unknown association between the modern cobble and its source member in the Onondaga Formation itself. It is possible that the modern cobble stems from the Edgecliff member and is geochemically similar to all cherts found throughout this member. However, the small sample size (n=9) that was used to define the Port Colborne outcrop is unrepresentative of the source area itself, and perhaps of its original stratigraphic locale in general in this portion of the Onondaga Formation. This small sample size seem justified at the time of undertaking as the scope of this project was exploratory in nature and funding was limited, but the results illustrate that these samples do not characterize this portion of the formation with assurance. As well, the nature of the sampling might have affected the final classification as well. The bivariate plots in Figures 29-33 illustrate the diffuse nature of the Port Colborne samples. The samples used, as previously discussed, were a mix of archaeological (stemming form the Late Archaic component of the Ansari site) and modern. Specifically, the modern samples (identified as "Port Colborne" in Appendix 1) were removed from a chert nodule found on the shore of Lake Erie. Upon inspection of the trace elemental concentrations, these samples seemingly have elevated levels of sodium, vanadium, barium, strontium, iodine, calcium and copper with relatively low values of calcium. These concentrations can potentially be attributed to chemical weathering of the chert, which has been addressed by other researchers (Jarvis 1988, Luedtke 1987). Luedtke (1978) has suggested that chert flakes are especially vulnerable due to their small size and extreme thinness (Luedtke 1978: 418-420). Jarvis (1988) has noted that the levels of sodium in archaeological samples were lower than levels found in geological samples due to chemical leaching (Jarvis 1988). However, as stated previously, these differences can also be attributed to the possibility that this cobble stems from a different member of the Onondaga Formation than the archaeological samples, despite their proximity.

With this said, a more ideal strategy to characterize the Port Colborne cherts in the future would not only include more samples in an attempt to glean a representative geochemical profile the locale through geochemcial differentiation of the remaining chert bearing members present in this portion of the Onondaga Formation – this type of stratigraphic geochemcial resolution is key in geochemically quantifying the degree of variation present. As well, any future study should be careful to use only flakes removed from interior, unweathered portions in an optimistic attempt to reduce the effects of chemical enrichment/leaching which hinder subsequent statistical treatments of the data.

ii. *Behavioral Implications- Lithic procurement at the Peace Bridge Site*

a) Lithic procurement and use on the Peace Bridge site

These results stemming from the archaeological samples have some potential behavioral implications. The on-site feature (Feature 73) samples had been interpreted as an area where bifacial blanks were reduced (Robertson et al. 1997). The above analysis provides evidence that some portion of the chert gleaned from this feature stemmed from the other side of the Niagara River, as can be observed by the regular outcome in both iterations of the discriminant function using all geological samples. Although these geochemical differences could be potentially ascribed to variations in the vertical member of origin, the pragmatic reality is that the only member represented in the Peace Bridge quarry is the Edgecliff member (von Bitter pers.comm..). In this light, despite the potential for the geochemical differences illuminated here to be attributed to stratigraphic origin, the members eluded to only exist in other locales along the Formation removed from the Peace Bridge site. In this light, the potential for an off-site sample to be present on the Peace bridge site remains significant. The presence of chert stemming from other outcrops found in on-site contexts eludes to the notion that chert procurement and use was not limited to the immediate area of the Peace Bridge quarry itself. In any event, the presence of chert from across the Niagara River would have to be explained in terms of personal transport or exchange. If this result is taken as accurate, then it follows that the intuitive significance of the Peace Bridge site operating as more than an area of procurement during the Late Archaic is supported. However, it is impossible to know without dating if the quarry area was in operation when the deposition of Feature 73 took place, and perhaps the most accessible chert source then was indeed across the Niagara River. The assignment of these samples to sources both on and off site suggests a broad chert procurement strategy where lithic procurement was undertaken using multiple sources. This is in keeping with the broad resource use-base conceived of during the Archaic as discussed earlier.

iii. Behavioral Implications - Off-site Archaeological Samples

The outcome of the analysis of these samples is speculative at best. Both iterations using the geological samples rendered differing outcrops of origins for these samples. These differing ascriptions of origin have significant behavioral implications, and without a degree of precision in the results, only general conclusions can be made.

However, in the second iteration using pooled Port Colborne and Peace Bridge samples, the posterior probabilities were much higher than in the unpooled analysis. Despite any repetition of the results, the most significant observation gleaned form these iterations is the notion that in both cases the archaeological samples have been identified as having come from the western portion of the escarpment, where the potential for both stratigraphic and spatial geochemical differences are possible. This has some interesting implications concerning late Archaic behavior. All of the off-site archaeological samples were found in generalized lithic scatters on the north shore of Lake Ontario. These sites are distant from the eastern portion of the Onondaga Formation and multiple watersheds have to be traversed to reach these locales. In fact, these areas are likely part of the upland hunting grounds that are believed to have been frequented by the hunter-gatherers of the Late Archaic. This study illustrates that none of the archaeological samples were ascribed to outcrops east of the East Amherst outcrop. To some degree, this seems unspectacular if hunter-gatherer behavior can be modeled using optimal foraging theory – the western portion of the formation is closer to the selected sites than the eastern half. However, a number of questions can be posited given a northern gradient for the movement of chert from the western portion of the formation, including:

1) How far east on the north shore of the Lake Ontario are these 'western' cherts observed?
2) Is the lack of cherts form the 'eastern' half of a formation an exhibit of territorialism during the Late Archaic?
3) Given that cherts form this portion of the formation are traveling at least as far as the north shore of Lake Ontario, is there a inherent quality of embodied by the chert (its quality as a raw material, grafted symbolic meaning or its place of origin) that demands its procurement over such distances or is its procurement a result of an embedded procurement pattern?

However, the pragmatic reality of the results is that the failure of the Port Colborne outcrop to be geochemically distinct in the confines of this study severely curtails any off-site conclusions concerning the distributional analysis of Onondaga chert in the greater context of southern Ontario. In fact, to better illustrate this point, Figure 33 is offered as a revision of the plots of the canonical discriminate functions. This figure, in which all of the geological samples were used, displays the locations of the unknown samples. As can be seen from the loose cluster, the off-site samples are, to some degree, isolated from the other clusters defined by the geological outcrops. Given this evidence, it seems possible that either (a) the outcrop from which these samples originate has not been identified (perhaps an outcrop farther west?) or (b) chemical weathering of the samples has altered the geochemical signatures which in turn has isolated them in terms of group membership using discriminant analysis or (c) these differences can be attributed to differing stratigraphic origins of the archaeological along Onondaga Formation. The latter case is easily envisioned when one compares even the most basic color descriptions of the off-site samples (typically dark gray to light gray cherts) with those of the on-site cherts (very dark gray to gray cherts) (see Appendix 2). However, on a promising note, the precision of the two samples removed from points found on the Greenwood (AlGv-148) site point to the potential success of a more rigorous research regime.

However, a number of actions can be undertaken to alleviate these issues

(1) It is possible that the sampling of the off-site samples themselves is actually unrepresentative of the points themselves. The pressure flaking used to remove the samples (even though a number of flakes were removed from around the circumference of the point in order to achieve an acceptable mass) likely removed highly weathered portions due to the extreme thinness. At the time of sampling, this was the intention, as this technique would impact the artifact as little as possible. However, in retrospect a

more robust sampling of these points, on order to sample the unweathered portions, might prove significant.

(2) As stated before, the weakness of discriminant analysis is the fact that it cannot assign unknowns to unknown groups. In this light another statistical procedure might prove beneficial, such as Principal Components Analysis or other previously mentioned analyses.

(3) This study rested upon the pooling of data gleaned from this study and that of Jarvis (1988, 1990). Fortunately, the nature of the standards used in the processing of the samples allowed for a relatively high number of elements to be utilized for the subsequent statistical analysis. However, data still had to be removed in order to achieve a homogenous dataset. As the discriminate analysis had fewer vectors in which to build a discriminant function, the resulting analysis was potentially not as efficient as possible. Future studies might be rendered more successful if the samples are processed with a longer reactor time, the outcome being that more time in the reactor 'activates' elements with longer half-lives which could be detected and measured. These elements could potentially lend themselves to statistical analyses. In short, the success of a discriminant analysis is directly related to the strength and number of vectors it embodies.

(4) A more controlled and rigorous sampling strategy must be employed in order to quantify geochemcial differences between stratigraphic members of the Onondaga Formation itself. The 'vertical' geochemical variation must be understood before spatial (or 'horizontal') differences can be quantified and relied upon to describe source areas along the formation, otherwise both vectors can potentially account for the observed differences.

(5) A suite of geochemical elements that are less susceptible to chemical weathering should be chosen and analyzed for any subsequent analysis. Less mobile elements are more likely to be representative of the relationship between artifact and source despite environmental and temporal alterations to both.

CHAPTER VII: CONCLUSIONS

I. Introduction

The data from the Peace Bridge (AfGr-9) site in the town of Fort, Erie, Ontario and previous studies of the region allowed for an examination of the spatial movement of chert derived from the Onondaga Formation in broader regional contexts of the Archaic period in the Niagara peninsula. The Peace Bridge site incorporates a precontact quarry with substantial evidence of lithic reduction activities. As such, this site is an example of an intensive locale for lithic exploitation. Despite the relatively small proportion excavated, the site has shown evidence of finished stone tools, complex feature staining that is indicative of Genesee period living floors or structures, a number of subsequent Transitional Woodland house structures, and a three thousand year mortuary tradition.

It seems possible that the site functioned as a central manufacturing and distribution center of finished tools, which, along with preforms and unmodified raw material, were circulated inland to other communities. Genesee Period points or preforms made from Onondaga chert have been found beyond the immediate vicinity of Onondaga source area, where the Peace Bridge site is situated. This raises a number of questions as to the regional organization of lithic procurement and/or exchange during the Late Archaic.

This study used induced neutron activation analysis (INAA) as a technique to ascribe provenance to Onondaga chert derived from the Peace Bridge quarry. This technique was, in turn, used on off-site archaeological samples in an attempt to assign provenance to either the Peace Bridge site or any of the geochemically described outcrops previously defined on the Onondaga Formation.

The following questions were addressed systematically by carrying out the following requisite analyses:

(1) Induced Neutron Activation Analysis (INAA) was performed on a suite of lithic samples derived from the precontact Onondaga chert quarry within the Peace Bridge Site in order to ascertain if geochemical patterning, illuminated in previous studies, continued into the southern Ontario portion of the Onondaga escarpment, paving the way for geochemical provenance techniques to be used to be provenance lithics to the Peace Bridge site

(2) Samples derived from on-site contexts were assayed to address the nature of on-site lithic procurement and use during the Late Archaic Genesee Period occupation of the site

(3) Samples derived from Late Archaic Genesee off-site contexts were examined to ascertain if material from off-site contexts could be ascribed to the Peace Bridge quarry

II. Summary of Results

In order to address the specific and general hypotheses initially proposed for this study, the results of each of the steps addressed above will be examined in a stepwise manner before any holistic conclusions are made.

Can the Peace bridge quarry outcrop be geochemcially distinguished?

This question, which is a key component of the research design, was addressed with a degree of reservation in this analysis. The combination of the INAA data gleaned by Jarvis (1988, 1990) with the comprehensive data of the Peace Bridge quarry cut demonstrated that the facies shift, a geochemcial gradient inherent in the Onondaga Formation identified by Jarvis (1988, 1990), continues into the Peace Bridge portion of the Formation. However, the data gleaned by Jarvis (1988, 1990) failed to provide an adequate geochemical comparison between different chert bearing members of the Onondaga Formation itself. In this light, the geochemical gradient identified by Jarvis (1988, 1990) might reflect not only a spatial (or 'horizontal') vector, but also represent a stratigraphic (or 'vertical') variation as well. Without an understanding of the geochemical relationship between the different members exposed in the western half of the formation, any observed geochemical gradient can potentially be attributed to either stratigraphic or spatial differences, or a combination of both. This inability in both studies to rule out a vertical gradient severely curtails any potential of an identified and isolated spatial geochemical gradient that can be used for the geochemical provenience of chert. The analysis of INAA data by bivariate plot analysis illustrated that bromine, sodium, chlorine, calcium and magnesium were highly correlated elements that could be potentially used to distinguish outcrops along this continuous formation. However, it was also observed that chemical weathering (either enrichment or leaching) altered significantly the elemental concentrations on exposed cherts surfaces. Ironically, all of the elements quantified and used in this study (both in bivariate plots and in the subsequent discriminate analysis) were found to be mobile and susceptible to chemical weathering. In tandem, the lack of a geochemical profile between members of the Onondaga Formation and the measurement and use of more reactive and mobile elements in constructing statistical relationships between different portions of the Onondaga Formation render any comprehensive construction of a geochemical provenience within the bounds of this study remote. The reasoning is simple: there are too many potential mechanisms that can account for the observed geochemical trend that this study (or others before) has not ruled out. Specifically, the potential for stratigraphic variation and chemical contamination/alteration cannot be ruled out in lieu of a spatial variation. However, multivariate statistical analysis illustrated that geochemical trace element analysis can potentially be a feasible technique for the provenance of Onondaga chert from the Peace Bridge quarry cut, and the Onondaga Formation as a whole if the above concerns are ruled out as potential causes. The relatively high cross-validated success rate of 72.6% using multivariate discriminate analysis confirms this notion. Of particular note is the observed high rate of success despite the necessary paring of the dataset to common measured elements between the two datasets (only nine were utilized in the final analysis). In this light, it seems likely that any future study that can harness a greater array of constituent elemental data will only add strength to the distinctions observed here.

However, these results only attest to the success of potentially distinguishing the Peace Bridge outcrop form those further to the east (East Amherst, Williamsville and Centerpointe). Any study that aims to address a broad distributional analysis of Onondaga chert must be able to provenance the Onondaga Formation in a holistic manner. In this light, the Peace Bridge outcrop must also be geochemcially distinguishable from outcrops to the west as well. The results from the samples derived from a more westerly outcrop (Port Colborne and the Ansari site) are somewhat inconclusive. First and foremost was the observation that there is some degree of geochemcial overlap with the Peace Bridge samples. The first reaction to this observation is to conclude that either the observed geochemical facies shift diminishes somewhere near the western margin of the Peace Bridge outcrop, as would be necessary to observe a geochemical homogeneity over such a long portion of the Formation or that the Port Colborne cobble stems from the same member of origin as cherts from peace Bridge, namely the Edgecliff member. A deeper examination of the data indicates that the inconclusive results of the Port Colborne samples are seemingly due to sample error and the 'unrepresentativenes' of the Port Colborne samples to that portion of the Onondaga Formation, and not a comprehensive lack of a geochemical gradient in the Onondaga Formation itself. The potential for geochemical separation of the Peace Bridge outcrops with more western portions is elusive given the results of a singular study of only the Peace Bridge and Port Colborne samples. The results from this analysis illustrate an 85% success rate during cross-validation, despite a comparatively low pairwise group statistic measure.

The poor results from the Port Colborne samples can be attributed to a number of factors, the first and foremost of which was the small sample size used to characterize the Port Colborne portion of the Onondaga Formation (n=9). This small sample size seem justified at the time of undertaking, as the scope of this project was exploratory in nature and funding was limited, but the results illustrate that these samples do not characterize this portion of the formation with assurance. As well, the nature of the sampling likely affected the final results. The samples used, as previously discussed, were derived from archaeological and modern contexts. Upon inspection, the modern, unprovenanced samples demonstrated elevated levels of sodium, vanadium, barium, strontium, iodine, calcium and copper with relatively low values of calcium. It is possible that the modern sample represents a different member of the Onondaga Formation than the chert used in the archaeological samples. As well, all of the samples were weathered and geochemically altered. These factors point to an overall 'unrepresentativness', both spatially and stratigraphically, of the Port Colborne samples to the Port Colborne portion of the Onondaga Formation. As well, the small sample size and the sampling technique used rendered the subsequent results more suspect.

In conclusion, it can be demonstrated that the Peace Bridge outcrop can potentially be geochemically separable from outcrops to the east. However, the results offered by this study are inconclusive in terms of a comprehensive observation of a more western, geochemical gradient identified as a facies shift. Although the failure of these samples to provide a geochemical provenance technique for the identification of westerly outcrops hampered the resulting conclusions, it did not render this study completely unsuccessful, as will be discussed below.

Were on-site archeological samples derived from the local (on-site) mining cut?

These results stemming from the archaeological samples afforded some interesting results. The on-site feature (Feature 73) samples (n=3) had been interpreted as an area where bifacial blanks were reduced (Robertson et al. 1997). Despite the poor representation of the Port Colborne locale, this analysis provides evidence that some portion of the chert gleaned from this feature likely stemmed from *both* on-site and off-site contexts. During the course of multivariate analysis, the repetitive assignment of a portion of these samples to the East Amherst locale of the Formation, on other side of the Niagara River, points to the likely origin of some of these samples. In particular, the pooling of the Peace Bridge and Port Colborne samples, which in essence formed a discriminant category for all outcrops west of the East Amherst outcrop, afforded the same result: that these samples are representative of on- and off-site origins.

Were off-site archeological samples derived from the local (on-site) mining cut?

It is in the analysis of these samples that the lack of a Port Colborne geochemical signature is severely felt. The outcome of the analysis of these samples is speculative at best. Multivariate analysis, in the first instance using all geological samples, ascribed these samples to either the Port Colborne or East Amherst locales. However, given the problems associated with Port Colborne geochemical signature, these results cannot be stated with assurance. However, the second iteration using pooled Port Colborne and Peace Bridge samples provided some interesting results. Here, it must be restated that the conceptual notion behind the pooling of the Peace Bridge and Port Colborne samples was to provide membership criteria for all locales west of (and including) the Peace Bridge mining cut, thereby alleviating to some degree the problems associated with the Port Colborne samples. This iteration assigned all of the off-site samples to either the Peace Bridge or East Amherst locales, with probabilities ranging from 60%-96%. These results are promising given the robust sampling of both of these locales, but the lack of repetition across differing manipulations of the dataset demand that these results be taken as tentative. Again, these wavering assignments can be attributed to a large extent to the weak Port Colborne geochemical signature and the lack of a stratigraphic geochemical profile.

The most significant observation gleaned form these iterations are that all of the off-site archaeological samples were assigned to locales on the western portion of the Formation despite any repetition of results. More importantly, the assurance of the assignments from the results of the pooled Port Colborne and Peace Bridge samples point to the potential strength of this technique in ascribing provenance to off-site archaeological samples.

Although the data suggests that a portion of the off-site samples can be ascribed to the immediate area surrounding the Peace Bridge site, the data does not allow for any provenance assignment with assurance to the Peace Bridge mining area. In this light, the data is inconclusive due to the lack of a robust geochemical signature for the Port Colborne outcrop.

III. Implications for hypothesis

This stepwise treatment of the results of this nested research strategy can now be utilized to address the initial hypotheses stated at the onset of this investigation. These will be addressed in a similar case basis (as above).

> <u>Hypothesis</u>: *If culturally modified lithics from inter-site contexts can be sourced to the component quarry cut, then some degree of lithic reduction activities occurred on-site. The null hypotheses is that lithic material found on site is derived from sources other than the identified component quarry cut or the provenance methodology employed in this study is not applicable to the Peace Bridge quarry.*

The likely presence of chert derived from both on-site and off-site contexts found in on-site contexts indicates that chert procurement and use were not limited to the immediate area of the Peace Bridge quarry itself.

In this light, this hypothesis was correct, that some degree of lithic reduction activities occurred on-site. However, the presence of chert from across the Niagara River has to be explained in terms of personal transport or exchange. In short, if this result is taken as accurate, then it follows that the Peace Bridge site operated as more than an area of procurement during the Late Archaic. These results suggest that a broader chert procurement strategy was utilized during the Late Archaic, where lithics were procured from multiple sources. This is in keeping with the broad resource use-base developed of during the Archaic as discussed earlier.

> <u>Hypothesis:</u> *If culturally modified lithic material sourced to the Peace Bridge quarry are identified in regional contexts beyond the immediate surroundings of the Peace Bridge site, then this identified movement of culturally modified lithic material into*

off-site contexts must be explained in behavioral terms, including potential inter-band exchange, regional occupation areas (band territories) or through differential access to raw material source. The null hypothesis that that culturally modified lithic material is found only in local, on-site contexts

The evidence supports the notion that the western portion of the Onondaga Escarpment was a lithic procurement area for Late Archaic peoples that frequented the north shore of Lake Ontario. However, despite an observed northern vector for the movement of Onondaga chert from these western locales, the lack of a comprehensive geochemical signature for outcrops west of the Peace Bridge site precludes any ascription with assurance of off-site samples to the Peace Bridge site itself. This is not to state that this hypothesis is untestable, as the results afforded by this study demonstrate that this question can be addresses. However, this hypothesis cannot be addressed with any conviction within the scope of this study.

Despite the inability of this study to identify with confidence the movement of material derived from the Peace Bridge site, this investigation has shown with a degree of confidence that the Peace Bridge mining cut is open to provenance study using geochemical techniques. Ironically, the demonstration of the success of this technique (as applied to the Onondaga Formation) was illustrated by identification of lithic material from *off-site* contexts that were present within the boundaries of the Peace Bridge site. These results have some interesting implications with respect to Late Archaic lithic industries. All of the off-site archaeological samples were found in generalized lithic scatters on the north shore of Lake Ontario. These sites are distant from the eastern portion of the Onondaga Formation and multiple watersheds have to be traversed to in order to reach these localities. This study illustrates that none of the archaeological samples were ascribed to outcrops east of the East Amherst outcrop. To some degree, this seems unspectacular if hunter-gatherer behavior is optimal – the western portion of the formation is closer to the selected sites than the eastern half.

However, this study identified a northern gradient for the movement of chert from the western portion of the Onondaga Formation. The implications of this result have both methodological and behavioral significance. Nearly one half of this broad spanning geological formation, which is known to have numerous chert outcrops, is unrepresented in the samples used in this study. As well, the destination of the cherts derived from the Peace Bridge outcrop remains concealed – why? It is certainly possible that these eastern cherts have been found in southern Ontario contexts but were unsampled here. The same answer can be given for the lack of identified Peace Bridge cherts. On the other hand, this observation can also be attributed to issues of differential lithic access and territoriality. It is likely, given the wide spanning geographic area over which material from this period is found, that these trends may have been operating in some form during the Broad Point Late Archaic. Although no earlier tradition has yet to be identified, grassroots participation in regional exchange networks must have been the norm if the ensuing well-structured, far-flung and institutionalized exchange networks are to be explained. In the past, questions such as these could not previously be addressed, as a larger scheme for constructing a distributional analysis based upon geochemical provenance could not be undertaken. In other words, investigators did not have the rights tools, nor was it known if any tools existed, which could help address this question in a southern Ontario context. It is in this light that this study was the most promising, as it paves the way for the refinement of a potentially successful technique for the ascription of provenance to lithic artifacts derived form Onondaga Formation. If used properly, the potential exists for the construction of a broad spatial analysis of Onondaga chert, in which provenance can be assigned not only to the destination, but to source 'regions' defined on the Onondaga Formation. This form of distributional examination is the first crucial step to any of the analyses described previously. All distributional studies rely upon the ability to discern source and destination locales spatially. This study provides an ideal, if not wholly refined, technique for such an undertaking, and in turn paves the way for a more comprehensive study of the Peace Bridge site and its role in Late Archaic procurement and exchange patterns.

IV. Implications for future studies

This study illustrates that this technique can be successful when a large dataset is at hand. In this light, the success of this examination is in no small part due to the pooling of data gleaned by Jarvis (1988, 1990). Any future geochemical study of intra-outcrop variation in the Onondaga Formation would be well advised to assure that datasets of multiple studies could be pooled into a larger, holistic database. As well, greater resolution is likely attainable if more outcrops along the length of the Onondaga Formation are sampled comprehensively. As well, a key requirement is the creation of a stratigraphic geochemical profile for these sampled outcrops in order to rule out vertical geochemcial variation. A greater investment in the further characterization of cherts from known locales will only strengthen the resulting provenance ascriptions.

However, this is not the only lesson learned from this investigation. The following should be undertaken:

(i) A more controlled and rigorous sampling strategy must be employed in order to quantify geochemcial differences between stratigraphic members of the Onondaga Formation itself. The 'vertical' geochemical variation must be understood before spatial (or 'horizontal') differences can be quantified and relied upon to describe source areas along the formation, otherwise both vectors can potentially account for the observed geochemical differences.

(ii) A suite of geochemical elements that are less susceptible to chemical weathering should be chosen and analyzed for any subsequent analysis. Less mobile elements are more likely to be representative of the relationship between artifact and source despite environmental and temporal alterations to both. In this light, a better understanding of the mineralogical makeup and potential contaminants of the Onondaga Formation would be of great benefit.

(iii) Sampling and reduction techniques should take care to include more than highly weathered, thin flakes removed from exterior surfaces. Unweathered, interior surfaces will likely provide a more unadulterated, representative sample. However, this consideration must be balanced against the destructive nature of the technique.

(iv) Although the statistical treatments used in this study were proven relatively successful in this study, the fact remains that it can be dangerous to propose broad sweeping behavioral generalizations on the results of a single, statistical line or evidence. This is particularly true of discriminant analysis, as it cannot assign unknowns to unknown groups. Discriminant analysis can render the results that are somewhat misleading if the underlying assumptions are not thoroughly understood. In short, it can be a dangerous tool if used in a recipe-like manner. In this light, multiple statistical procedures might prove beneficial, such as Principal Components Analysis, Analysis of Variance, Correspondence Analysis, or other applicable statistical treatments could be used in concert. This notion remains true for the ascription of provenance to an artifact as well. Multiple lines of evidence, such as visual examination, thin-sectioning and palynological studies can also be used in concert to reduce uncertainty in the final ascription of provenance.

(v) Future studies might be rendered more successful if the samples are processed with a longer reactor time, the outcome being that more time in the reactor 'activates' elements with longer half-lives which could be detected and measured. A larger suite of elements under study could potentially lend themselves to more robust statistical analyses, as the success of a discriminant analysis is directly related to the strength and number of vectors it embodies.

(vi) Specifically, with respect to this study, the need for a more appropriate sampling of cherts from the Port Colborne locale is pressing. A better representation of this locale geochemcially will render the potential results much more successful and applicable, for the Peace Bridge site and within a broader regional context. Such a study is currently being planned.

As stated previously, studies of artifact movement across space expand upon previous diffusion research by attempting to establish both the existence of prehistoric inter-regional contact and by specifying the mechanisms of this interaction (Earle and Ericson 1977). Regardless of the mechanism, goods and/or information are exchanged as a result of personal interactions. There exists a number of behaviors and types of relationships that would be expected to occur in hunting and gathering societies (either individually or in concert) that account for the movement of goods and the resultant archaeological patterning: obligatory sharing and gift giving founded on ties of real or ascribed kinship, fusion of settlement and subsistence patterns, the payment of bride wealth in conjunction with marriage rules, the establishment of personal trading partners, and the practice of redistributing goods as part of communal feasting or rituals (Sahlins 1972, Stewart 1994). The ethnographic records illustrates that issues surrounding inter-regional contact are rooted in notions of band territoriality. Any exchange networks derived from these phenomena would generally be informal (Stewart 1994).

Pre-contact hunter-gatherers of the Late Archaic did not exist in isolation, and were likely a component of larger groups that gathered together at periodic intervals. These meetings were likely not purely the meeting of groups, but rather as meetings of individuals who happen to be members of a number of different social groups or spheres. Such meetings are likely common among hunter-gatherers, where the 'smaller bands that constitute hunter-gatherer society meet together for talk, for ritual, for exchange, to prepare for or conduct the exchange of marriage partners, in short to conduct a very full range of human interactions' (Renfrew 1992: 9). In this light, the full range of interactions is more aptly characterized as one of 'communication' rather than of 'exchange', since the underlying motivation and functional role of the interactions may not primarily be the acquisition of material goods (Renfrew 1992)

The results of this study illuminate the potential for the Peace Bridge site, and its component quarry as a locale for such a wide degree of activities. This study has provided a powerful technique that can be used to describe lithics distributions stemming from the Onondaga Formation with a resolution that has been unattainable in previous studies. The ability to describe such a regional distribution is a key component for any holistic spatial or exchange analysis within a regional context. The results show that some degree of lithic reduction activities occurred on-site, and that the presence of chert from across the Niagara River has to be explained in terms of personal transport or exchange. As well, the evidence supports the idea that the western portion of the Onondaga Escarpment was a lithic procurement area for Late Archaic peoples that frequented the north shore of Lake Ontario. This evidence points to the notion that that exploitation of quarry sites or raw material resources may have been integrated or "embedded" within the overall subsistence system (Binford 1979, Johnson 1984, Robertson and Williamson 2000). In other words, rather than lithic procurement being the sole object of travel to a known source area, lithic procurement activities were likely to have been carried out in tandem with the exploitation of local faunal and plant resources. It is possible that the Late Archaic peoples of the Niagara Peninsula likely treated quarries 'like every other location, carrying on routine subsistence activities while undertaking stone procurement (Daniel Jr. 2001, Robertson and Williamson 2000). Archaic peoples employed an adaptive strategy that balanced the need for tool stone that was predictable, but limited in occurrence, with the more widely available but less predictable need for subsistence sources' (Daniel Jr. 2001:261). The end result was a settlement configuration that included access to high-quality knappable stone sources while concomitantly fulfilling subsistence needs.

The spatial distribution of cultural material as observed in the archaeological record is the product of *both* the organizational structure driving the movement of material and the geographical distribution of the artifacts themselves. However, the spatial distribution of cultural material never represents a situation at a single point in time. Rather, it is a palimpsest of activities over time (Renfrew 1984). As well, there also exists a seemingly unsurpassable dilemma in exchange studies, as Hodder (1992) succinctly states: "it is simply impossible to test whether [precontact] artifacts moved from source to destination by exchange from person to person, or whether, on the other hand, individuals went directly to the source" (Hodder 1992: 124). As well, it is certainly conceivable that archaeological artifacts arrived at their destination through mechanisms wholly unrelated to any exchange system in place. Although ethnographic studies certainly show that material exchange could take place, and likely did in the past, it is difficult to observe this archaeologically.

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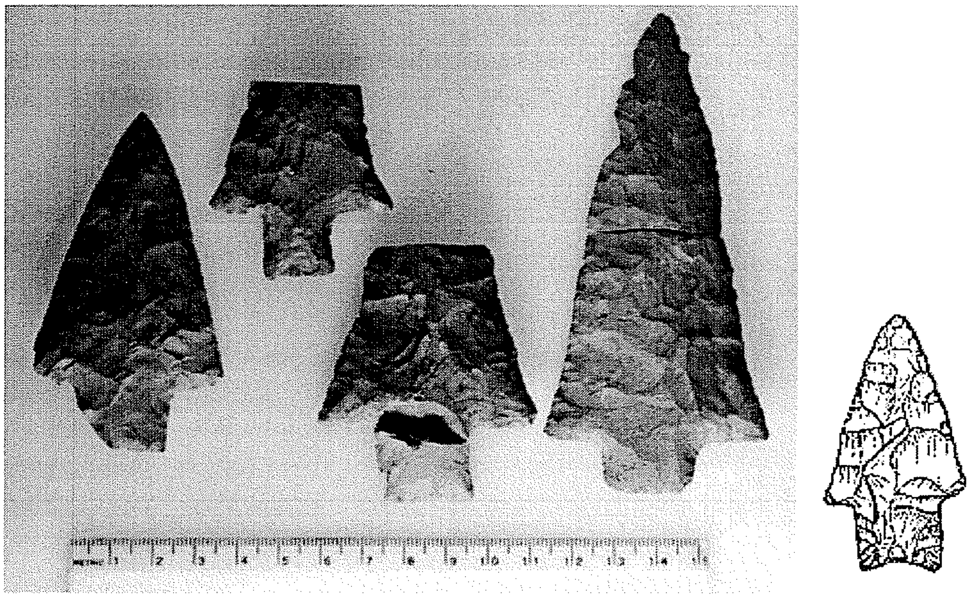


Figure 1: Genesee Points from London, Ontario, Canada (Ontario Archaeological Society (http://www.ssc.uwo.ca/assoc/oas/points/genesee.html) 2003; Kenyon 1981- Photo: J. Keron)

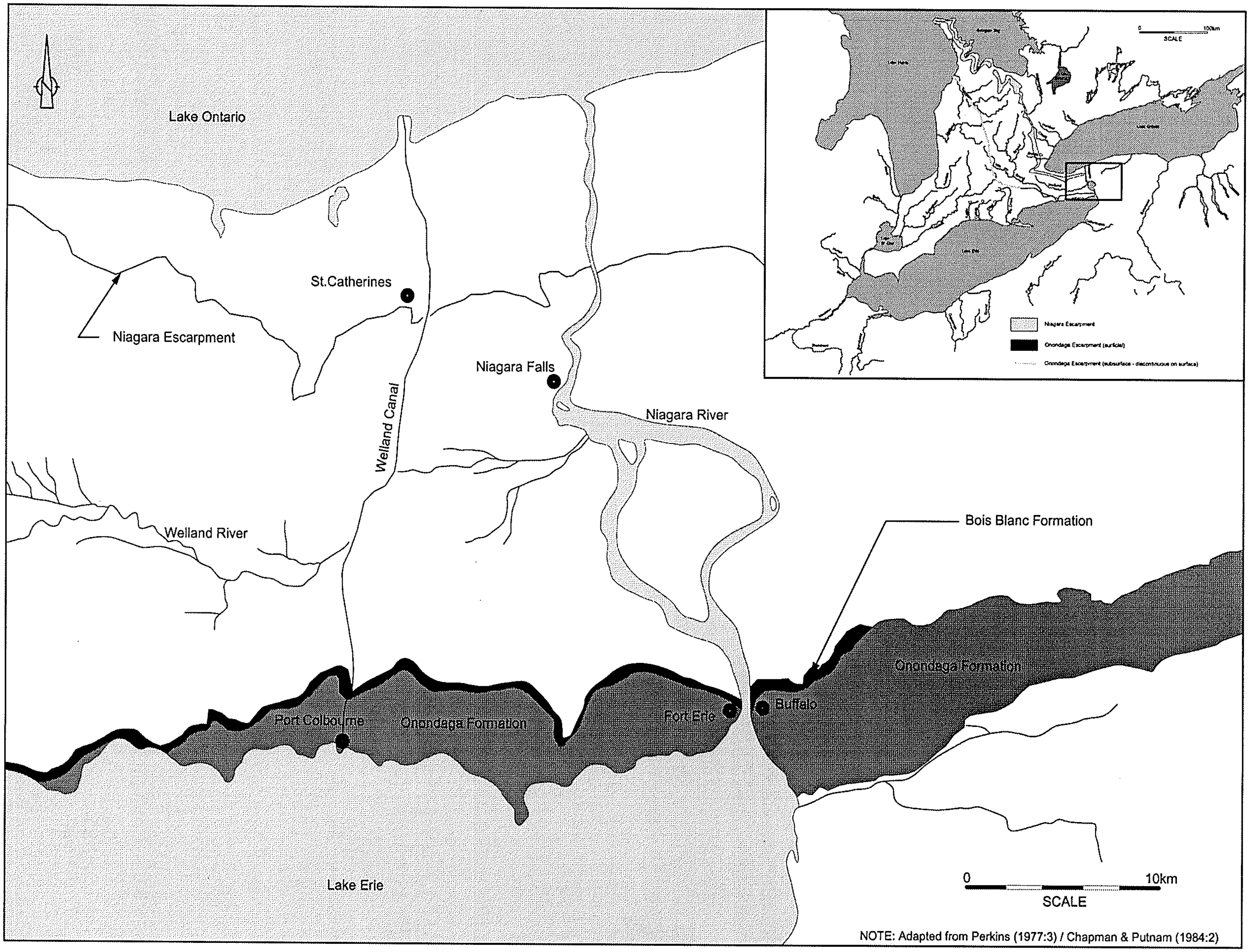


Figure 2: The Onondaga Geological Formation

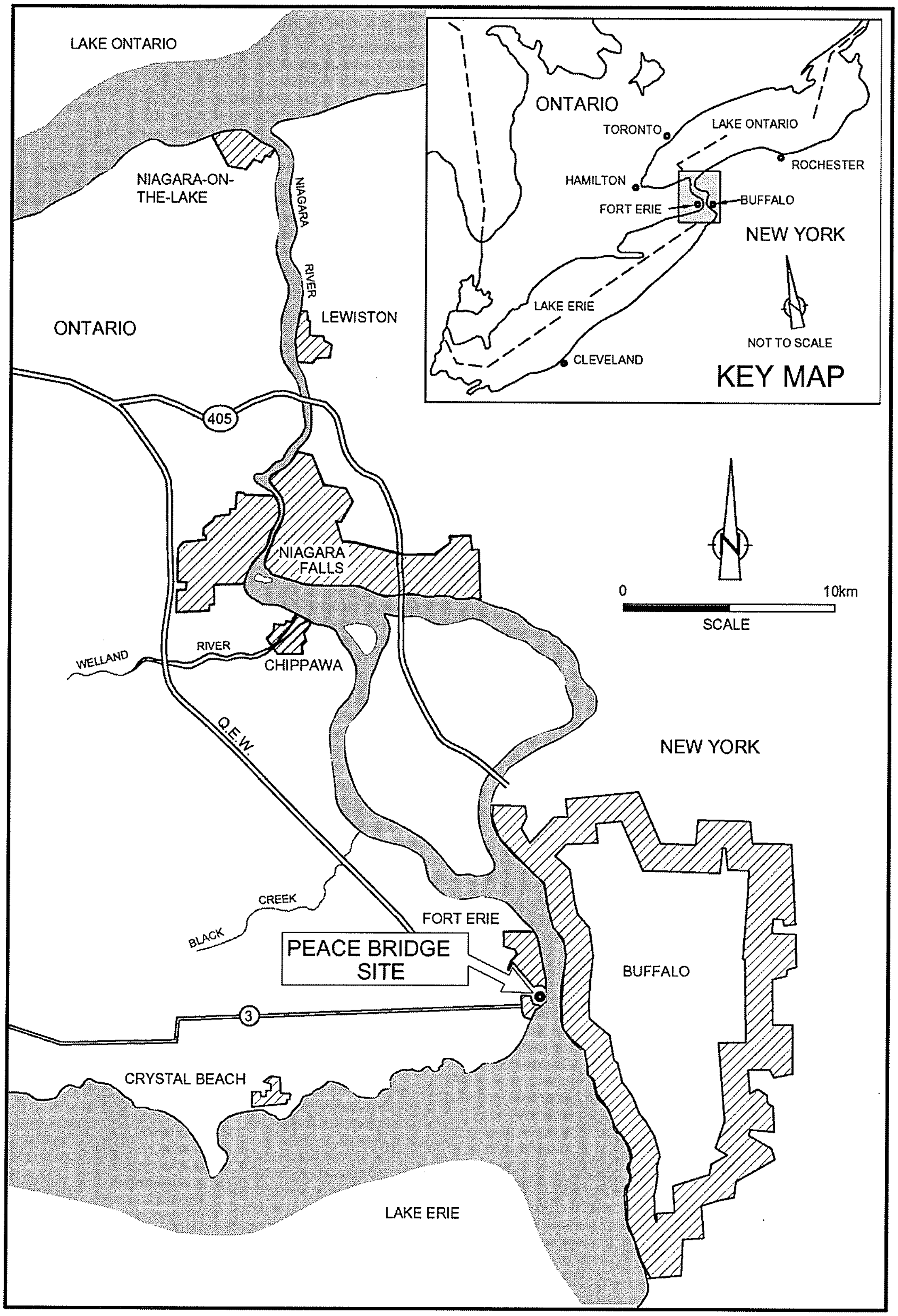


Figure 3: The Peace Bridge (AfGr-9) site, Fort Erie, Ontario and the Niagara Frontier

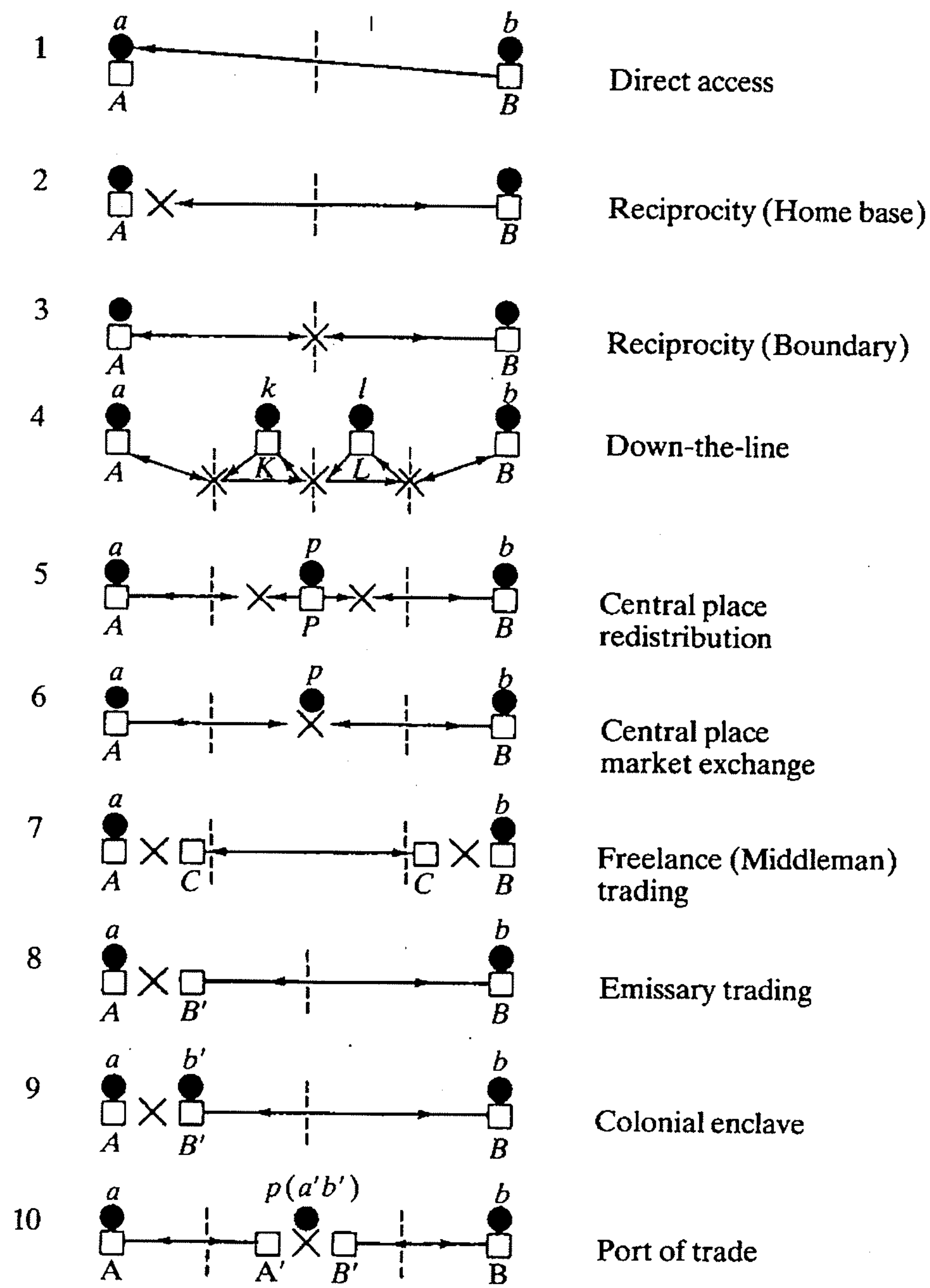


Figure 4: Modes of Exchange and their Spatial Implications
NOTE: Circles *a* and *b* indicate (respectively) the point of origin and the place of receipt of the commodity, squares *A* and *B* represent the person at the source and the recipient. Circle *p* is the central place, square *P* the central person. Exchange transactions are indicated by a cross and territorial boundaries by a broken line (from Renfrew, 1984:120)

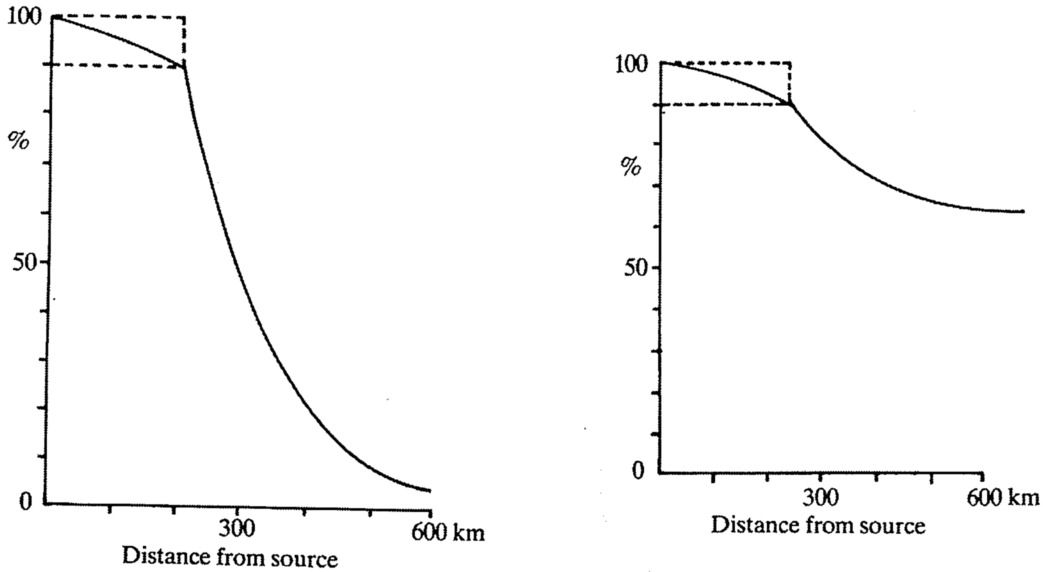


Figure 5: Down-the-line exchange – fall-off in abundance (measured as a percentage of the initial amount removed) of an idealized commodity with distance from source. The illustration on the right is a modification of down-the-line exchange, prestige-chain exchange. In the model, drop-off is more gradual due to the nature of the commodity being exchanged (Renfrew 1977:124,127)

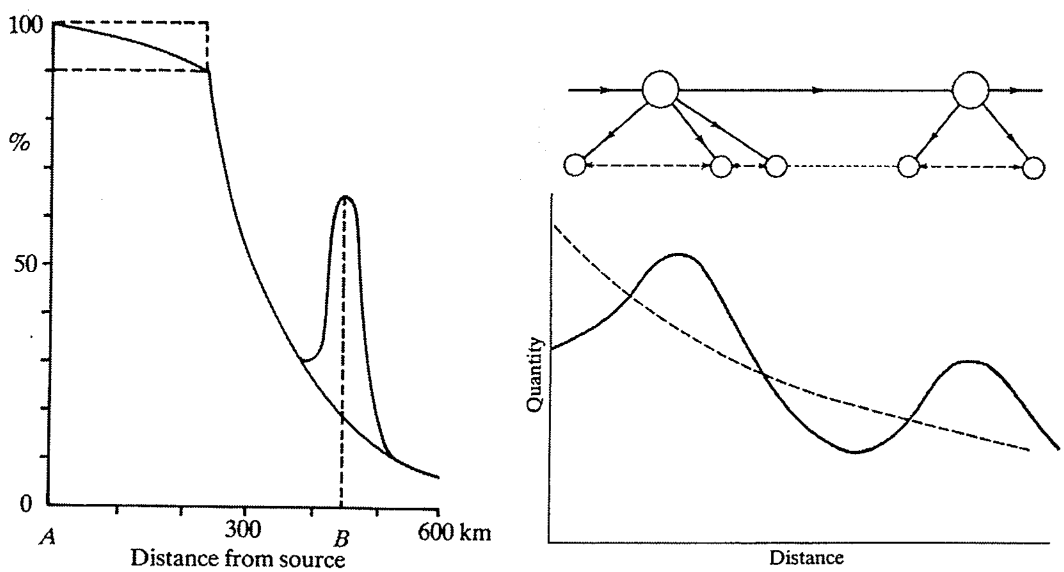


Figure 6: Directional Exchange (redistribution) – fall-off in abundance with distance from a source. Location *B* represents a 'central-place'. The diagram on the right illustrates the relationship between commodities traveling in the exchange network through the 'central-place' and onto the more marginalized area that are serviced by that locale and the resulting fall-off curve. (Renfrew 1984:126)

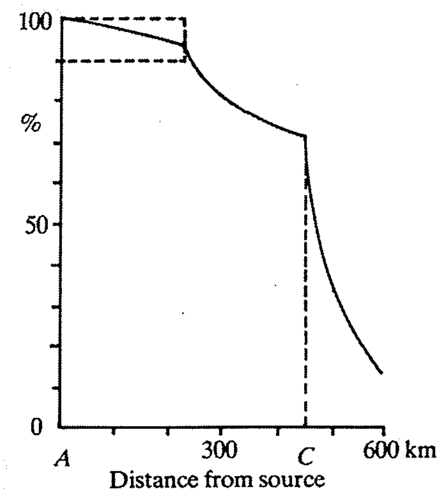


Figure 7: Middleman or Free-lance exchange: fall-off in abundance with distance from source. Point *C* on Figure 7 represents the boundary of the regions served by the participant middleman (Renfrew 1984:127)

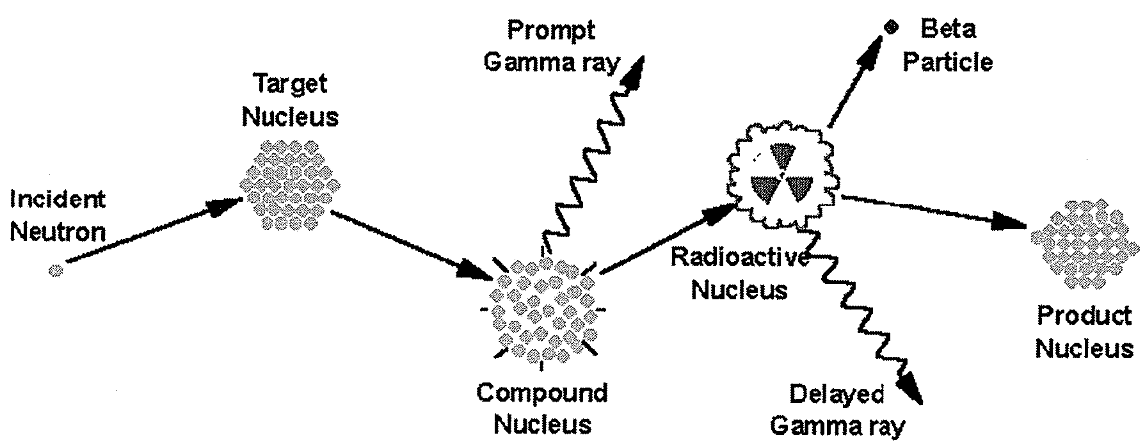


Figure 8: Neutron Activation Analysis - Diagram illustrating the process of neutron capture by a target nucleus followed by the emission of gamma rays (Glasscock 2000)

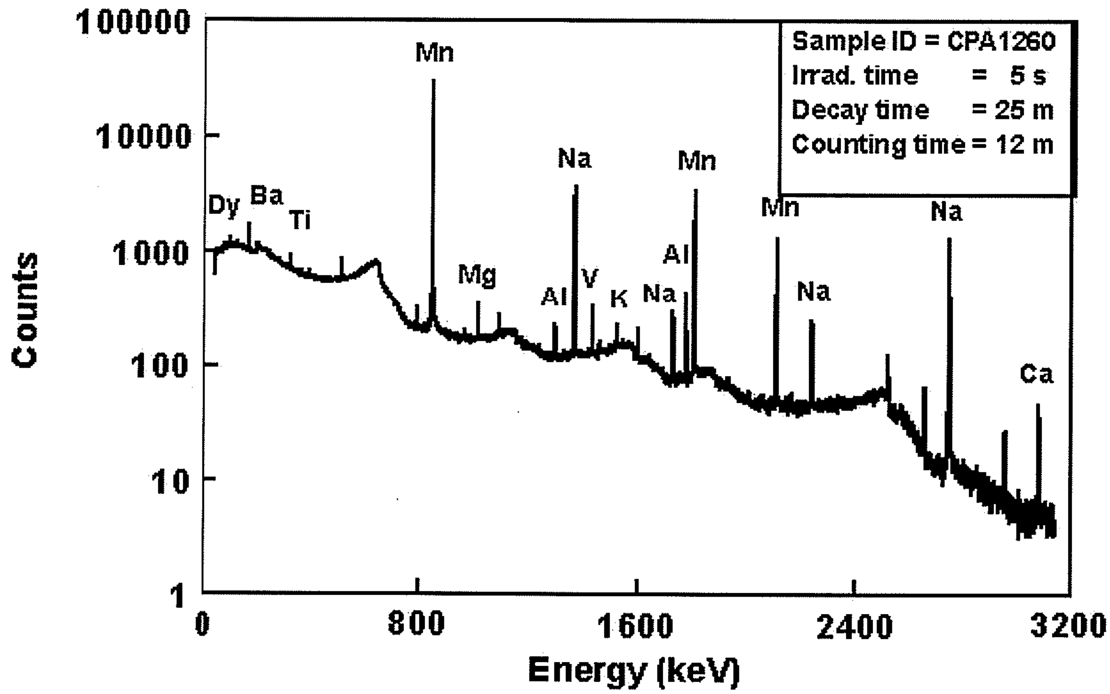


Figure 9: Typical gamma-ray spectrum showing several short-lived elements in a sample of pottery irradiated for 5 seconds, decayed for 25 minutes, and counted for 12 minutes with a HPGe detector (Glasscock 2000)

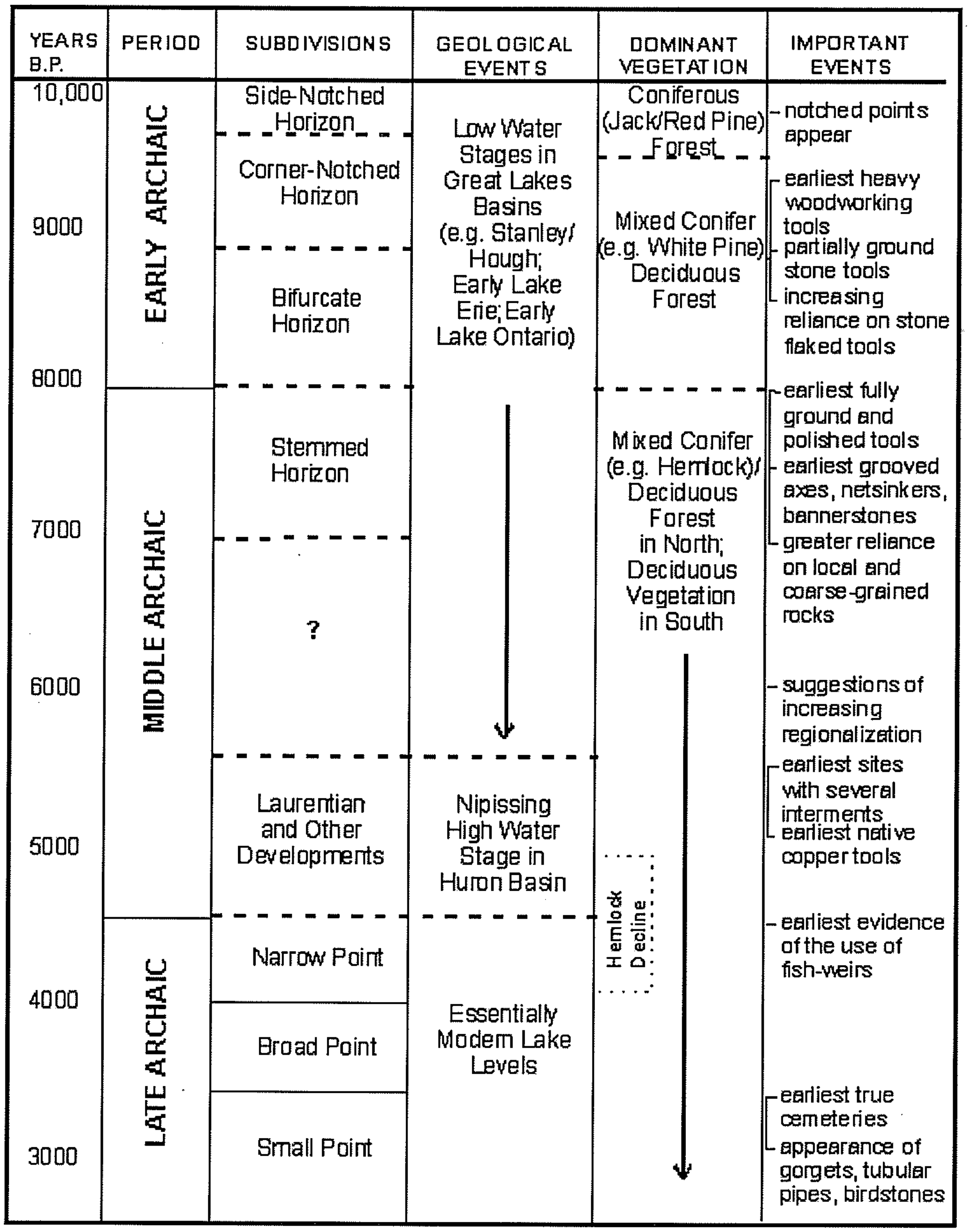


Figure 10: Chronological, regional and assemblage characteristics of the Archaic of southern Ontario (from Ellis et al. 1990: 69)

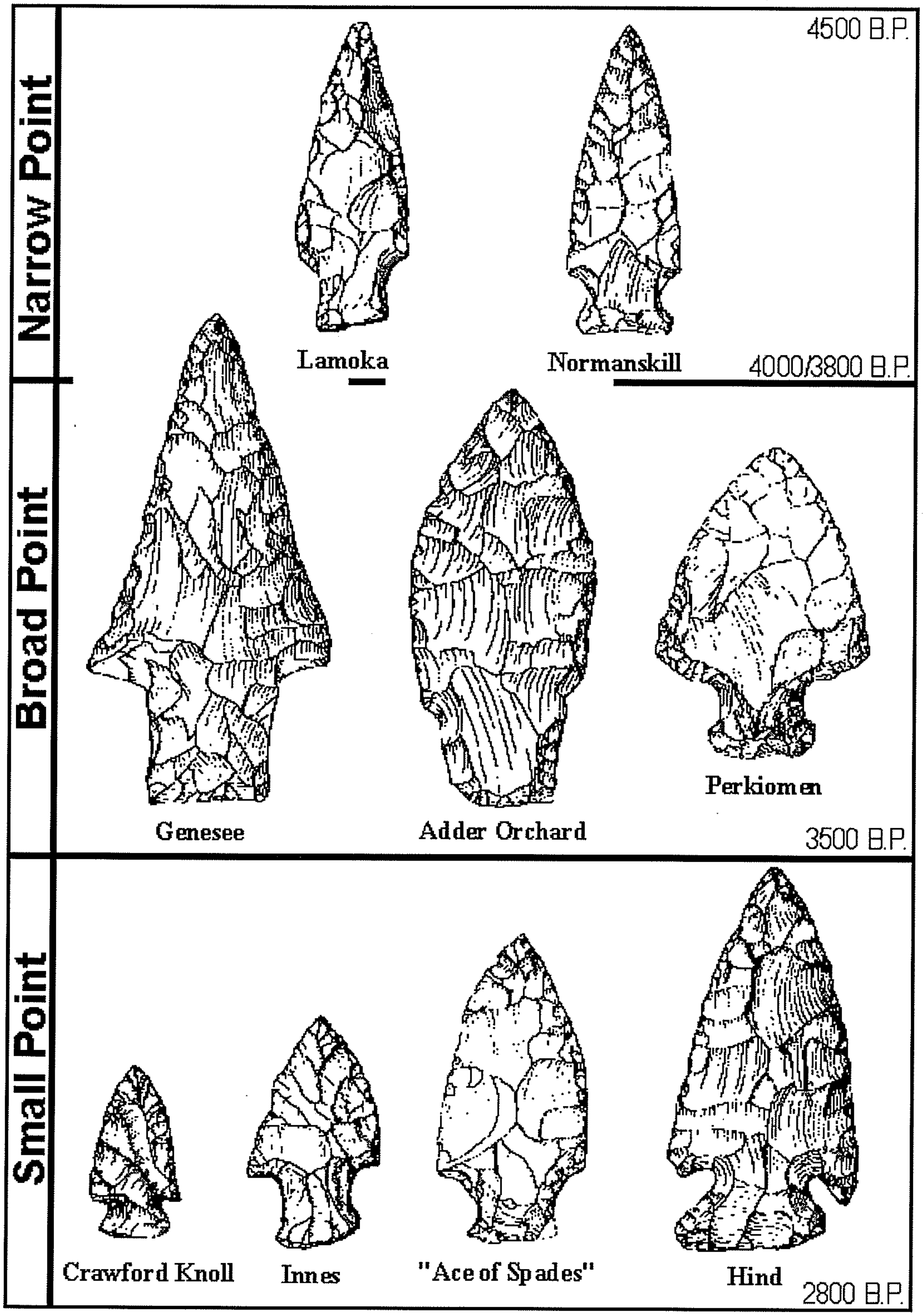


Figure 11: Late Archaic Point Types in Southern Ontario (illustrations approximate relative size – from Ellis et al. 1990: 97)

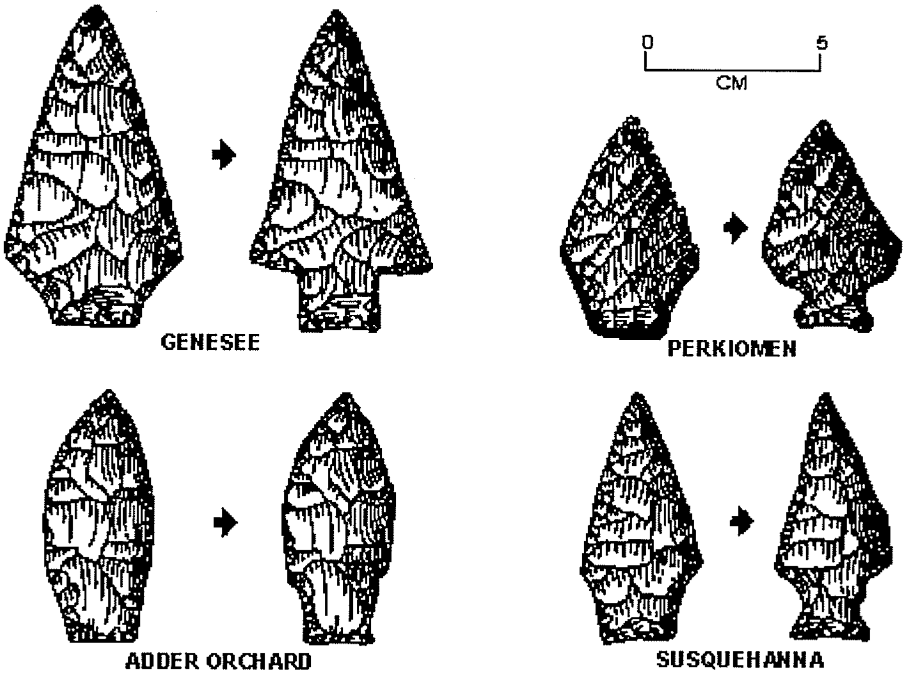


Figure 12: Late Archaic Broad Point Types and Related Pentagonal Preforms (from Ellis et al. 1990: 102)

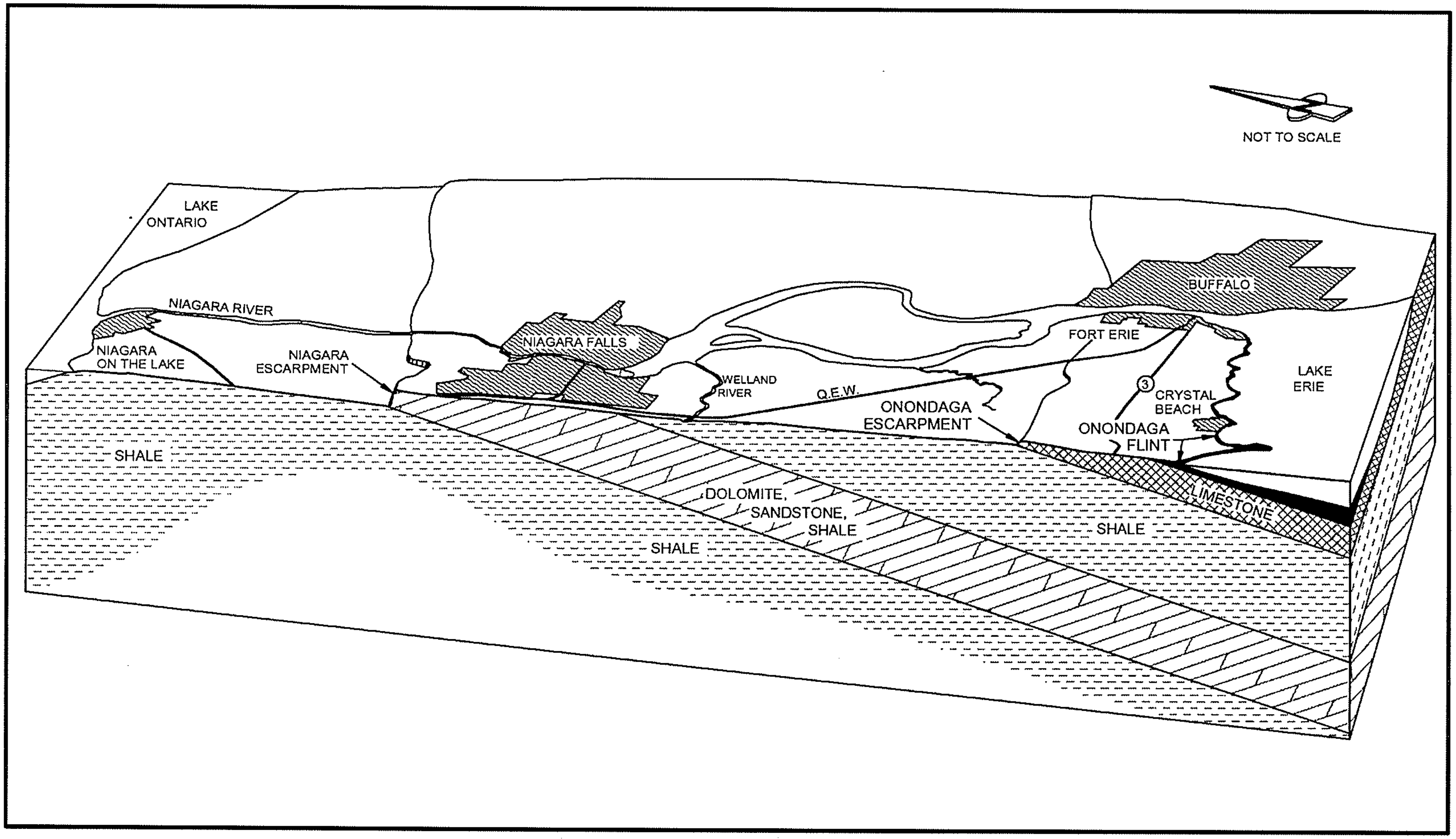
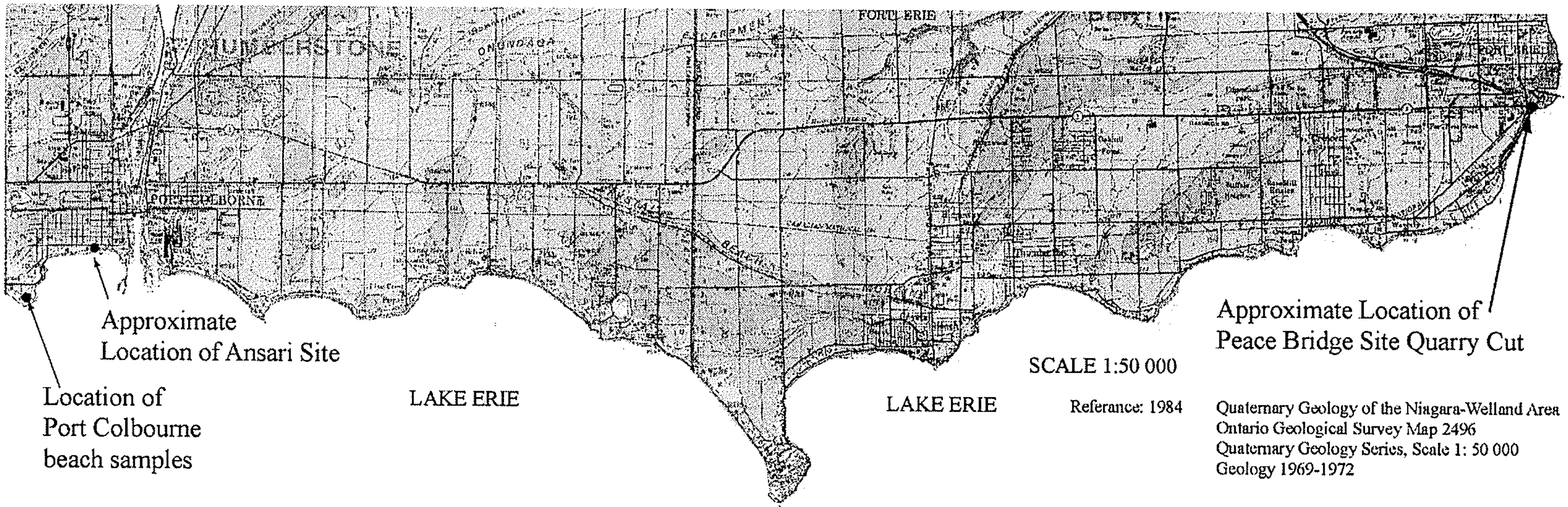
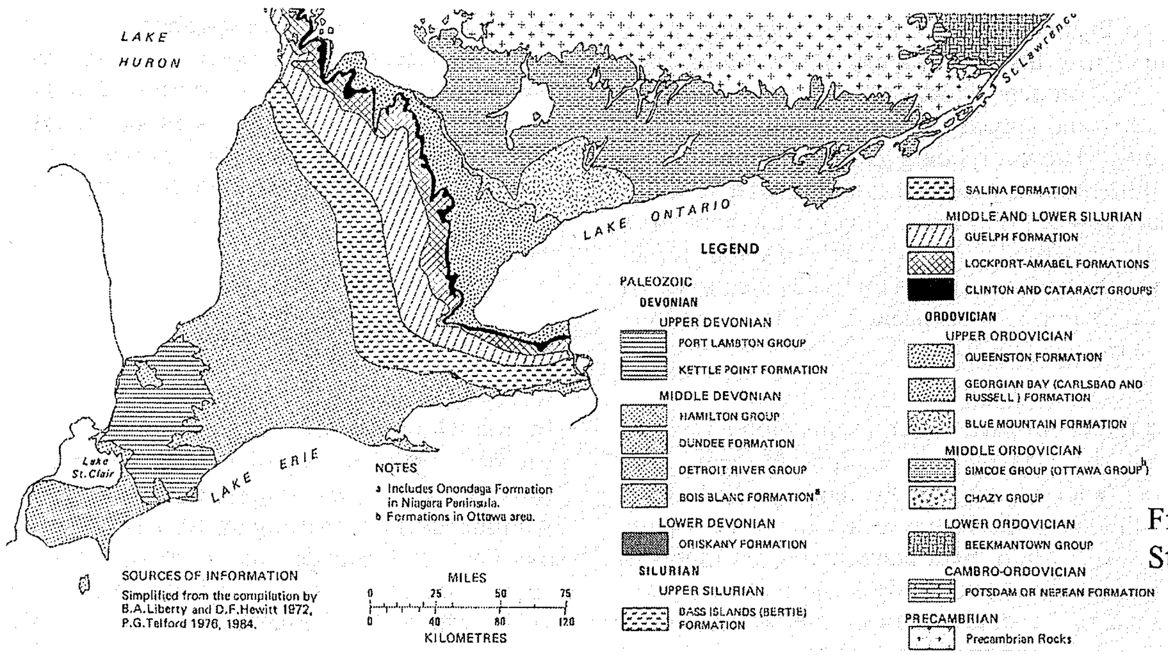


Figure 13: The Onondaga Formation in the Niagara Frontier





Bedrock Geology of Southern Ontario (Chapman & Putnam 1984:2)

Figure 14: Quaternary Geology of Study Area (Ontario portion)

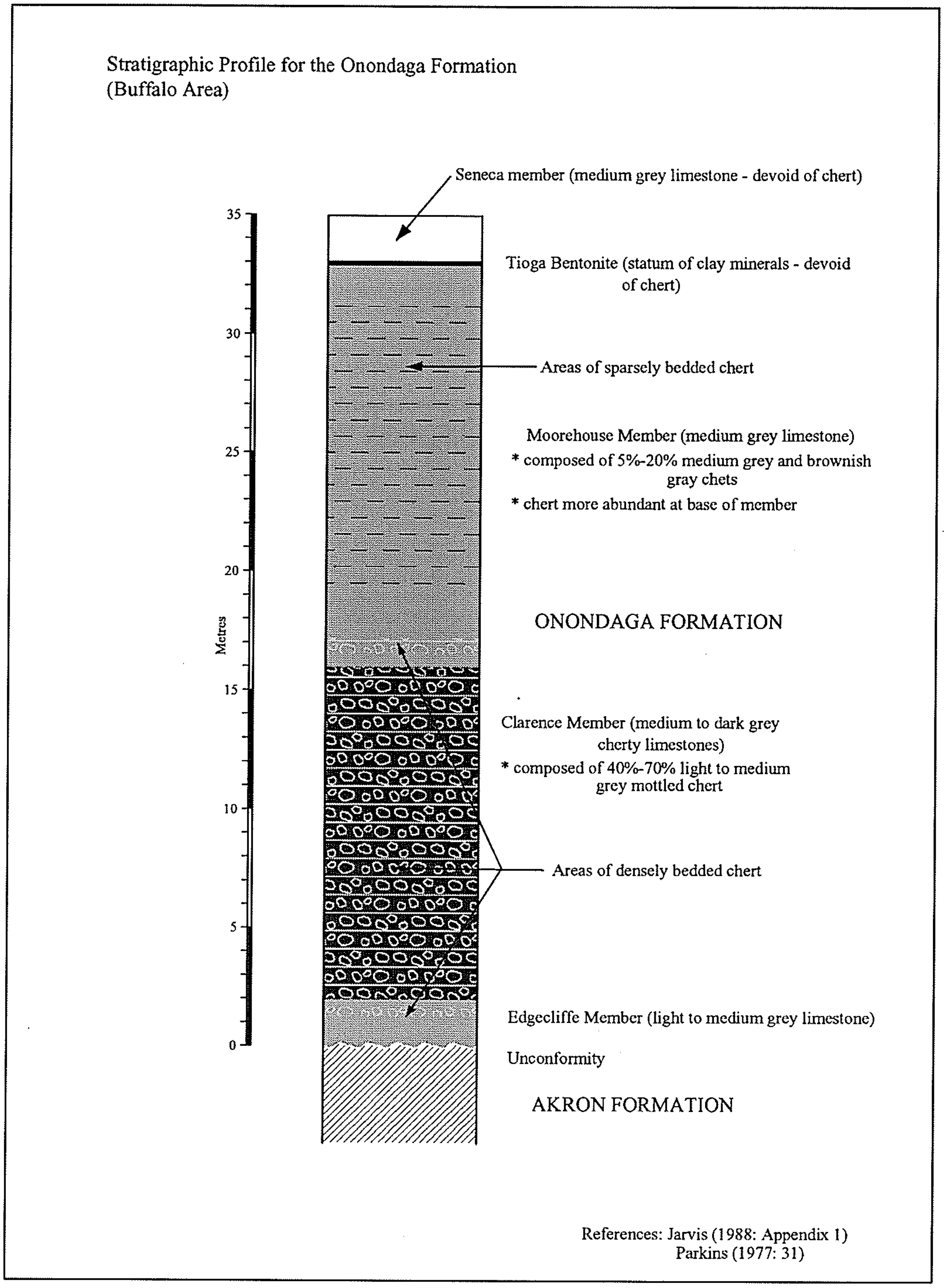


Figure 15: Stratigraphic Profile of the Onondaga Formation

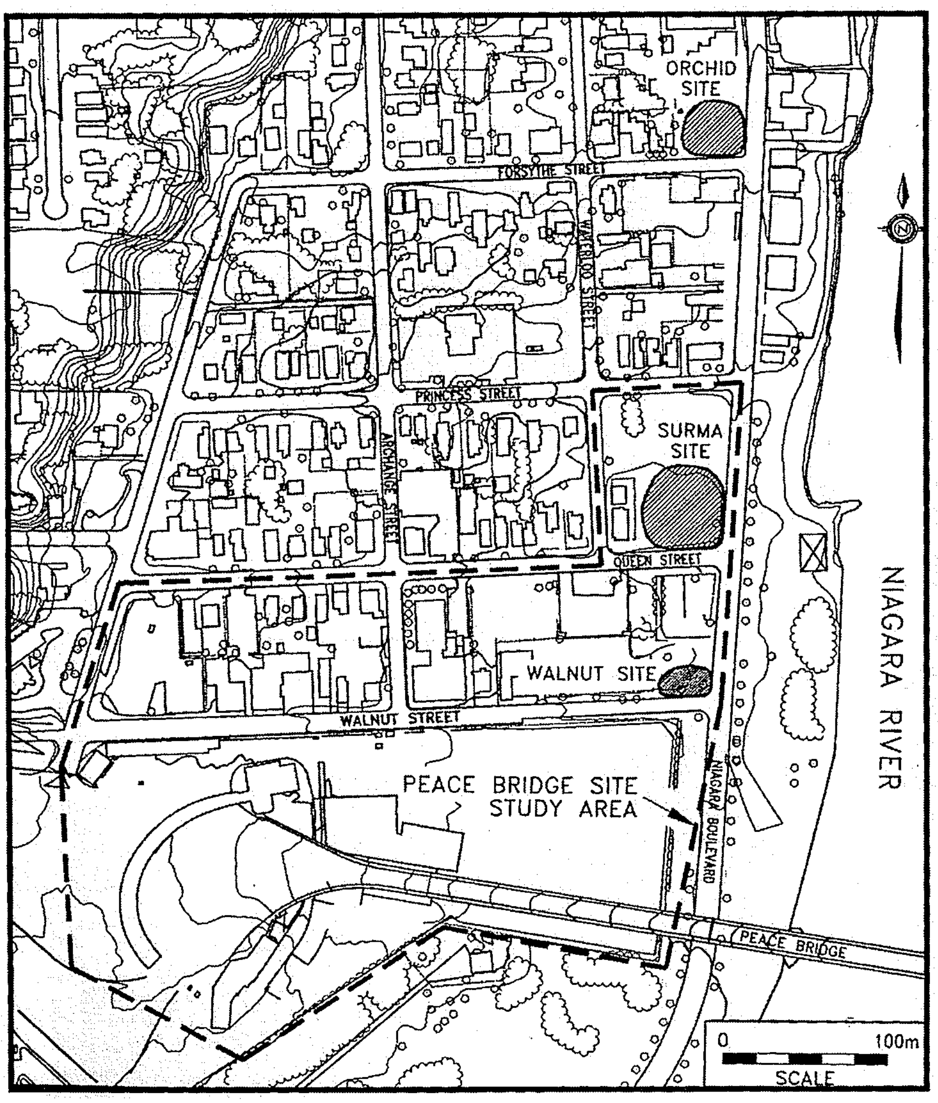


Figure 16: The Peace Bridge site (AfGr-9) and its components.
NOTE: The closely spaced lines on the left side of the illustration represent the large ridge of glacial sediment deposited by the Laurentide Ice Sheet during the last glaciation, approximately 13 000 years ago

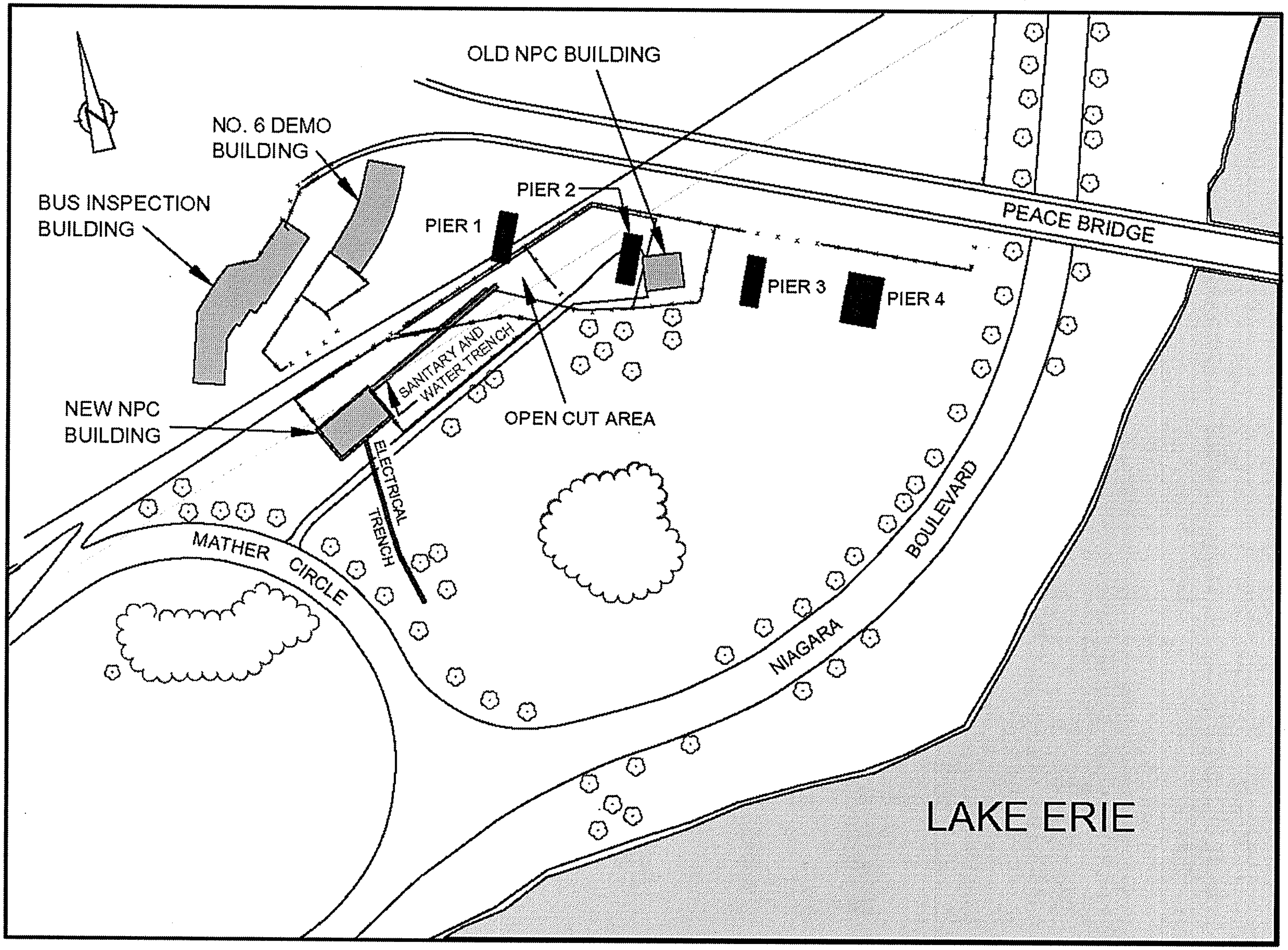


Figure 17: Detail of the 1997/1998 Archaeological Study Area at the Peace Bridge site (AfGr-9)
NOTE: map not to scale

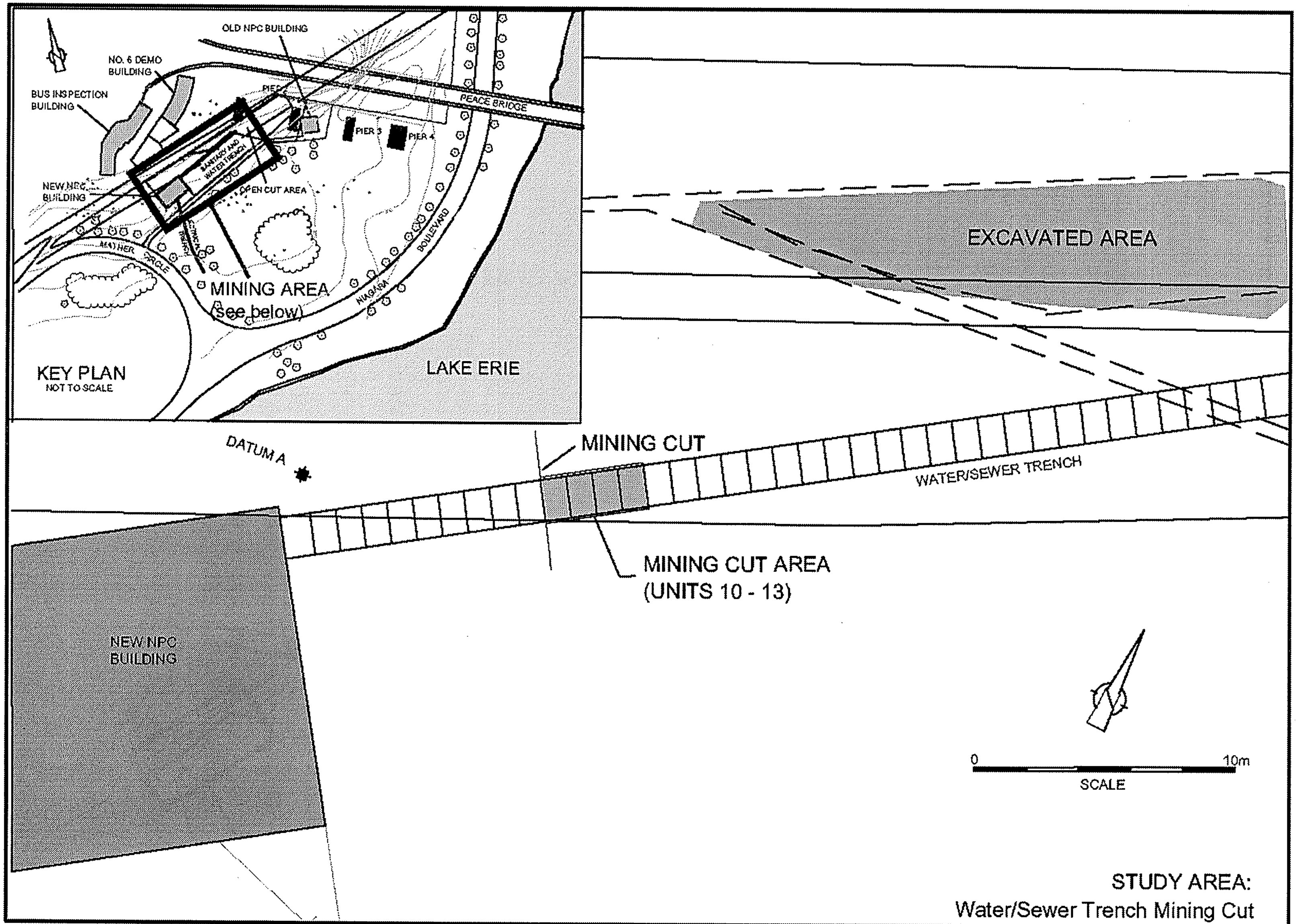


Figure 18: The 1997/1998 Archaeological Study Area at the Peace Bridge site (AfGr-9) - detail of the mining cut area
NOTE: Map not to scale

Figure 19: The Peace Bridge site (AfGr-9) Quarry Cut – plan view looking southeast (Photo: ASI)

Figure 20: The Peace Bridge site (AfGr-9) Quarry Cut – west profile of units 11 and 12 (Photo: ASI)

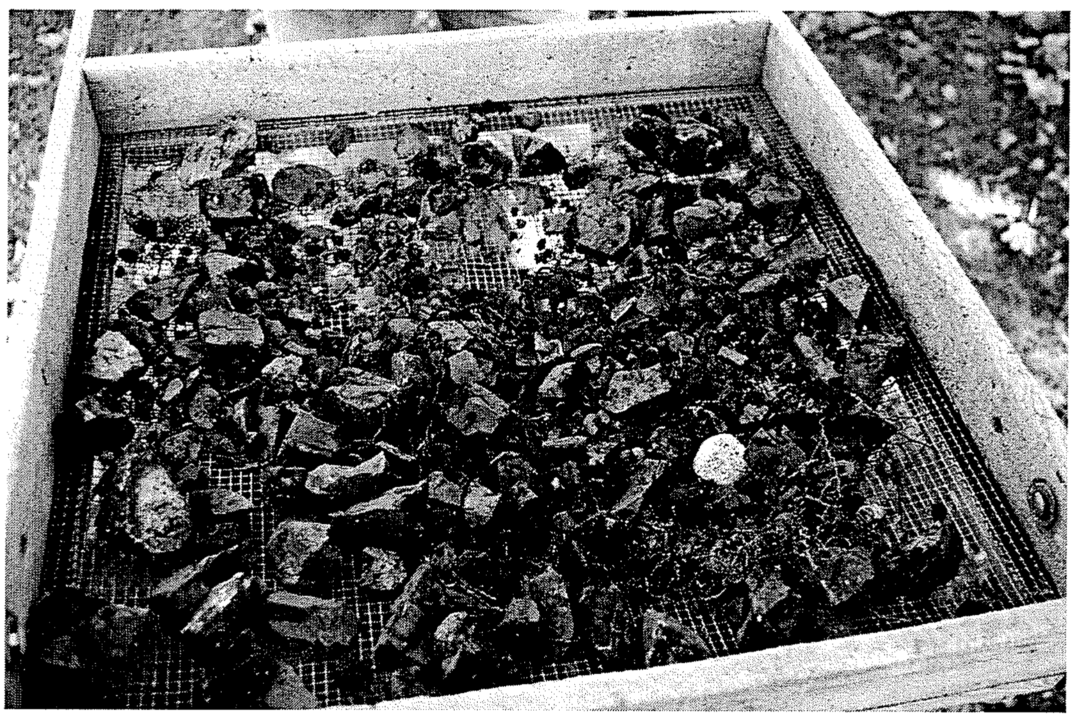


Figure 21: The Peace Bridge site (AfGr-9) Quarry Cut – an example of artifact density derived from screening approximately 2.5liters of fill. All material observed in screen is culturally modified Onondaga chert (Photo: ASI)

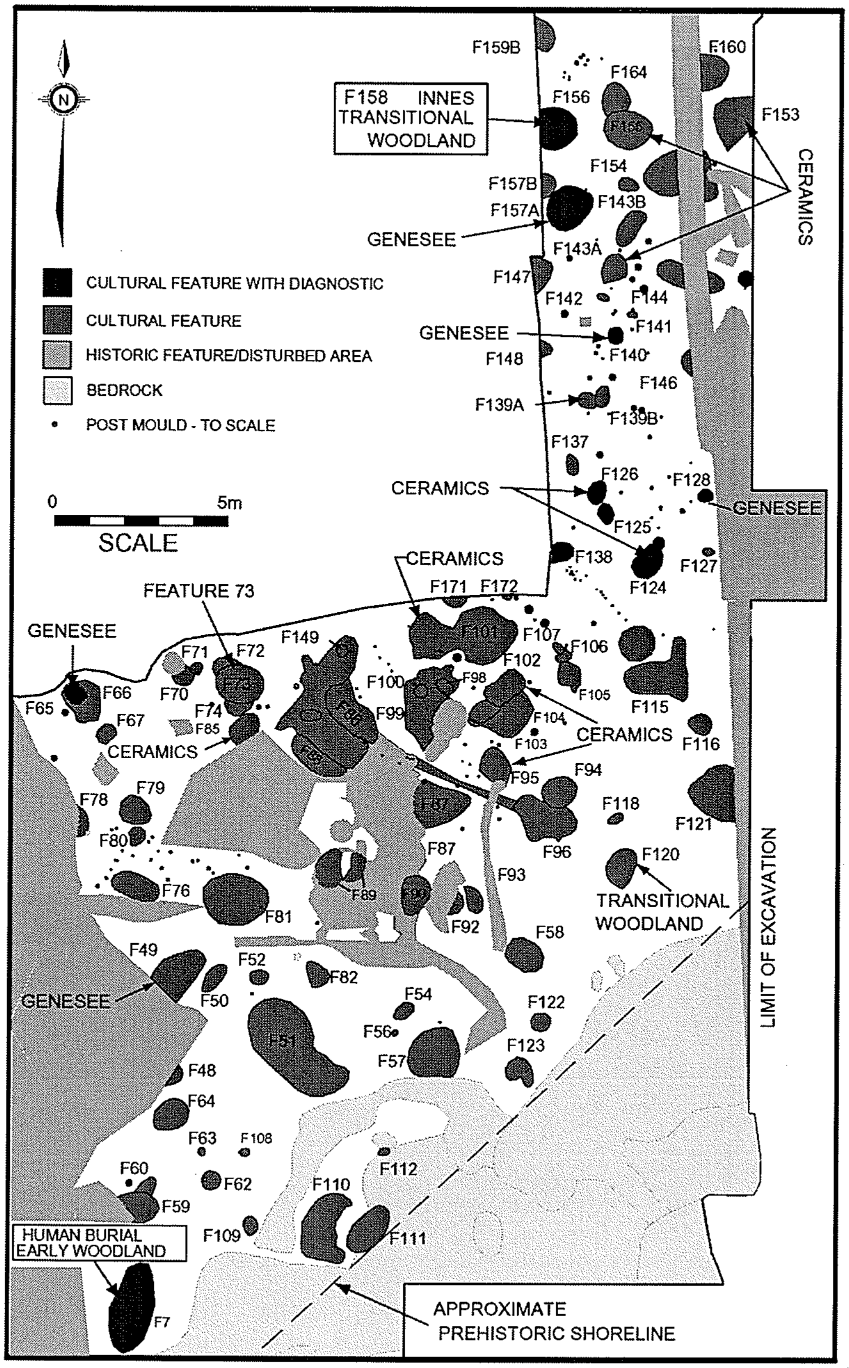


Figure 22: Features from a portion (East Truck Pad) of the Peace Bridge Site during the 1994-1997 Investigations
*Note the density of subterranean features and Feature 73 in the northwest corner

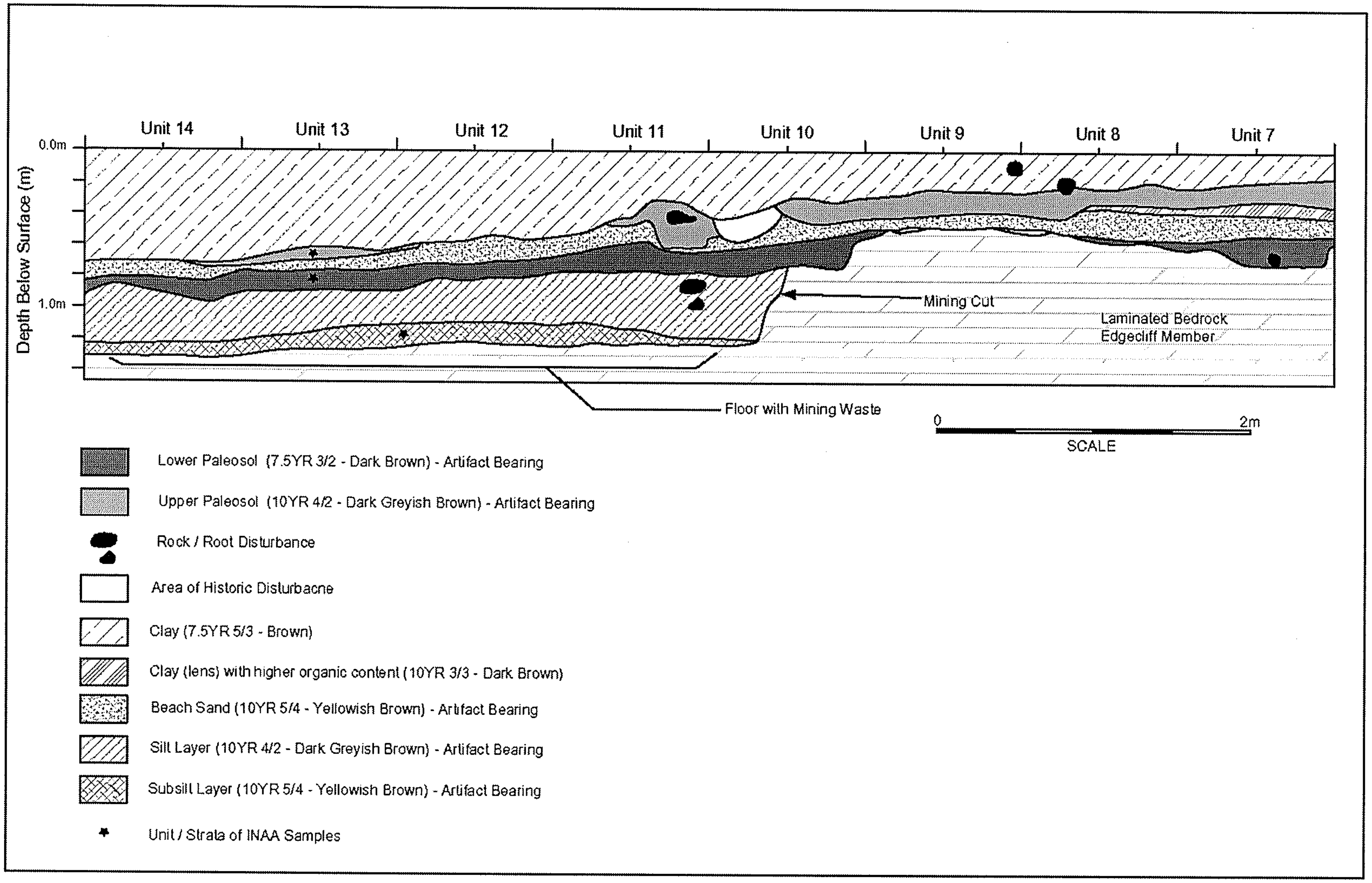


Figure 23: East Profile of Water and Sanitary Trench Units 7-14
*note: NAA samples removed from Upper Paleosol, Lower Paleosol and Subsilt Layers

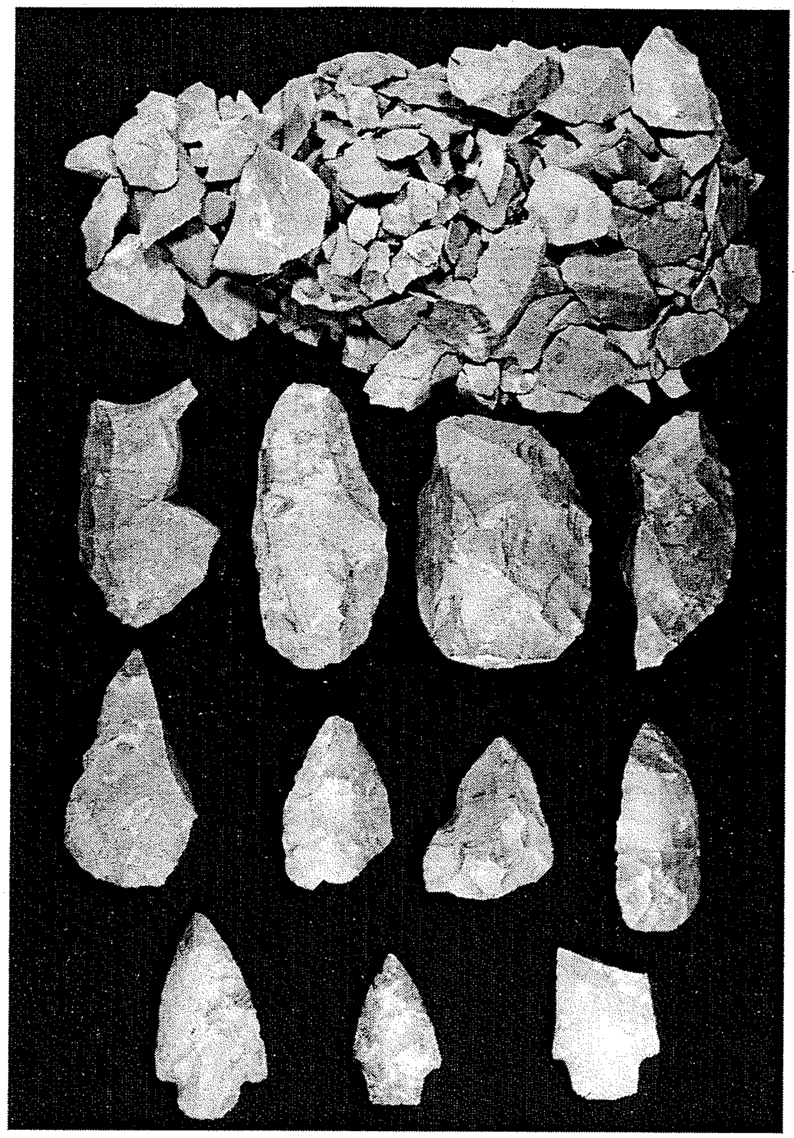


Figure 24: The Feature 73 (Area 4, East Truck Pad) Assemblage from the Peace Bridge site (AfGr-9) – n=3 samples removed for INAA analysis (Photo: ASI)

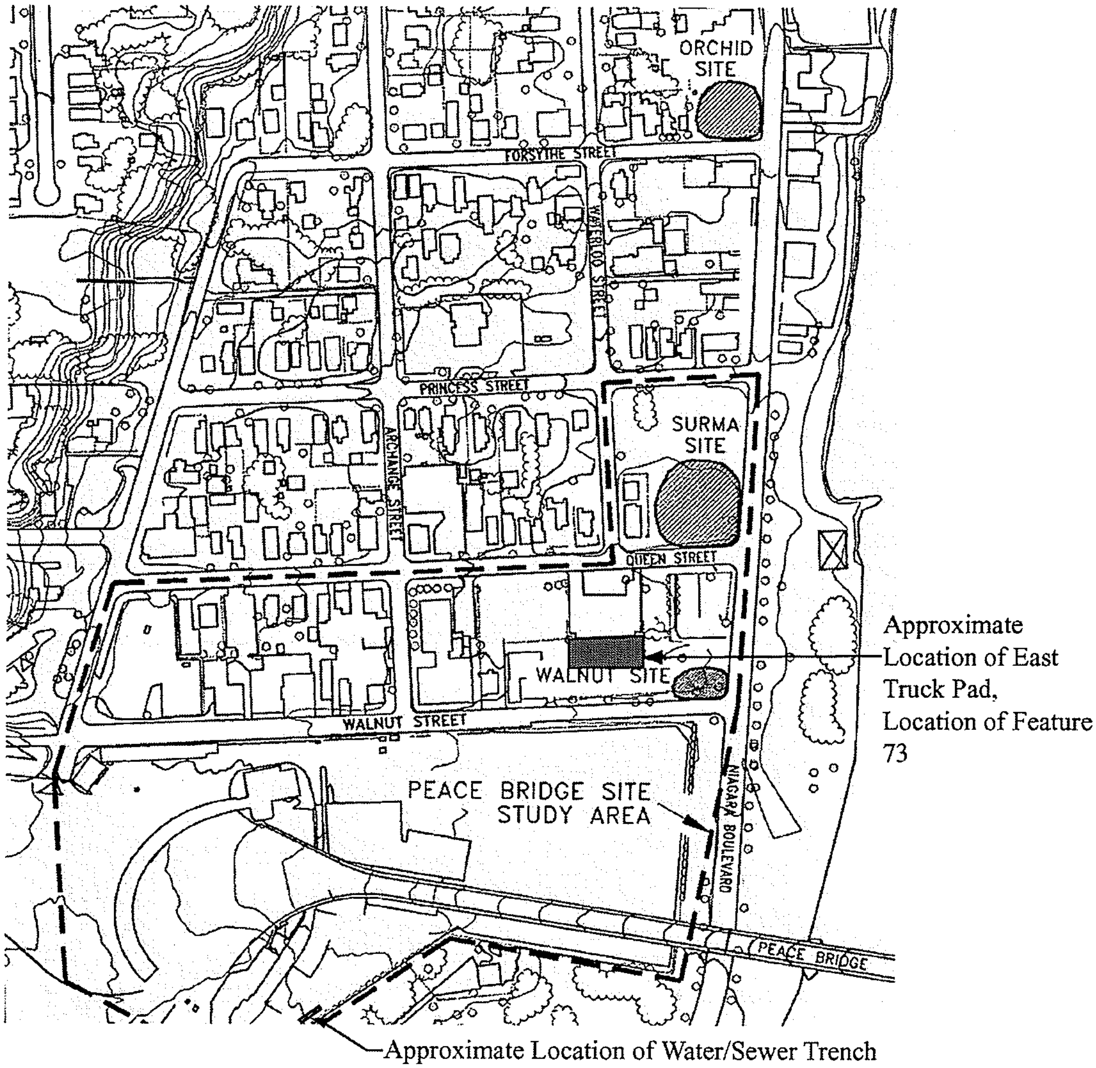


Figure 25: Approximate locations of the East Truck Pad Area, with Feature 73, and the Water/Sewer Trench

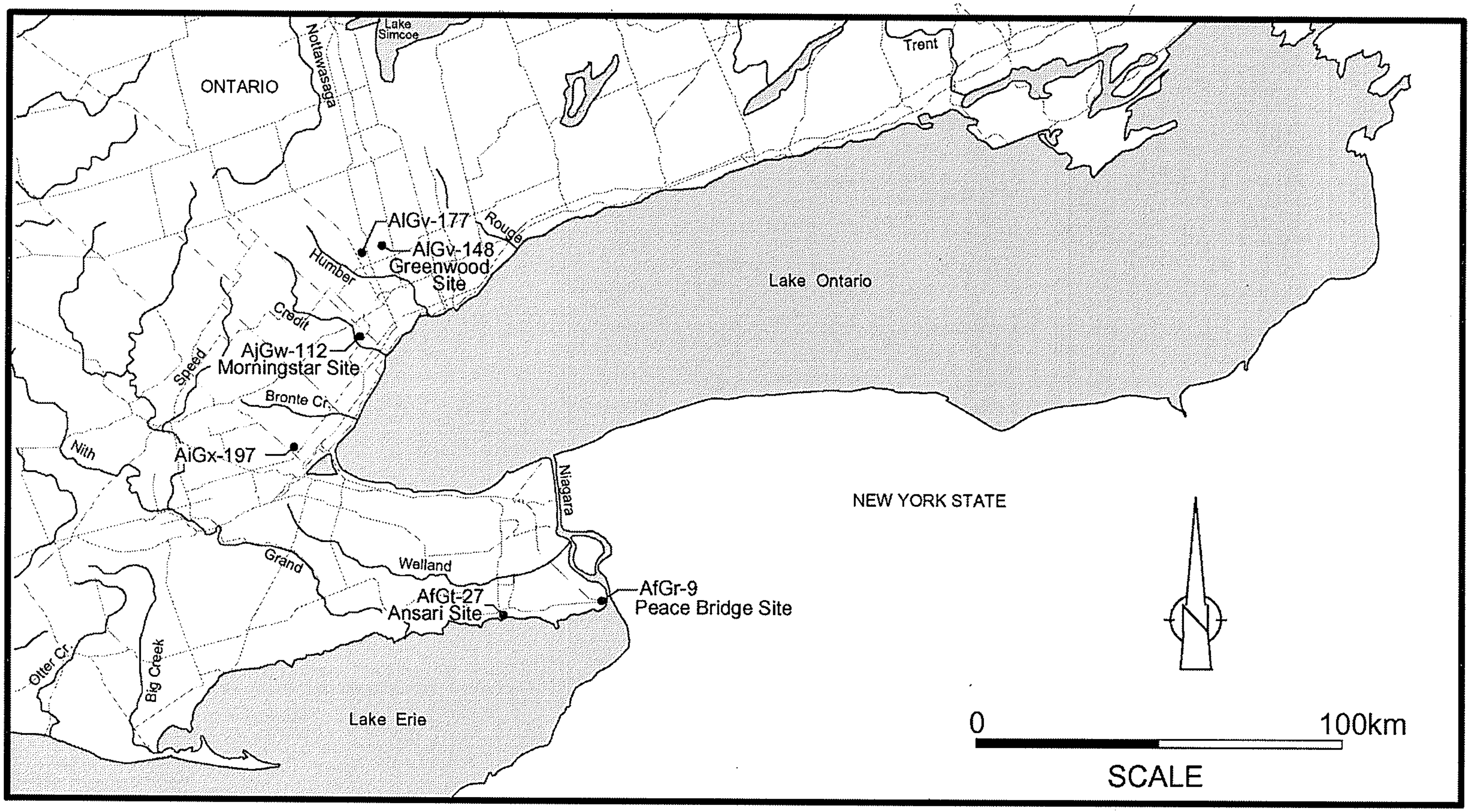


Figure 26: Map of Sample Site Locations

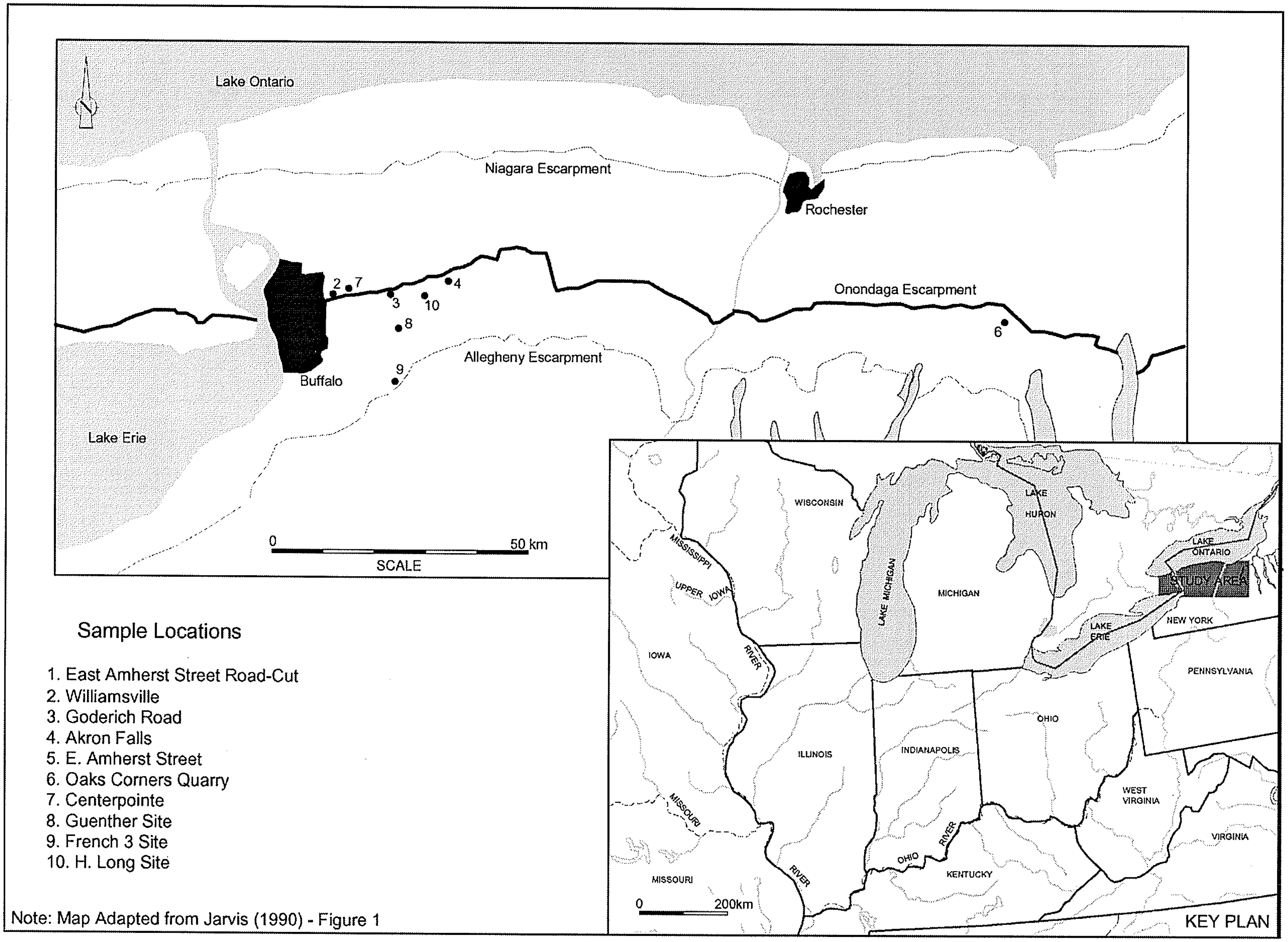


Figure 27: Jarvis (1990) Study Area in Western New York State

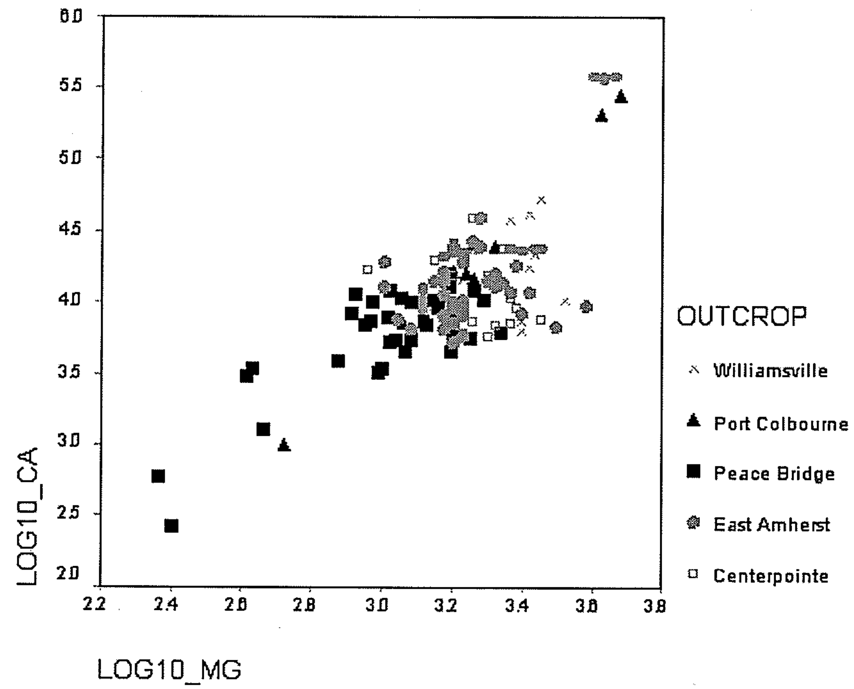


Figure 28: Plot of Ca/Mg log (10) transformed concentrations of chert samples by outcrop
Total number of samples plotted = 129 (including data from Jarvis (1988))

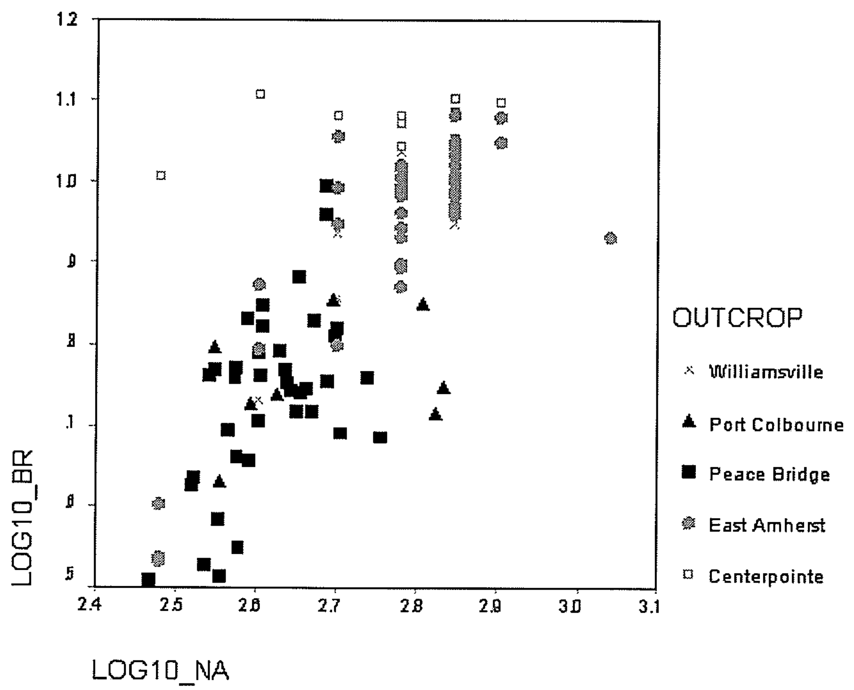


Figure 29: Plot of Br/Na log (10) transformed concentrations of chert samples by outcrop
Total number of samples plotted = 129 (including data from Jarvis (1988))

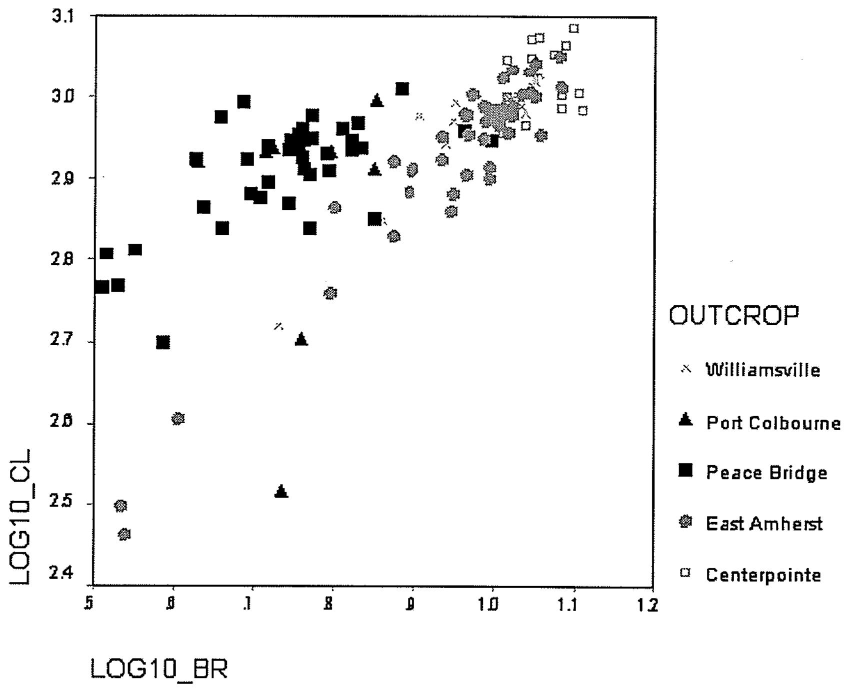


Figure 30: Plot of Cl/Br log (10) transformed concentrations of chert samples by outcrop
Total number of samples plotted = 129 (including data from Jarvis (1988))

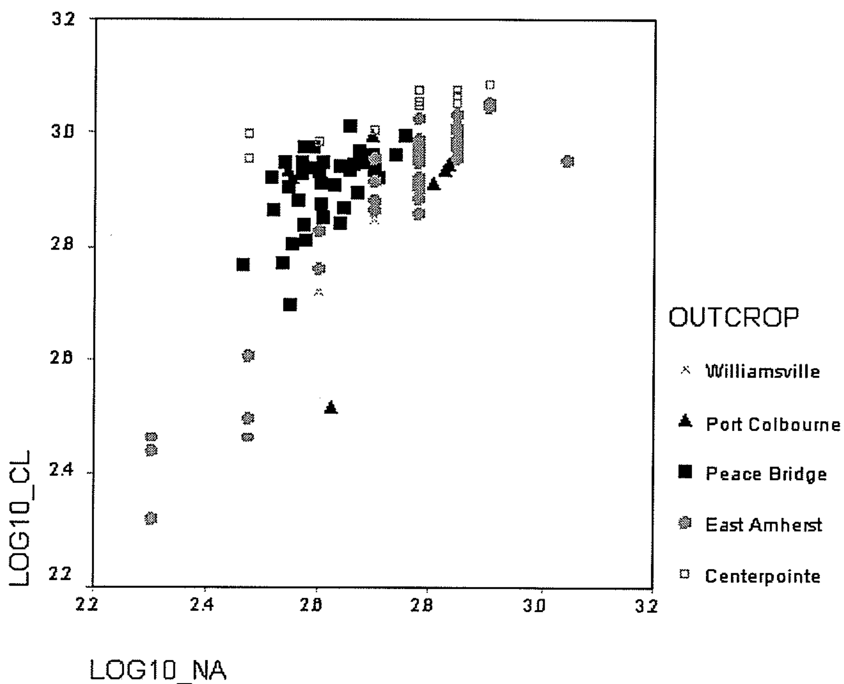


Figure 31: Plot of Cl/Na log (10) transformed concentrations of chert samples by outcrop
Total number of samples plotted = 129 (including data from Jarvis (1988))

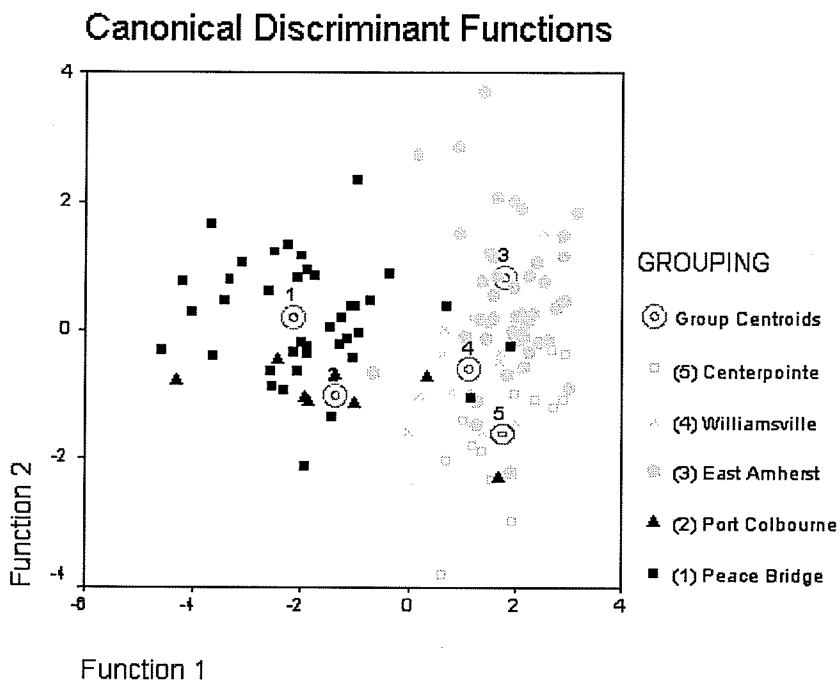


Figure 32: Canonical Discriminate Functions of outcrop groupings
Group centroids are defined by multivariate mean of each group for the two canonical functions (including data from Jarvis (1988))

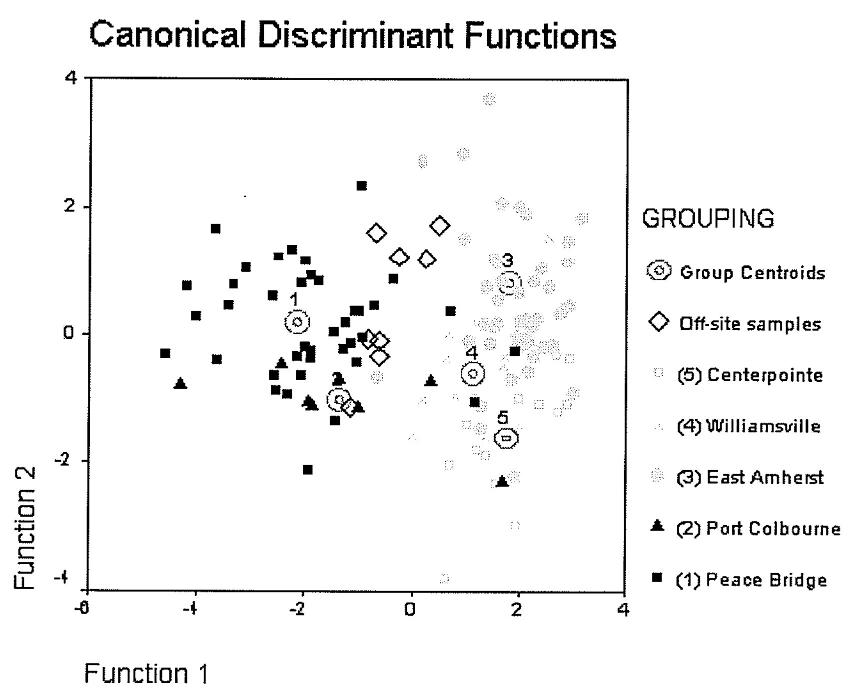


Figure 33: Canonical Discriminate Functions of outcrop groupings with unknown samples (including data from Jarvis (1988))

Precision	Mean Coefficient of Variation			
	V=0.1	V=0.3	*V=0.5*	*V=0.7*
0.20	1	9	24	47
0.10	4	35	96	188
0.05	15	138	384	753
0.03	43	384	1067	2092
0.01	384	3457	9604	18824

Table 1: Sample Sizes required given different amounts of variation and precision at the 0.95 Level of confidence (Luedtke and Meyers 1984:289)

	F73-1	**OS-1**	**OS-5**
Al	1.0	1.6	2.3
Ba	16	-	-
Br	6.6	8.6	9.8
Ca	1.9	5.2	12
Cl	1.2	1.2	1.2
Co	-	-	-
Cu	-	-	-
I	-	-	-
K	5.8	8.8	12
Mg	5	15	-
Mn	2.5	1.2	1.6
Na	0.9	1.6	1.6
Si	4.9	4.7	6.4
Sr	23	-	-
Ti	28	22	26
V	6.0	8.4	8.9

Table 2: 68% Confidence level estimates expressed as a relative percentage
Note: - = a non-dectectable peak, therefore the analytical precision estimate is >30%

	N							
	Valid	Missing	Mean (ppm)	Std. Deviation	Skewness	Std. Error of Skewness	Min. Value	Max. Value
U	47	9	<0.14	0.0077	2.549	0.347	<0.0745	<0.40
Dy	48	8	<0.13	0.0012	5.385	0.343	<0.0623	<0.8810
Ba	56	0	<22	16.4	3.998	0.319	<8.5	<112.0
Ti	55	1	<100	47.0	1.119	0.322	<49.1	<236.0
Sr	55	1	<26	11	4.497	0.322	<14	<91
I	56	0	<0.551	0.330	1.6664	0.319	<0.257	<1.410
Br	56	0	5.54	1.26	0.919	0.319	3.23	9.90
Mg	53	3	1275	834	2.135	0.327	230	4780
Si	55	1	450000	31000	-4.623	0.322	260000	480000
Na	55	1	427	86	1.012	0.322	259	683
V	55	1	3.7	1.4	1.367	0.322	1.2	8.70
K	56	0	1131	463	0.354	0.319	385	2165
Al	56	0	3290	845	0.622	0.319	1300	5470
Mn	55	1	15.1	12.0	3.655	0.322	5.5	71.3
Cl	56	0	778	188	-0.839	0.319	326	1023
Ca	56	0	15400	43400	5.206	0.319	268	269000
Co	56	0	<0.916	0.456	2.496	0.319	<0.559	<2.690
Cu	56	0	<24.4	9.9	3.263	0.3199	<14.1	<70.8

Table 3: Descriptive Statistics for all Ontario Chert Samples

Note: 10 000ppm = 1%, N=sample number and Missing sample reading denotes that the element was not present in case sample. It also be noted that elements fell below the 68% confidence limit were designated with the "<" prefix (these samples rendered elements which were near or below the instrumental detection limit – the concentration offered is the estimated highest amount of the element that could be present but not measurable - these concentrations are in essence 'zero' for all pragmatic purposes)

	N Valid	N Missing	Mean (ppm)	Std. Deviation	Skewness	Std. Error of Skewness	Min. Value	Max. Value
U	39	0	<0.14	0.0073	2.747	0.378	<0.0745	<0.04
Dy	39	0	<0.11	0.0035	3.063	0.378	<0.062	<0.270
Ba	39	0	<20.6	<16.1	5.097	0.378	<8.5	<112.0
Ti	39	0	<100	<50	0.938	0.378	<49	<236
Sr	39	0	<25	5	0.221	0.378	<14	<34
I	39	0	<0.398	0.001	0.676	0.378	<0.257	<0.585
Br	39	0	5.61	1.41	0.789	0.393	3.23	9.90
Mg	36	3	1169	476	-0.123	0.393	230	2180
Si	39	0	460000	14000	-0.647	0.378	420000	480000
Na	39	0	488	63	0.343	0.378	292	567
V	39	0	4.0	1.3	1.572	0.378	2.14	8.70
K	39	0	1200	493	0.000	0.378	385	2165
Al	36	3	3408	626	0.816	0.393	2280	5350
Mn	39	0	13.8	10.7	4.412	0.378	5.5	71.3
Cl	39	0	817	117	-0.852	0.378	499	1023
Ca	36	3	7029	3595	0.190	0.393	268	15700
Co	39	0	<0.738	0.105	0.666	0.378	<0.559	<1.010
Cu	39	0	<23.0	4.90	0.916	0.378	<14.1	<37.4

Table 4: Descriptive Statistics for the Peace Bridge Site (AfGr-9) Site Chert Samples

Note: 10 000ppm = 1%, N=sample number and Missing sample reading denotes that the element was not present in case sample. It also be noted that elements fell below the 68% confidence limit were designated with the "<" prefix (these samples rendered elements which were near or below the instrumental detection limit – the concentration offered is the estimated highest amount of the element that could be present but not measurable - these concentrations are in essence 'zero' for all pragmatic purposes)

	N Valid	Missing	Mean (ppm)	Std. Deviation	Skewness	Std. Error of Skewness	Min. Value	Max. Value
U	8	1	<0.16	0.0095	2.331	0.752	<0.0853	<0.3820
Dy	9	0	<0.23	0.26	2.429	0.717	<0.0751	<0.8810
Ba	9	0	<30.3	20.3	1.430	0.717	<13.5	<67.2
Ti	8	1	<113	51	1.953	0.752	<69	<227
Sr	8	0	<37	23	2.406	0.752	<20	<91
I	9	0	<0.647	0.429	1.416	0.717	<0.313	<1.400
Br	9	0	5.8	0.9	0.175	0.717	4.3	7.1
Mg	9	0	2190	1390	1.161	0.717	530	4780
Si	9	0	420000	66000	-2.447	0.752	260000	470000
Na	8	1	501	143	0.348	0.752	351	683
V	8	1	3.0	2.1	1.978	0.752	1.20	7.86
K	9	0	1027	472	1.014	0.717	510	1867
Al	9	0	3630	1130	0.697	0.717	2600	5470
Mn	8	1	19.0	19.9	2.744	0.752	9.9	67.9
Cl	9	0	767	210	-1.561	0.717	326	984
Ca	9	0	63500	98800	1.724	0.717	963	269000
Co	9	0	<1.2	0.79	1.407	0.717	<0.58	<2.69
Cu	9	0	<34.6	19.9	1.245	0.717	<17.6	<70.8

Table 5: Descriptive Statistics for the Port Colborne Chert Samples

Note: 10 000ppm = 1%, N=sample number and Missing sample reading denotes that the element was not present in case sample. It also be noted that elements fell below the 68% confidence limit were designated with the "<" prefix (these samples rendered elements which were near or below the instrumental detection limit – the concentration offered is the estimated highest amount of the element that could be present but not measurable - these concentrations are in essence 'zero' for all pragmatic purposes) analysis)

	Mean (ppm)	Skewness	Log (10) Mean	Log (10) Skewness.
Br	8.17	-0.181	0.89	-0.629
Mg	1775	1.306	3.20	-1.029
Si	450000	-0.933	5.65	-2.217
Na	541	0.069	2.71	-0.708
V	3.9	1.344	0.56	0.176
K	1221	0.877	3.05	-0.180
Al	3676	0.807	3.55	-0.500
Mn	15.4	3.718	1.11	2.055
Cl	866	-1.362	2.92	-2.464
Ca	24500	5.031	4.05	0.585

Table 6: Comparison of Skewness values (normality of dataset) for all outcrop data Note: total sample size is n=129.Outliers have been removed from dataset. This table illustrates only those elements that were deemed acceptable for statistical analysis

	Log10 Br	Log10 Mg	Log10 Si	Log10 Na	Log10 V	Log10 K	Log10 Al	Log10 Mn	Log10 Cl	Log10 Ca
Log10_Br										
Pearson's r	1.00									
Sig.(1-tailed)	-									
N	125									
Log10_Mg										
Pearson's r	0.396**	1.00								
Sig.(1-tailed)	0.000	-								
N	122	126								
Log10_Si										
Pearson's r	0.007	-0.237**	1.00							
Sig.(1-tailed)	0.468	0.004	-							
N	124	122	125							
Log10_Na										
Pearson's r	0.779**	0.133	0.066	1.00						
Sig.(1-tailed)	0.000	0.069	0.234	-						
N	124	125	125	128						
Log10_V										
Pearson's r	-0.163*	0.302**	0.063	-0.246**	1.00					
Sig.(1-tailed)	0.036	0.000	0.242	0.003	-					
N	124	125	125	128	128					
Log10_K										
Pearson's r	0.070	0.428**	-0.052	-0.128	-0.580**	1.00				
Sig.(1-tailed)	0.243	0.000	0.304	0.099	0.000	-				
N	101	101	101	103	103	104				
Log10_Al										
Pearson's r	0.019	0.233**	0.177*	0.234**	0.496**	0.307**	1.00			
Sig.(1-tailed	0.416	0.004	0.024	0.004	0.000	0.001	-			
N)	125	126	125	128	128	104	129			
Log10_Mn										
Pearson's r	-0.152**	0.460**	-0.413**	-0.372**	-0493**	0.339**	-0.015	1.00		
Sig.(1-tailed)	0.046	0.000	0.000	0.000	0.000	0.000	0.434	-		
N	124	125	125	128	128	103	128	128		
Log10_Cl										
Pearson's r	0.701**	-0.196**	0.241**	0.717**	-0.400**	-0.235**	0.017	-0.586**	1.00	
Sig.(1-tailed)	0.000	0.014	0.003	0.000	0.000	0.008	0.422	0.000	-	
N	125	126	125	128	128	104	129	128	129	
Log10_Ca										
Pearson's r	0.257**	0.720**	-0.364**	-0.086	0.117	0.288**	0.005	0.508**	-0.433**	1.00
Sig.(1-tailed)	0.002	0.000	0.000	0.167	0.094	0.002	0.479	0.000	0.000	-
N	125	126	125	128	128	104	129	128	129	129

Table 7: Pearson Correlations Coefficients for transformed trace element data
Note: total sample size is n=129.Outliers have been removed from dataset. This table illustrates only those elements that were deemed acceptable for statistical analysis
** = Correlation is significant at the 0.01 level (1-tailed)
* = Correlation is significant at the 0.05 level (1-tailed)

Grouping	RANK	Log Determinant.
Peace Bridge (1)	6	-33.268
Port Colborne (2)	6	-33.902
East Amherst (3)	6	-32.367
Williamsville (4)	6	-36.114
Centerpointe (5)	6	-36.134
Pooled within-groups	6	-30.264

Table 8: Log Determinants of Discriminant Analysis Groupings
Note: total sample size is n=129.Outliers have been removed from dataset

			Predicted Group Membership					
		Grouping	Peace Bridge	Port Colborne	E.Amherst	Williamsville	Centerpointe	Total
Original	Count	Peace Bridge	32	3	0	4	0	39
		Port Colborne	43	3	0	1	0	8
		East Amherst	0	1	40	2	5	48
		Williamsville	0	0	4	8	3	15
		Centerpointe	0	0	2	0	12	14
	Percent	Peace Bridge	82.1	7.7	0	10.3	0	100
		Port Colborne	50	37.5	0	12.5	0	100
		East Amherst	0	2.1	83.3	4.2	10.4	100
		Williamsville	0	0	26.7	53.3	20	100
		Centerpointe	0	0	14.3	0	85.7	100
Cross-Validated	Count	Peace Bridge	30	3	1	5	0	39
		Port Colborne	4	3	0	1	0	8
		East Amherst	0	1	39	2	6	48
		Williamsville	0	0	5	6	4	15
		Centerpointe	0	0	2	0	12	14
	Percent	Peace Bridge	76.9	7.7	2.6	12.8	0	100
		Port Colborne	50	37.5	0	12.5	0	100
		East Amherst	0	2.1	81.3	4.2	12.5	100
		Williamsville	0	0	33.3	40.0	26.7	100
		Centerpointe	0	0	14.3	0	85.7	100

Table 9: Discriminate Analysis classification results for all geological samples
Note: total sample size is n=129.Outliers have been removed from dataset. Cross-validation is done only for those cases used in the analysis. In cross validation, each case is classified by the functions derived from all other cases other than that case. 76.6% of original grouped cases correctly classified. 72.6% of cross-validated grouped cases correctly classified.

	Peace Bridge	Port Colborne	East Amherst	Williamsville	Centerpointe
Peace Bridge					
Port Colborne	4.727				
East Amherst	42.261	14.819			
Williamsville	16.954	8.019	6.304		
Centerpointe	26.695	93.973	8.778	5.024	

Table 10: Pairwise Group Comparisons for all geological samples

Sample	Predicted Group Membership	Posterior Probability	Second Group Membership	Posterior Probability
Feature 73- Peace Bridge East Truck Pad	East Amherst	0.772	Port Colborne	0.074
Feature 73- Peace Bridge East Truck Pad	Peace Bridge	0.402	Port Colborne	0.396
Feature 73- Peace Bridge East Truck Pad	East Amherst	0.402	Port Colborne	0.335
AiGx-197 P8 (Waterdown Flamborough)	East Amherst	0.565	Peace Bridge	0.391
AlGv-177 P5 (Crooked Creek)	Port Colborne	0.953	Peace Bridge	0.023
AjGw-112 (Morning star)	East Amherst	0.413	Peace Bridge	0.387
AlGv-148 P3 (Greenwood site)	Port Colborne	0.605	Peace Bridge	0.303
AlGv-148 P3 (Greenwood site)	Port Colborne	0.521	Peace Bridge	0.314

Table 11: Discriminate Analysis classification results for archaeological samples using all geological samples
Posterior probabilities are a function of the distance from the group mean centroid to the case study – i.e. a low probability of membership can be interpreted as a large distance from the case to the group centroid.

	Peace Bridge	East Amherst	Williamsville	Centerpointe
Peace Bridge				
East Amherst	52.324			
Williamsville	18.809	7.560		
Centerpointe	28.041	8.208	3.749	

Table 12: Pairwise Group Comparisons for pooled Peace Bridge and Port Colborne geological samples

		Grouping	Predicted Group Membership Peace Bridge	E.Amherst	Williamsville	Centerpointe	Total
Original	**Count**	Peace Bridge	40	1	5	1	47
		East Amherst	1	41	2	4	48
		Williamsville	0	3	6	6	15
48		Centerpointe	0	2	1	11	14
	Percent	Peace Bridge	85.1	2.1	10.6	2.1	100
		East Amherst	2.1	85.4	4.2	8.3	100
		Williamsville	0	20	40	40	100
		Centerpointe	0	14.3	7.1	78.6	100
Cross-Validated	**Count**	Peace Bridge	39	2	5	1	47
		East Amherst	1	40	2	5	48
		Williamsville	0	3	6	6	15
		Centerpointe	0	2	1	11	14
	Percent	Peace Bridge	83.0	4.3	10.6	2.1	100
		East Amherst	2.1	83.3	4.2	10.4	100
		Williamsville	0	20	40	40	100
		Centerpointe	0	14.3	7.1	78.6	100

Table 13: Discriminate Analysis classification results for all geological samples with the Peace Bridge and Port Colborne samples pooled (identified as Peace Bridge)
Note: total sample size is n=129.Outliers have been removed from dataset. Cross-validation is done only for those cases used in the analysis. In cross validation, each case is classified by the functions derived from all other cases other than that case. 79.0% of original grouped cases correctly classified. 77.4% of cross-validated grouped cases

Sample	Predicted Group Membership	Posterior Probability	Second Group Membership	Posterior Probability
Feature 73- Peace Bridge East Truck Pad	East Amherst	0.798	Williamsville	0.097
Feature 73- Peace Bridge East Truck Pad	Peace Bridge	0.707	East Amherst	0.274
Feature 73- Peace Bridge East Truck Pad	East Amherst	0.543	Peace Bridge	0.421
AiGx-197 P8 (Waterdown Flamborough)	Peace Bridge	0.785	Williamsville	0.205
AlGv-177 P5 (Crooked Creek)	East Amherst	0.964	Peace Bridge	0.022
AjGw-112 (Morning star)	Peace Bridge	0.662	Williamsville	0.262
AlGv-148 P3 (Greenwood site)	Peace Bridge	0.752	Williamsville	0.150
AlGv-148 P3 (Greenwood site)	Peace Bridge	0.608	Williamsville	0.363

Table 14: Discriminate Analysis classification results for archaeological samples using pooled geological samples from Peace Bridge and Port Colborne
Posterior probabilities are a function of the distance from the group mean centroid to the case study – i.e. a low probability of membership can be interpreted as a large distance from the case to the group centroid.

			Predicted Group Membership		
		Grouping	**Peace Bridge**	**E.Amherst**	**Total**
Original	**Count**	Peace Bridge	35	4	39
		East Amherst	2	6	8
	Percent	Peace Bridge	89.7	10.3	100
		East Amherst	25	75	100
Cross-Validated	**Count**	Peace Bridge	35	4	39
		East Amherst	3	5	8
	Percent	Peace Bridge	89.7	10.3	100
		East Amherst	37.5	62.5	100

Table 15: Discriminate Analysis classification results for all geological samples with the Peace Bridge and Port Colborne samples pooled (identified as Peace Bridge)
Note: total sample size is n=56.Outliers have been removed from dataset. Cross-validation is done only for those cases used in the analysis. In cross validation, each case is classified by the functions derived from all other cases other than that case. 87.2% of original grouped cases correctly classified. 85.1% of cross-validated grouped cases

Sample	Predicted Group Membership	Posterior Probability	Second Group Membership	Posterior Probability
Feature 73- Peace Bridge East Truck Pad	Peace Bridge	0.974	Port Colborne	0.026
Feature 73- Peace Bridge East Truck Pad	Peace Bridge	0.951	Port Colborne	0.049
Feature 73- Peace Bridge East Truck Pad	Peace Bridge	0.896	Port Colborne	0.104
AiGx-197 P8 (Waterdown Flamborough)	Peace Bridge	0.854	Port Colborne	0.146
AlGv-177 P5 (Crooked Creek)	Peace Bridge	0.971	Port Colborne	0.029
AjGw-112 (Morning star)	Peace Bridge	0.883	Port Colborne	0.117
AlGv-148 P3 (Greenwood site)	Peace Bridge	0.779	Port Colborne	0.221
AlGv-148 P3 (Greenwood site)	Peace Bridge	0.947	Port Colborne	0.053

Table 16: Discriminate Analysis classification results for archaeological samples using only the Peace Bridge and Port Colborne geological data
Posterior probabilities are a function of the distance from the group mean centroid to the case study – i.e. a low probability of membership can be interpreted as a large distance from the case to the group centroid. In discriminat analysis with only two potential groups of membership, posterior probabilities for group membership will sum to a value of 1.0.

APPENDIX 1: INAA Data Summary

Sample #	Outcrop	U	Dy	Ba	Ti	Sr	I	Br	Mg%	Si%	Na%	V	K	Al%	Mn	Cl	Ca%	Co	Cu
PB1	Peace Bridge (subsilt)	<0.0858	0.197	<10.40	171	<17	<0.322	3.38	0.075	45	0.0343	5.66	1599	0.443	23.1	586	0.383	<0.638	<21.50
PB2	Peace Bridge (subsilt)	<0.0745	<0.0623	<8.500	<49.1	<14	<0.257	3.23	0.089	47	0.0292	3.8	1025	0.314	8.67	584	0.702	<0.559	<19.10
PB3	Peace Bridge (L.paleosol)	<0.0926	<0.0780	<11.00	<54.4	<18	<0.337	4.22	0.103	47	0.0329	4.45	1127	0.297	9.05	837	0.779	<0.653	<20.60
PB4	Peace Bridge (L.paleosol)	<0.0835	<0.0738	<10.30	122	<16	<0.295	4.31	0.081	47	0.0332	3.54	1236	0.311	7.47	734	0.836	<0.584	<20.10
PB5	Peace Bridge (L.paleosol)	<0.131	<0.117	<17.10	<85.5	<31	<0.585	4.56	0.104	46	0.0375	3.99	1429	0.336	71.3	691	0.525	<0.882	<24.70
PB6	Peace Bridge (L.paleosol)	<0.0942	<0.0802	<11.10	125	<18	<0.338	3.54	<0.023	45	0.0377	2.3	<415	0.228	9.87	649	0.0594	<0.667	<22.00
PB7	Peace Bridge (L.paleosol)	<0.0963	<0.0845	36.5	<57.5	<22	<0.361	4.91	0.159	46	0.0507	4.78	982	0.343	11.1	837	0.547	<0.671	<22.70
PB8	Peace Bridge (L.paleosol)	<0.0932	<0.0800	<14.40	114	<21	<0.346	3.26	<0.025	45	0.0357	2.83	<435	0.387	13.7	641	<0.0268	<0.658	<22.30
PB9	Peace Bridge (U.paleosol)	<0.103	<0.0888	<16.10	<58.8	<23	<0.377	5.75	0.092	45	0.0373	3.85	1171	0.344	14.4	845	0.736	<0.726	<25.10
PB10	Peace Bridge (U.paleosol)	<0.0976	<0.0862	<15.40	<54.7	<22	<0.343	5.79	0.093	46	0.0346	2.55	1150	0.298	10.1	885	0.996	<0.670	<21.40
PB11	Peace Bridge (U.paleosol)	<0.107	<0.0960	112	170	<25	<0.376	5.86	0.182	45	0.0433	6.66	1855	0.535	18.1	694	1.21	<0.816	<20.70
PB12	Peace Bridge (U.paleosol)	<0.127	<0.115	<20.50	<70.5	<26	<0.395	5.09	0.084	47	0.0401	3.4	1079	0.412	9.1	753	1.13	<0.858	<26.10
PB13	Peace Bridge (U.paleosol)	<0.103	<0.0957	<17.00	158	<20	<0.302	3.84	0.041	47	0.0356	2.39	<385	0.363	5.51	499	0.308	<0.650	<15.40
PB14	Peace Bridge (U.paleosol)	<0.107	<0.0929	<19.00	205	<24	<0.348	6.19	0.141	43	0.0425	3.77	1432	0.32	11.3	811	1.02	<0.756	<20.40
PB15	Peace Bridge (U.paleosol)	<0.132	<0.117	<20.90	<74.8	<31	<0.438	6.16	0.112	48	0.04	2.8	<582	0.283	10.2	853	1.07	<0.925	<29.10
PB16	Peace Bridge (U.paleosol)	<0.131	<0.117	<20.90	166	<30	<0.466	7.63	0.159	47	0.045	5.39	1863	0.353	10.2	1023	0.57	<0.858	<26.30
PB17	Peace Bridge (U.paleosol)	<0.0977	<0.0863	<15.80	110	<23	<0.358	5.54	0.218	46	0.044	3.77	<512	0.252	17.9	741	0.606	<0.631	<17.70
PB18	Peace Bridge (U.paleosol)	<0.108	<0.0954	<17.20	<59.0	<24	<0.366	5.86	0.155	43	0.0351	4.66	<576	0.407	11.3	803	1.28	<0.712	<18.90
PB19	Peace Bridge (U.paleosol)	<0.142	<0.135	<23.30	<63.7	<33	<0.518	5.52	0.109	47	0.0451	4.59	<881	0.4	9.06	860	0.538	<0.884	<25.10
PB20	Peace Bridge (U.paleosol)	<0.119	<0.112	<20.00	<57.2	<28	<0.425	6.74	0.179	47	0.0468	4.26	2165	0.349	10.7	931	0.561	<0.757	<22.70
PB21	Peace Bridge (U.paleosol)	<0.126	<0.116	<20.90	177	<30	<0.439	5.74	0.116	46	0.0545	4.49	1622	0.386	10.7	912	0.45	<0.819	<23.40
PB22	Peace Bridge (L.paleosol)	<0.110	<0.109	<19.60	130	<26	<0.399	5.67	0.155	45	0.0435	3.29	<695	0.3	12	875	1.57	<0.707	<17.70
PB23	Peace Bridge (L.paleosol)	<0.115	<0.107	<18.60	<52.5	<27	<0.419	5.22	0.097	44	0.0467	2.83	<672	0.273	13.6	787	0.325	<0.729	<20.00
PB24	Peace Bridge (L.paleosol)	<0.375	<0.108	<19.30	<54.2	<30	<0.433	5.79	0.104	46	0.0402	3.49	<703	0.286	26.2	818	1.19	<0.732	<20.20
PB25	Peace Bridge (L.paleosol)	<0.126	<0.124	<21.80	134	<30	<0.449	5.68	0.144	46	0.0486	4.25	1668	0.379	9.42	899	0.907	<0.771	<21.60
PB26	Peace Bridge (L.paleosol)	<0.0986	<0.0952	<16.90	96.4	<24	<0.344	4.95	0.043	47	0.0365	3.35	1433	0.299	5.76	762	0.344	<0.587	<14.10
PB27	Peace Bridge (L.paleosol)	<0.0994	<0.0904	<16.10	93.9	<23	<0.350	5.9	0.119	48	0.0373	2.84	1333	0.316	9.72	888	0.995	<0.635	<17.10
PB28	Peace Bridge (L.paleosol)	<0.120	<0.110	<20.00	<57.7	<29	<0.432	5.91	0.134	46	0.0376	2.95	1367	0.303	9.64	947	0.7	<0.784	<23.30
PB29	Peace Bridge (L.paleosol)	<0.112	<0.103	<18.60	<59.1	<27	<0.403	5.21	0.13	46	0.0446	4.07	1548	0.312	10.2	872	0.731	<0.753	<21.30
PB30	Peace Bridge (L.paleosol)	<0.141	<0.120	<21.80	<86.8	<31	<0.480	4.52	<0.046	44	0.039	4.36	1542	0.383	12.5	942	0.129	<1.010	<37.40
PB31	Peace Bridge (L.paleosol)	<0.101	<0.0919	<16.20	107	<23	<0.353	6.78	0.099	45	0.0388	3.15	1289	0.251	9.42	866	0.345	<0.657	<18.50
PB32	Peace Bridge (L.paleosol)	<0.100	<0.0908	37.3	<55.3	<23	<0.366	6.63	0.158	44	0.0406	4.34	1450	0.346	9.32	886	0.453	<0.689	<22.50
PB33	Peace Bridge (U.paleosol)	<0.124	<0.113	<15.90	<61.2	<26	<0.484	4.85	0.119	44	0.0567	2.7	<611	0.296	12	985	0.55	<0.806	<27.60
PB34	Peace Bridge (U.paleosol)	<0.146	<0.132	<24.00	<73.5	<34	<0.488	6.45	0.164	46	0.0497	4.34	1610	0.424	13.1	916	0.892	<0.955	<28.50
PB35	Peace Bridge (U.paleosol)	<0.117	<0.106	<19.50	141	<28	<0.420	6.62	0.195	45	0.0501	4.26	<633	0.423	11	860	1.02	<0.759	<21.50
PB36	Peace Bridge (U.paleosol)	<0.114	<0.103	<18.30	<59.1	<25	<0.391	5.57	0.161	42	0.0459	2.14	1307	0.318	8.6	883	0.819	<0.770	<23.40
B.0013a	Peace Bridge (L.silt)	0.4	0.27	<13	236	<17	<.39	7.05	N/A	46.1	0.04055	8.7	2130	0.51	27.8	711.75	0.193	<.66	<31
B.0013b	Peace Bridge (L.silt)	0.26	0.13	<13	<52	<16	<.37	9.15	N/A	45.5	0.0484	4.1	1360	0.32	19.5	909.25	0.8235	<.67	<33
B.0013c	Peace Bridge (L.silt)	0.31	<.096	<16	156	<24	<.56	9.9	N/A	46.1	0.0484	5.1	1920	0.13	15.8	885.25	0.69765	<.73	<32
A1	Colborne/Ansari	<0.0853	<0.0751	<13.50	125	<20	<0.313	7.1	0.053	46	0.0494	3.31	1005	0.281	17.8	984	0.0963	<0.580	<17.70
A2	Colborne/Ansari	<0.103	<0.0922	<16.90	119	<23	<0.337	6.22	0.114	43	0.0351	3.13	1179	0.388	10.7	852	0.684	<0.652	<17.60
A3	Colborne/Ansari	<0.131	<0.118	<21.40	<69.1	<29	<0.430	5.3	0.182	47	0.0391	2.94	<687	0.456	12.7	864	1.38	<0.841	<25.30
A4	ColborneAnsari	<0.101	<0.0903	<16.20	108	<23	<0.344	4.25	0.159	43	0.0357	2.83	<510	0.282	11.3	831	1.56	<0.659	<19.80
P1	Port Colborne	<0.382	0.881	<63.30	<227	<91	<1.370	<5.450	0.478	<26.	0.0422	7.86	<1701	0.504	67.9	326	26.9	<2.450	<65.00
P2	Port Colborne		<0.378	<67.20			<1.400	<5.740	0.421		-		<1867	0.547		504	20	<2.690	<70.80
P3	Port Colborne	<0.172	<0.157	<28.20	<98.6	<37	<0.595	7.05	0.182	42	0.0642	<1.700	<803	0.273	9.86	813	2.58	<1.170	<36.30
P4	Port Colborne	<0.141	<0.125	<21.70	<79.1	<33	<0.501	5.58	0.174	44	0.0683	<1.400	<685	0.279	10.6	873	1.53	<0.988	<31.00
P5	Port Colborne	<0.150	<0.139	<24.20	<76.0	<36	<0.529	5.17	0.208	43	0.0668	<1.200	<804	0.26	11.2	854	2.42	<0.966	<28.20
F73-1	Feature 73 - Peace Bridge - east truck park	N/A	N/A	15.1	70.5	22.5	<1.22	5.8	0.161	48	0.0499	3.7	1093	0.285	12.9	694	0.484	<0.591	<16.10
F73-2	Feature 73 - Peace Bridge - east truck park	N/A	N/A	9.82	92.4	15.6	<1.20	4.69	0.0764	48	0.0497	3.29	1108	0.272	11.5	644	0.222	<1.380	<18.50
F73-3	Feature 73 - Peace Bridge - east truck park	N/A	N/A	11.5	124.2	24	<1.26	5.1	0.162	47	0.0461	3.13	974	0.262	11	639	0.988	<1.630	<18.90
OS-1	AiGx-197 (95TL-02) - P8 (Waterdown)	N/A	N/A	<9.990	87.5	<18.50	<1.07	4.18	0.0417	48	0.0259	2.66	800	0.21	30.1	535	0.0906	<1.310	<16.10
OS-2	AlGv-177 (00PY-01) - P5 (Crooked Creek)	N/A	N/A	9.18	100.5	15.8	<1.02	5	0.0249	48	0.0364	3.61	884	0.237	10.3	535	0.0519	<1.830	<19.80
OS-3	AjGw-112 (88ED-01) (Morning star)	N/A	N/A	10.7	<57.70	19.5	<1.20	5.1	0.0406	44	0.0368	4.1	764	0.216	20.3	605	0.0586	<2.250	<22.10
OS-4	AlGv-148 (95VT-02) - P3 (Greenwood)	N/A	N/A	11.3	<55.80	17.2	<1.11	4.67	0.0434	47	0.0318	2.67	840	0.219	18.9	569	0.284	<1.030	<21.20
OS-5	AlGv-148 (95VT-02) - P3 (Greenwood)	N/A	N/A	12.5	110.7	22.9	<1.41	4.7	<0.0269	46	0.0402	3.91	815	0.241	27	611	0.0504	<1.500	<27.10

10 000ppm=1%

> detection limit data at 68% confidence - estimated highest amount of element that could be present and not measurable

NOTE: All concentrations in ppm unless otherwise noted

APPENDIX 2: Sample Descriptions

Sample #	Provenience	Unit	Cortex Present?	Weathered?	Mottling/Banding Present?	Fossils Present?	Color (Munsell Description)
P1	Peace Bridge (subsilt)	Unit 12	yes	yes	yes	no	7.5YR 5/2- brown (85%) and 10YR6/2 - gray (15%)
P2	Peace Bridge (subsilt)	Unit 12	no	yes	yes	no	7.5YR 5/2 - brown (85%) and 10YR 6/2 - gray (15%)
P3	Peace Bridge (L.paleosol)	Unit 13	yes	yes	no	no	5YR 5/1- gray (100%)
P4	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	7.5YR 4/1 - dark gray (80%) mottled with 5YR 5/1- white(20%)
P5	Peace Bridge (L.paleosol)	Unit 13	yes	yes	yes	no	7.5YR 4/1- dk.gray (70%) mottled with 7.5YR 7/1- light gray (15%) and 5YR white (15%)
P6	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	yes	7.5YR 5/2 -brown (80%) mottled with 7.5YR 7/1- light gray (20%)
P7	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	yes	7.5YR 3/1- very dk. gray (90%) mottled with 7.5YR 5/1- gray (10%)
P8	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	5YR 7/2 - pinkish gray (80%) mottled with 5YR 8/1- white (20%)
P9	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	5YR 4/1- dk.gray (80%) banded with 5YR 7/1- light gray (10%) and 5YR 2.5/1- black (10%)
P10	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	2.5YR 5/1- reddish gray (85%) mottled with 5YR 8/1- white (15%)
P11	Peace Bridge (U.paleosol)	Unit 13	yes	yes	yes	no	7.5YR 3/1- v.dk.gray (85%) and 7.5YR 4/1- dk.gray (15%)
P12	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 5/1- gray (90%) 5YR 8/1- white (10%)
P13	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	N 7/ light gray- (90%) mottled with N 7/ gray- (Gley) (10%)
P14	Peace Bridge (U.paleosol)	Unit 13	yes	yes	yes	no	10YR 4/1 - v.dk.gray (80%) mottled with 10YR 4/2 - dk.grayish brown (20%)
P15	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	10YR 3/1- v.dk.gray (85%) mottled with 10YR 5/1- gray (15%)
P16	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 3/1- v.dk.gray (90%) mottled with 10YR 5/1 - gray (10%)
P17	Peace Bridge (U.paleosol)	Unit 13	yes	yes	yes	no	7.5YR 3/1- v.dk.gray (80%) mottled with 10YR 5/1 - gray (20%)
P18	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 4/1- dk.gray with small band of 7.5YR 5/1 gray (>5%)
P19	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 3/1 - v.dk.gray(50%) - 7.5YR 5/1 -gray (50%)
P20	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 3/1 - v.dk.gray(30%) - 7.5YR 5/1 -gray (70%)
P21	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 3/1 - v.dk.gray(30%) - 7.5YR 5/1 -gray (70%)
P22	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	10YR 4/1- dk.gray (90%) - light banding of 10YR 6/1- gray (10%)
P23	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	10YR 5/1 - gray (50%) banded with 2.5YR 8/1- white (50%)
P24	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	10YR 5/1 - gray (70%) mottled with 10YR 5/3 brown (30%)
P25	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	10YR 4/1 dk.gray(85%) banded with 10YR 7/1-light gray (15%)
P26	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	yes	10YR 4/1 - dk. gray (60%) banded with 10YR 7/1- light gray (20%) and 10 YR 6/1 - gray (20%)
P27	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	7.5YR 4/1- dk.gray (90%) mottled with small amounts of 7.5YR 4/2 - brown (10%)
P28	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	7.5YR 4/1- dk.gray (90%) mottled with small amounts of 7.5YR 4/2 - brown (10%)
P29	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	yes	7.5YR 4/1 - dk.gray (80%) banded with 10YR 6/1 - gray (10%) and 10YR 2/1 - black (10%)
P30	Peace Bridge (L.paleosol)	Unit 13	no	yes	no	no	10YR 3/1 - black (100%)
P31	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	10YR 4/1 - dk. gray (60%) banded with 10YR 7/1 - light gray (20%) and 10YR 6/1- gray (20%)
P32	Peace Bridge (L.paleosol)	Unit 13	no	yes	yes	no	10YR 4/1 - dk. gray (70%) banded with 10YR 7/1- light gray (20%) and 10YR 6/1 - gray (10%)
P33	Peace Bridge (U.paleosol)	Unit 13	no	yes	yes	no	7.5YR 5/1- v.dk.gray (60%) banded with 7.5YR 5/3- brown (20%) and 7.5YR 7/1- light gray (20%)
P34	Peace Bridge (U.paleosol)	Unit 13	yes	yes	yes	no	7.5YR 5/1 (v.dk.gray) (80%) mottled with 7.5 YR 7/1 (light gray (20%)
P35	Peace Bridge (U.paleosol)	Unit 13	no	no	yes	no	7.5YR 5/1 - v.dk.gray (80%) mottled with 7.5YR 7/1- light gray (10%) and 7.5YR 5/3 - brown (10%)
P36	Peace Bridge (U.paleosol)	Unit 13	no	no	yes	no	7.5YR 5/1- v.dk.gray (80%) mottled with 7.5 YR 7/1- light gray (10%)
B.0013a	Peace Bridge (L.silt)	Unit 13	yes	yes	yes	no	7.5YR 4/1- dk.gray (85%) mottled with 10YR 5/1 - gray (10%) and 10YR 7/1- gray (5%)
B.0013b	Peace Bridge (L.silt)	Unit 13	no	yes	yes	no	7.5YR 4/1- dk.gray (85%) mottled with 10YR 5/1 - gray (10%) and 10YR 7/1- gray (5%)
B.0013c	Peace Bridge (L.silt)	Unit 13	no	no	yes	no	7.5YR 4/1- dk.gray (85%) mottled with 10YR 5/1 - gray (10%) and 10YR 7/1- gray (5%)
A1	Colbourne/Ansari	Feature 3	no	yes	yes	no	2.5Y 4/1 - dark gray (85%) mottled with 10YR 6/1- grey(15%)
A2	Colbourne/Ansari	Feature 3	no	yes	yes	no	2.5Y 4/1 - dark gray (85%) mottled with 10YR 6/1- grey(15%)
A3	Colbourne/Ansari	Feature 3	no	yes	yes	no	2.5Y 4/1 - dark gray (75%) mottled with 10YR 6/1- gray (15%) and 10YR 3/1- v.dk.gray (10%)
A4	Colbourne/Ansari	Feature 3	yes	yes	yes	no	2.5Y 4/1- dark gray (85%) mottled with 10YR 6/1- gray (15%)
P1	Port Colbourne	n/a	yes	yes	yes	no	10YR 3/2 - v.dk.grayish brown (90%) mottled with 10 YR 7/1- light gray (10%)
P2	Port Colbourne	n/a	yes	yes	no	no	10YR.3/2- v.dk.grayish brown (100%)
P3	Port Colbourne	n/a	no	no	no	no	7.5YR 3/1 v.dk.gray (100%)
P4	Port Colbourne	n/a	no	no	yes	no	7.5YR 3/1- v.dk.gray (50%) and 7.5 YR 4/1- dk.gray (50%)
P5	Port Colbourne	n/a	no	no	yes	no	7.5YR 3/1- v.dk.gray (50%) and 7.5 YR 4/1- dk.gray (50%)
F73-1	Feature 73 - Peace Bridge	East Truck Park	no	yes	yes	no	7.5YR4/1- dk.gray (80%) mottled with 7.5 YR 7/1- light gray (20%)
F73-2	Feature 73 - Peace Bridge	East Truck Park	no	yes	yes	no	7.5YR 5/1- v.dk.gray (85%) mottled with 7.5 YR 7/1- light gray (15%)
F73-3	Feature 73 - Peace Bridge	East Truck Park	no	yes	yes	no	7.5YR 5/1- v.dk.gray (90%) mottled with 7.5 YR 7/1- light gray (10%)
OS-1	AiGx-197- P8 (Waterdown)	n/a	no	yes	yes	no	10YR 5/1 - gray (50%) banded with 2.5YR 8/1- white (50%)
OS-2	AlGv-177- P5 (Crooked Creek)	n/a	no	yes	yes	no	10YR 4/1 - dk. gray (60%) banded with 10YR 7/1- light gray (20%) and 10 YR 6/1 - gray (20%)
OS-3	AjGw-112 - (Morning star)	n/a	no	yes	yes	no	2.5Y 4/1- dark gray (80%) mottled with 10YR 6/1- gray (20%)
OS-4	AlGv-148 - P3 (Greenwood)	n/a	no	yes	yes	no	10YR 4/1 - dk. gray (80%) banded with 10YR 7/1- light gray (20%)
OS-5	AlGv-148 - P3 (Greenwood)	n/a	no	yes	yes	no	10YR 4/1 - dk. gray (70%) banded with 10YR 7/1- light gray (30%)