DATING AND PROVENANCING OF SHERDS FROM FIVE BALSAM LAKE AREA SITES

by

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A Thesis

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DATING AND PROVENANCING OF SHERDS FROM FIVE BALSAM LAKE AREA SITES

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ABSTRACT

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This thesis provides additional insight on the occupation of the upper Trent River valley of Ontario by Iroquoian people during the period of approximately one hundred years that preceded the eventual consolidation of the Huron Confederacy in Simcoe County. The data are obtained by means of an archaeometric analysis of ceramic sherds recovered at late Iroquoian sites located in the Balsam Lake area.

The results of the research support the hypothesis that these communities were impacted by the early effects of European trade. Dating of the ceramic by thermo luminescence confirms and refines the chronological sequence for these sites suggested previously by others through stylistic analysis. Determination of ceramic fabric composition by trace element analysis supports the proposed transition of the interactions between the local population and the St. Lawrence Iroquois from trading relationships to eventual absorption of the latter into the local Huron communities.

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1 - GENERAL BACKGROUND

One problem in Ontario prehistory which has not yet been entirely resolved involves the Native populations whose traces have been discovered in the Balsam Lake area of south-central Ontario (Ramsden, 1988a, 1988b). The general sequence of events dealing with their development and with their relations with their eastern neighbours, the St. Lawrence Iroquois, which has been proposed as most logical is based on the stylistic analysis of recovered ceramics.

This technique has been used both to date sites and to postulate the increase in contact with and the eventual absorption of St. Lawrence Valley people. Indeed, on the basis of stylistic dates, the presence of metal artefacts at some Balsam Lake sites has led also to the inference that European goods had reached the people in this region prior to contact along a well established route (Ramsden, 1978: 105)

According to Ramsden (1988: 46) the early Iroquoian occupation of the Balsam Lake area had begun by approximately AD 1200 and lasted for some four hundred years. During the fifteenth century people appear to have inhabited small and scattered non palisaded villages located on sites which were not chosen with any regard to defence. The material culture which emerges from the artefacts recovered at these sites appears to be homogeneous. "However a distinctive characteristic that sets it apart from the material culture of other contemporaneous Huron sites is the unusual predominance of certain design motifs on ceramic pots of local manufacture" (Ramsden, 1988: 46).

In the sixteenth century changes appear to occur in the Balsam Lake area. Distinctive ceramics in the style of the St. Lawrence Valley Iroquois start to be found

among the material recovered from sites of this period. As well the first fragments of European copper are recovered. Excavations at sites such as Jamieson and Kirche have unearthed signs of progressively more extensive palisades being erected around villages. At the latter site there is evidence of palisade and house expansions which have suggested the need to accommodate the arrival from other regions of Ontario of newcomers intent on exploiting European trade (Ramsden, 1988: 47).

The excavation of the Coulter site, which has been dated somewhat later than Jamieson and Kirche, shows evidence of several palisade extensions some of which have been interpreted as "compounds ... outside of the main stockade to enclose groups of outsiders' houses" (Ramsden, 1988: 47). Of interest is the fact that different style Huron pottery was found in various areas of the village. Several metal artefacts of European manufacture have been also recovered as well as significant amounts of St. Lawrence Iroquoian style ceramics. In his 1988 article Ramsden suggests that it is possible that by this time competition for access to trade routes may have become fierce. Thus the Huron attracted from diverse parts of southern Ontario by the potential of the lucrative exchanges with the European may have been enticed to amalgamate together as this improved their relative safety.

Excavation of the Benson site which has been dated to the end of the sixteenth century shows no signs of village expansion. However the village appears to have two areas one with prevalent Huron ceramic style and the other with significant amounts of St. Lawrence material. This has been interpreted as suggesting the possible absorption of the latter people into the Balsam Lake communities either as refugees or as captives (Ramsden, 1988: 48).

The questions that arise are associated with the correct dating of the archaeological materials and their differentiation by manufacturing sources: whether European material

did reach the Balsam Lake area early and whether the St. Lawrence Iroquois style ceramics recovered at the Balsam Lake Huron sites were produced locally or elsewhere and in which periods they were made.

The stylistic evidence for the Balsam Lake material has been interpreted to indicate the potential for different sources of production of the pottery at different times. Sites identified as "early" display ceramics which seem to be exclusively of local Huron manufacture, while sherds associated with St. Lawrence Iroquois styles begin to appear later and become more frequent over time. The sequence of events postulated from the presence of the latter styles proposes a peaceful stage leading to increased trade between the Huron and their eastern neighbours and a conflict stage leading to the destruction of the St. Lawrence Iroquois and their absorption into Balsam Lake communities. However, the dates assigned based on stylistic evidence to the later Balsam Lake sites in which artefacts of European metal have been recovered are so critically close to the time of contact that they warrant closer study.

Temporal context for material findings is essential to archaeology. It permits the placing of recovered material in the sequence of human cultural development and allows both comparisons between earlier and later periods and between contemporary cultures. Equally fundamental is the identification of the sources of the artefacts recovered, because they reveal not only the level of activity of the communities under examination but potentially also the exchanges and intercourse with adjoining and remote cultural entities.

Both are persistent problems in archaeology. Recovery of material with actual calender dates on it is generally restricted temporally and geographically and does not include Native artefacts from northeastern America.

Similarly the manufacturing source of archaeological artefacts is generally unknown except for those few items on which city of provenance or maker marks were stamped. North American material does not carry trademarks and as such it cannot be assigned directly to any one site.

It is therefore important to find other means to ascertain both temporal context and provenance of artefacts. Trigger among others advocates greater chronological precision and the improved analysis of pottery in support of enhanced interpretations of findings in Iroquoian Archaeology (Trigger, 1985: 73, 180).

Thermoluminescence (T-L) and trace element analysis are techniques which permit the consideration of these problems. One of their advantages is that they both can be applied to ceramics. "Ceramics are one of the tangible products of man's culture. Their relative widespread manufacture among cultures of the world, their relative imperishable quality, their persistence through time and their almost universal presence have made them a very important tool for the archaeologist in his study of the past" (Arnold, 1988: 1).

Ceramics not only have had widespread use but have been objects of exchange since their first production and reflect cultural historical relationships through time (Arnold, 1988: 14; Adams, 1979: 727-744; Grieder, 1975: 850 - 851). One of the common archaeological paradigms is that "culture is viewed as an integrated whole with its parts interacting in such a way that change in one part produced changes in one or more other parts" (Arnold, 1988: 10). This interrelatedness of culture paradigm affects the archaeological analysis of ceramic. As Trigger et al. say: "if clay used by different villages, tribal groups, or regions could be distinguished, pottery entering a site as a result of trade, visits or population movements could be differentiated from that made locally" (1980: 120). Therefore it is important to be able to discriminate between different sources of pottery production.



Portion of tree-ring calibration curve for ¹⁴C-dating covering the past 1600 years. (After Ralph, Michael, and Han (1973). MASCA Newsl. 9, 1.)

Figure 1

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The first evidence that thermal luminescence of pottery was related to its age dates to 1960 (Grogler et Al. 1960; Kennedy and Knopff, 1960). T-L has proved to be extremely useful as a technique and its applications have extended even beyond ceramics. One of its major advantages is that it does not require the significant correction necessary when radiocarbon is used for dating of certain periods (Figure 1). T-L yields results of a comparable degree of accuracy and cross-linking of ¹⁴C and T-L dates is in fact reported routinely by Oxford University through their AMS program.

In 1990, I carried out work on ceramic sherds and soils from several southern Ontario sites occupied in the sixteenth and seventeenth century and therefore relatively similar to the Balsam Lake sites in temporal terms. The dates determined in the analysis for sherds recovered from the Davey, Fournier and Train sites fall reasonably within historically supported values (Volterra et al., 1991: Figs. 17, 21). Unfortunately, however, in spite of its definite applicability to Ontario material, this technique appears to have enjoyed little use in Ontario Archaeology. Search of published literature has revealed no other such use of thermoluminescence in this region.

"Ceramics are related to the area in which they are made primarily through the material used for the pottery fabric. The identification of the mineral present in the paste is the most valid approach to the location of manufacture, but when supplemented by trace element analysis, more precise locational data can often be obtained. ... Different compositions may reveal different pottery making populations in different locations" (Arnold, 1985: 236. See also Cuomo di Caprio, 1985: 256 - 257).

Trace element analysis is a very powerful tool for the determination of material provenance and has been used extensively for a number of such studies (Croudace et al., 1988; Trigger et al., 1980). Yellin and Maeir (1992) used trace element analysis to study the possible

origin of a pottery "crater" from the Mycenaen tomb at Tel Dan, and Mirti et al. (1990) to discriminate between an array of Roman pottery imported into the ancient town of Aosta. Pena, of the American School in Rome, is currently employing Activation Analysis on Roman pottery being recovered from his ongoing excavation on the Roman Palatine. Picon, of the Laboratoire de Ceramologie de Lyon, who has been studying ancient amphoras and their sources of production for several years, is also believed to be using currently trace element analysis, although no results of his work have been published. This technology can be applied to a number of other natural materials as well as ceramics (Williams-Thorpe, 1988; Bahn, 1987; Hancock et al., 1991; Glascock et al., 1992; Mahaney et al., 1992; Volterra et al., 1994).

As is the case for thermoluminescence, this is not one of the analytical procedures used frequently by Ontario archaeologists and remains virtually unused in their research in spite of the results achieved by trace element analysis world wide. The studies carried out to date (Trigger et al., 1980) have been of limited scope. One can only assume that the reluctance to utilize both these procedures is due to the perceived cost associated with any scientific process and with the traditional wide acceptance of stylistic means of establishing temporal context and provenance for Native Ontario ceramics. It could also be due to the fact that such archaeological analyses most often involve material of restricted geographical provenance and therefore relative dating of local artefacts is sufficient in these cases.

However, to provide answers to progressively refined and complex questions, it will become increasingly necessary to confirm linkages between Native cultures which are not just based on stylistic analysis but which are objectively verifiable and therefore demand the employment of scientific determinations. It thus becomes vital to demonstrate the clear feasibility of applying such techniques to Ontario archaeological material.

Most Iroquoian sites "are not stratified or of long occupation and ... sequence of culture could not be readily established simply by the study of the levels or strata of a site" (MacNeish , 1952: 2). In the past this has led to analyses of pottery types, dating and provenancing on stylistic bases exclusively. This method of dating is based on the presence of attributes in artefacts which have been associated with specific time horizons and cultural expressions. "Certain aspects of the artefact will be used to create distinction of flavour, type of lid ... It is this which helps us to recognize that an object is from a certain period" (Miller, 1987: 112).

The problem with stylistic dating, which has been the method preferred until now, is that it is based on an assumed chronology through ceramic seriations. As indicated above these in turn are based on the adoption of attributes which are deemed to be diagnostic. Such measurements produce only relative chronologies with starting and ending points in different times but not anchored to definite dates and encompassing periods of unknown different durations.

"The discovery in the early years of the twentieth century that certain of the ad hoc categories [of artefacts], later termed *stylistic*, or *historical* classes, displayed predictable temporal distributions provided a new basis for systematic type construction ... The cultural-historical types that developed in this context were etic classes embedded in a materialistic notion of variability" (Dunnell, 1986: 190). The classification of artefacts as a chronological tool had been used successfully in Europe. There the durations of cultural occupation encountered in archaeological research were significant in allowing the development of subtle temporal scales. In the northeast, where the durations of site occupation were brief, comparably fine temporal scales have not been developed (Dunnell, 1986).

It is obvious that archaeological linkage between form and chronology is empirical and, at best, it can be a relative and etic form of measurement. Etic typologies per-se ignore the

question of why they change in time. But even emic typologies, which have been attempted more recently, cannot discriminate entirely between changes which are related to cultural-social developments and those that are strictly due to environmental constraints (Dunnell, 1986: 192 - 193). An example of the latter would be the discarding of rim castellations a s a result of the poor quality of clay available. As a result we have no absolute certainty that empirical seriations are consistent from site to site (Ramsden, 1977), particularly since temporal and spatial coherence are normally established stratigraphically. In the northeast the frequent relocation of people to new sites and their short occupations render problematic the chronological differentiation of locations by stylistic analysis of artefacts.

If not able to provide definite dates, stylistic analysis theoretically should at least permit the identification of the source of artefact manufacture. Miller in fact says that just as certain aspects of an artefact create a distinction which allows us to recognize that it belongs to a certain period, these same attributes indicate provenance from specific locations (Miller, 1987: 112).

Such an identification is a significant part of the analysis of cultural development. For example, "when pottery types belonging to different regional traditions are found in a particular site they have been variously interpreted as evidence of trade or the presence of female prisoners or refugees from elsewhere" (Trigger, 1980: 120). Unfortunately stylistic analysis cannot discriminate between the two alternatives though such differentiation would lead to significant variance in the interpretation of the archaeological record.

2 - RESEARCH PROGRAM

An appropriate research program for the study of Balsam Lake material would have to demonstrate that the use of thermoluminescence and trace element analysis is relevant for understanding the hypothesized developments which took place in the upper Trent Valley during the sixteenth century. The original hypothesis was based on the stylistic study of ceramics recovered at local sites. The present research analyzes the basic components of this material (clay and temper) by means of scientific techniques.

All clays have quite uniform gross chemical compositions. However they differ at the trace element level because of their geological origin. We know that south central Ontario material is quite uniform and yet it can be differentiated from St. Lawrence Valley material as indicated by Trigger et al. (1980) and Kennedy (1993). Therefore it is reasonable to expect that locally manufactured pottery, in spite of stylistic identification, will be distinguishable from artefacts imported from the St. Lawrence Valley on the basis of trace element composition.

Accordingly, in support of the hypothesis, I will demonstrate with my research that it is possible to determine, with the assistance of scientific techniques:

- that the sites examined can be placed in a chronological sequence which is consistent with the hypothesized development of the Balsam Lake people;
- (2) that the ceramic material recovered at early sites is uniform in composition as well as in style;
- (3) that St. Lawrence Valley style artefacts from later sites can be differentiated by means of their elemental compositions from ceramics considered of local manufacture;

(4) that both St. Lawrence and local style pottery recovered at the most recent sites have essentially similar compositions.

To ascertain whether the material to be studied was manufactured at different times, samples were analyzed by thermoluminescence. It was necessary to examine pottery sherds which had been recovered at different sites and had already been differentiated by date and style on the basis of visual attributes.

To establish a reasonable research program, the sites selected for study were considered sufficiently separated in time to represent the hypothesized stages of cultural development for the Balsam Lake area. The pottery to be tested was identified as either St. Lawrence Valley or local by previous researchers on clear stylistic bases.

To complete the research, a number of potential clay sources reasonably close to each of the sites were identified and appropriate samples collected and tested. "The distance of the sources from a potter's house is not random, arbitrary or unimportant but rather provides an important feedback relationship for pottery production. ... Ceramic sources must be close enough to a population in order to be easily exploited" (Arnold, 1985: 32). Jarman (1972: 705-733), Clark (1977: 31-57), Christenson (1982: 419-426), Doxiadis (1970: 393-404) and Browman (1976: 465-477) have all discussed extensively the relationship between distance from resources and economic costs and returns.

Thorough analysis is given by Arnold in chapter 2 of his 1985 book on ceramic theory and cultural process. In tables 2.1 and 2.2 he produces lists of distances between potter's residence and sources of clay and temper for sites in different parts of the world. These range from less than 1 km to a maximum of 30 km with the

statistical maximum threshold distance at 6 to 9 km for clay and from 0.1 to 8 km for temper (Arnold, 1985: 58). Beyond this range special conditions must exist to drive potters to seek resources, instead of acquiring pottery through trade or exchange. Accordingly, clay samples for analysis would have to be sought within such a radius from each site being studied.

Sand to be used for temper is present on surface throughout the Balsam Lake area and therefore Native potters would have had easy access to this resource. Clay is instead much more difficult to locate in this region as evidenced from map P.2596 from the Geological Series of the Ministry of Natural Resources of Ontario and maps 2130 and 2131 of the Ontario Department of Mines, as well as from the Soil Survey of Victoria County (Canadian Department of Agriculture, 1957: 12). Thus a balance must be sought between the obstacles offered by the nature of the terrain and vegetation and the limited presence of surficial clay deposits.

It should be noted that the area is laced with lakes and streams that would have been navigable by cance even in the earliest periods under consideration. It is therefore possible that potters may have wandered further afield than theorized by Arnold (1985: 104). This would have been much more likely in earlier times when the region was reasonably free of warfare as demonstrated by the lack of protective palisades at such sites as Hardrock (Wright, 1964; Heidenreich, 1971: 139; Trigger, 1976: 44).



Figure 2

3 - SELECTION OF MATERIALS

To meet the objective of the research design, sherds were selected from five sites which had been dated from approximately AD 1450 to AD 1600. They were chosen to represent a geographical clustering and a temporal distribution which reflect the change in the presence of St. Lawrence Iroquois pottery in the region, as identified on stylistic grounds (Figure 2). Samples included Huron as well as St. Lawrence Iroquois material.

In total thirty-nine ceramic sherds from Balsam Lake sites were selected for analysis. Site data and sherd sample details are shown on Figures 3, 4 and 5. Photographs of the sherds are shown on Figures 6 and 7.

The six Hardrock samples came from the University of Toronto collection and were chosen at random (with the assistance of the curator J. Reid). All the material collected at this early site, except for three pieces, has been identified by previous researchers as locally made Huron style ceramic. The remaining thirty-three sherds were chosen from the McMaster University collection with the assistance of Professor P. Ramsden. These samples were not selected at random but rather were chosen because of their identification with either the local or the St. Lawrence Valley Iroquois style, based on discriminating attributes. Two sherds from the Benson site which were considered of "hybrid" style were also included. This was done to determine whether the trace element analysis would discern a compositional difference between them and other sherds from the same site.

The McMaster samples were also selected so that they included sherds recovered from different areas of the sites (Figure 5). It was thought possible that the

SITES IN PRESUMED CHRONOLOGICAL ORDER

| SITE | STYLISTIC DATE | | |
|----------|--|--|--|
| Hardrock | 1450 (C^{14} 510 +/- 70 BP = 1482 +/_ 70) | | |
| Jamieson | 1500 - 1550 | | |
| Kirche | 1550 +/_ 20 | | |
| Coulter | 1550 - 1580 | | |
| Benson | 1580 +/_ 20 | | |
| | | | |

Figure 3

| SITE DATA | | | | | |
|-----------|--|------------------------|----------|--------------|--|
| Site | Sherds type and location | Site type | People | Europ. Goods | |
| Hardrock | Local | | Hardrock | None | |
| Jamieson | St. Lawrence/Local | Village expanded | HardrocK | None | |
| Kirche | St. Lawrence/Local outside/inside | Village expanded | Benson | One | |
| Coulter | St. Lawrence/Hybrid/Local North end/South end | Large site expanded | Benson | Several | |
| Benson | St. Lawrence/Hybrid/Local NE sector | Village | Benson | Several | |

Figure 4

| SAMPLE SELECTION | | | |
|------------------|--|--|--|
| Site | Sample | | |
| Hardrock | 6 Huron | | |
| Jamieson | 2 Huron 2 St. Lawrence | | |
| Kirche | Huron from inside the palisade St. Lawrence from inside the palisade St. Lawrence from outside the palisade Huron from outside the palisade | | |
| Coulter | 6 Huron from main stockade4 St. Lawrence from main stockade2 St. Lawrence from outside the main stockade | | |
| Benson | St. Lawrence from NE sector Huron from NE sector "Hybrid" Huron from S sector St. Lawrence from S sector | | |

Figure 5





results of their analyses might indicate some temporal or provenance differences among them.

In addition to the ceramic, samples of clays and soils from the Balsam Lake area were collected for analysis (Figure 8). The former were obtained in an attempt to identify the potential sources of raw material for the pottery which had been made locally.

Ontario prehistoric people carefully selected raw materials to be used for the manufacture of smoking pipes and would travel long distances to obtain the proper clay or, when this was not available, they would trade for the pipes themselves. However for all other artefacts in common use the choice of clay sources was based on access and convenience. It is therefore reasonable to expect that these would be located within close range of the occupational sites.

Current geological surveys indicate that clay beds in the area are quite limited; none appears to be located on or adjacent to any of the sites under consideration, though a number of deposits exist within a reasonable distance (approximately 10 km) and are relatively accessible. Sometimes small amounts of fine depositional material will accumulate in localized pockets which are not identified on large mineralogical maps. Accordingly a number of visits to the five sites and the surrounding region were carried out between May and November 1993 to attempt to identify the mapped beds and to locate, if possible, any such additional localized deposits.

In spite of this effort no clay was found at most of the sites or in immediately adjoining areas. Only at Jamieson was a small clay bed identified and at Kirche and Benson mixtures of sand rich in clay were discovered. The latter material was not believed to be entirely suitable for pottery making in view of the large non-plastic component present. However in both instances samples were retained for testing. In addition eight





other samples of clay were gathered from separate beds located in the region at various distances from the sites (Figure 8).

All samples were collected at least 50 cms. below the present surface of the deposits except for those collected from roadside ditches in open cuts (samples 63, 68, 72 and 73) where tertiary deposits of clay appeared very shallow. All material was bagged and properly tagged.

4 - TECHNIQUES AND METHODOLOGY

Dating

The ability to associate dates with events long past, for which at times only limited physical evidence remains, has been essential for archeology from its early inception. The painstaking approaches taken by archaeologists in attempting to assign a temporal dimension to findings moderate the uncertainty resulting from the multiplicity of individual opinions.

However, notwithstanding careful classification of artiefacts and structures, the aesthetic and stylistic identification of findings has through the years yielded much debate based solely on partisan interpretations which could not be supported in a factual sense. Fortunately our capacity to measure and discern has increased with the development and application of new scientific approaches to archaeological research (Rainey, 1977: ix).

The utilization of new methods has improved the researchers' capacity to classify and establish sequences and to identify provenance and sources. Their application to the search for and the interpretation of the past has been rapid and in fact appears to have accelerated in recent years with the development of an array of electronic, physicochemical and computerized technologies (Rainey, 1971: ix).

New data obtained through these are currently revolutionizing established archaeological interpretations of human development, as in the case of the relationship between Neanderthal and Sapiens (Stringer, 1988; Valladas et al., 1988) or the debate around the earliest evidence of human presence in North America (Dillehay, et al. 1980). It is not unusual to seek supplemental evidence in support of carbon dating because, while generally accepted as a valuable tool by archaeologists, it is certainly not a method that can be employed unquestioningly in all instances. It is now well known that there exist and have existed in the past severe fluctuations in cosmic ray emissions resulting in varying ¹⁴C concentrations in the atmosphere. This would therefore result in different levels of carbon isotope absorption by living organisms. Confirmation of these variations becomes evident when radiocarbon dates are compared with dendrochronological ones determined for the same specimens (Figure 1). It should be noted that for the time period under study here the correction required for ¹⁴C dates is the most significant of the entire correlation. This renders any radiocarbon dates for all the Balsam Lake sites highly suspect (see also Dragoo, 1974: 26 and Timmins, 1985: 58a).

Furthermore it is also now well understood that considerable care must be taken in choosing and handling field recovered material to ensure contextual discrimination. Carbon, for example, is often found in the form of small particles which are normally more mobile than other larger material. It is also essential to avoid contamination with more recent organics.

The procedures involved in the recovery, storage and preparation of specimens to be radiocarbon dated are very complex and vary depending on the type of organic material involved and the chemical changes which may have taken place during burial. There is no standard way to carry out pre-treatment and each new application presents unique problems (Hedges et al., 1989: 100).

Analysis of the prepared samples is also complex and lengthy, and the accelerator mass spectrometry technique now employed requires significant capital expenditure and highly specialized staff to run. Thus clearly, in spite of its popularity, limitations exist in the use of ¹⁴C for dating archaeological material (Evin, 1985: 252).

Though ¹⁴C has become the preeminent method of chronological dating, it is a very expensive procedure to use. Other approaches exist which provide the required information at lower cost and with the same degree of accuracy, particularly when applied to the time period relevant to the Balsam Lake material.

The most accepted of these options is thermoluminescence (T-L). Like radiocarbon, it is an important technique which is now widely applied and has been instrumental in focusing our perception of archaeological time scales in different regions. "It is some 30 years since the first detection of luminescence from a ground up sample of pottery as it was heated. This raised the hopes of archaeologists that soon they would have a simple dating technique for a type of artefact that was prolific from the neolithic onward and directly related to man's activity" (Aitken, 1989: 147).

The initial tendency to think of thermoluminescence as a simple, cheap alternative to radiocarbon dating resulted in a severe reaction on the part of researchers when, after the first enthusiasm, a series of complexities gradually revealed themselves rendering the process relatively labour intensive and requiring specialist knowledge or supervision to ensure reliable results. However, as most of the problems have been overcome, T-L increasingly has demonstrated its effectiveness particularly in areas where suitable samples for radiocarbon are not available and for periods in which radiocarbon accuracy is poor because of time scale distortions associated with variations in isotope concentrations in air, soil and water (Figure 1). Progressive improvements in sample preparation and pre-treatment as well as in analysis methodology have also contributed to the achievement of results with accuracy comparable to radiocarbon dating and involving lower costs than the latter techniques.

Thermoluminescence now offers an approach to chronological dating which is on very sound scientific foundations. T-L dates, when available, are routinely reported
alongside ¹⁴C results by Oxford University and other research groups (Fleming, 1979: 129 - 133 and 191 - 208; Hedges et al., 1989; Prescott et al., 1983).

"Pour l'Archéologie, la datation par thermoluminescence constitue un voie très féconde dans la mesure où le matériel céramique est très frequent, très abondant et porteur de remarquables informations culturelles et technologiques. Par rapport au radiocarbone, cette méthode s'addressant à un matériau différent, permet l'exploration des vois demeurées jusqu' ici incertaines chronolo-giquement et d'entreprendre des datations croisée C¹⁴-TL chaque fois que cela est possible" (Schvoerer, 1985: 279).

The phenomenon of thermoluminescence in ancient pottery was first reported by the universities of Bern (Groegler et al., 1960) and California (Kennedy et al., 1960; Aitken, 1985). The formal methodology for the determination of chronological dates of archaeological ceramic samples via thermoluminescence was developed in the 1960s (Aitken et al., 1964; Ichikawa , 1965; Mazess et al., 1966; Ralph et al., 1966; Aitken et al., 1968; Mejdahl, 1969) and was refined over the following 25 years (Fleming, 1970; Murray et al., 1978; Wintle et al., 1977; Zimmerman, 1978; Fleming, 1979; Valladas et al., 1980; Prescott et al., 1982; Mejdahl et al., 1984; Aitken, 1984; Bell, 1984).

The determination of age of pottery by thermoluminescence is based on properties of the temper in the ceramic. Temper is used in ceramics to provide resistance to thermal shock both during initial firing and during use. It affects the viability of the ceramic by controlling shrinkage and by providing porosity in the matrix and thus arresting fissure cracks which are generated by induced thermal stresses. Equally importantly, it improves the permeability of the ceramic and provides more uniform drying prior to firing, particularly in the cool and damp weather of Ontario (Arnold, 1988: 61 - 77, 104) or the colder weather of arctic Canada and the Andes highlands (Arnold, 1988: 90, 97). "Yuma pottery, for example, dries in just a few hours, because it contains 80 - 86 per cent nonplastics" (Arnold, 1988: 97). Increased non-plastic in pottery permits ceramic production in a wider range of environments than otherwise would be possible. The combination of significant quantities of temper with the clay matrix was standard practice among the people of north-eastern North America.

A large number of materials from organics to inorganics has been used for temper through the ages. However the materials most commonly employed have been the natural sands available near most inhabited sites. The properties of sand are very useful in the dating of ceramics. Sands have crystalline structures. When bombarded by radiation, some electrons in crystals are released from their atoms and migrate through the crystal lattice until they are captured in traps. The greater the amount of radiation or the longer the period the crystals are irradiated at a constant rate, the greater the number of electrons so displaced. This occurs until trap saturation involving high amounts of radiation is reached. When the crystals are heated, sufficient energy is absorbed by the electrons to release them from the traps into recombination centres. When this occurs, energy is emitted in the form of photons. This phenomenon is called "thermoluminescence".

The measurement of the quantity of photons emitted upon heating will indicate the amount of radiation to which the crystal has been exposed over time and therefore, assuming a constant radiation dose, the length of time of irradiation can be calculated.

Typically in crystals there exist traps of different "depths"; electrons in deeper traps require greater amounts of energy to be released. Shallower traps are more unstable and electrons return easily to their original state. Accordingly when irradiated crystals are heated progressively they yield varying amounts of photons at different temperature levels. If photon yield is plotted as a function of temperature, typical glow curves will be developed (Figure 9).

With continued radiation over time, the electrons shift to deeper traps. Thus crystals irradiated only recently will yield comparatively larger amounts of photons at



Curve a: natural TL glow-curve. Curve b: glow-curve from natural TL plus TL induced by laboratory irradiation. Curve c: background incandescence.

Figure 9

3



Routine test for the presence of anomalous fading in the TL of fine-grains. Curve n is an immediate readout of a second-glow laboratory irradiation: curve o is a readout delayed for two months after the application of laboratory radiation.



the low end of the temperature scale (Figure 10) while crystals subject to bombardment over a long period of time will reveal a greater amount of light emission, upon heating, at higher temperatures.

While the glow curves appear smooth and continuous, they are in fact a combination of subsequent overlapping peaks each approximately 50 deg. C. wide. The temperature region in which the peak occurs depends on how securely the electrons are held by the traps. The peaks corresponding to the release of electrons from increasingly deeper traps occur at increasingly higher temperatures.

It is notable that, beyond approximately 400 deg. C., the light emitted by the crystals is no longer due entirely to released electrons but becomes increasingly and eventually totally due to incandescence of the crystals as sufficient energy is absorbed to empty all the traps.

Also significant is the fact that different crystals have different responses to radiation. Accordingly the number of photons emitted by crystals which have been subjected to radiation for the same period of time may be different and therefore a direct measurement of luminescence from glow curves is meaningless. However the crystal's sensitivity to radiation can be readily established by imposing on them different known laboratory doses and determining the quantities of photons emitted upon heating for different dose levels.

To transform a clay mixture into the hard usable product that is pottery, a product which will not revert to its natural mineral state, the water present in the raw material must be removed. The capillary free water is usually removed in the drying process after the artefact is shaped. The firing process removes the chemically bound water. This occurs at a temperature of approximately 400 deg. C. While the firing process of primitive pottery makers involved relatively low temperatures, they were sufficiently above the 400 deg. C. threshold. Thus in all cases, when pottery is first fired, the thermal



Simple representation of the process of 'time-zero' setting in TL dating of pottery.

Figure 11

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energy absorbed is such that it will release all the electrons accumulated in existing traps as a result of the preceding geological radiation history. This establishes a very convenient zero time or counting terminus after which the accumulation of trapped electrons determines the amount of time elapsed since the manufacture of the ceramic (Figure 11). A very simple relationship arises between artefact age and amount of radiation to which the artefact has been subjected:

Age = Amount of bombardment/yearly radiation

The accumulation of trapped electrons takes place with cooling of the pottery after manufacture, when the crystals are exposed to the natural radiation of the background and the presence of such materials as isotopes of uranium, thorium and potassium. Both the soil in which the artefact becomes eventually buried and the fabric of the pottery itself contain varying amounts of these natural radioisotopes. These materials, disintegrating naturally at constant rates, bombard the crystals of the ceramic temper with α , β and γ radiation continuously. Part of this radiation is dissipated in the form of heat but, as already discussed, some of the captive electrons present in the crystals of the ceramic temper become separated from their nuclei, setting up the pattern of migration and capture outlined above.

Once the pottery has been recovered from the field, its temper is separated from the matrix. The temper is chemically treated and is then heated to just over 400 deg. C. under controlled atmosphere. The photon yields are plotted against temperature producing the typical glow curves discussed above.

As already mentioned different crystals have different sensitivities to radiation, that is the migration and trapping of their electrons, as a result of imposed radiation, take place at different rates. To check on the crystal sensitivity and on the linearity of the

phenomenon, portions of the crystals separated from the main sample before glowing are subjected to known doses of γ ray laboratory radiation. The process of heating and plotting is then repeated for each subsample and new glow curves representing the amounts of electrons trapped after the different amounts of radiation are obtained.

At any one peak these results are indicative of the crystal response to known doses as added to the unknown natural dose. From these values the latter, that is the radiation to which the artefact has been subjected in its lifetime, can be calculated. This is achieved by plotting on rectangular co-ordinates the ratios of photon emissions for the known doses over the emissions for the natural dose (y axis) against the radiation dose (x axis). The curve obtained must pass through the coordinate 1, 0 and its intercept along the x axis is the measure of the unknown natural radiation (Figure 12).

There are a few problems which complicate the determination of age. According to Winter (1971: 121) they fall into two groups: those that arise from the T-L phenomenon itself, and those that, external to the phenomenon, arise from peculiarities of pottery and the circumstances in which it exists .

As discussed elsewhere, electrons in deeper crystal traps require greater amounts of energy to become free to migrate; conversely, little energy is needed to dislodge them from shallow traps. Therefore electrons in deep traps are much more stable than those in shallow ones (Aitken, 1985: 7). This is quite evident from an observation of the glow curves which represent the electrons contained in different traps, explaining the absence of T-L below approximately 200 deg. C. in ancient material and the very significant presence of trapped electrons at low thermal energy levels for materials which have just been irradiated. "For dating purposes, it is only the traps that have accumulated electrons without leakage that are of interest: this

Determination of the Natural irradiation dose absorbed by crystals





n Natural dose

5.2

γ Known laboratory dose

 2γ Known laboratory dose



Curve N is the 'natural' glow-curve from one portion of the sample and curve N + β is the 'natural + artificial' glow-curve obtained from another portion to which an artificial dose of beta radiation has been administered; the thermal signal is also shown. The dashed line represents the ratio of the two glow-curves. The plateau level of 0.47 indicates that the dose equivalent to the natural thermoluminescence is 0.47/(1 - 0.47), i.e. 0.88, times the artificial dose used (10 Gy in this case).



usually means traps for which the thermoluminescence glow-peak occurs at 300 deg. C. or higher" (Aitken, 1985: 7).

Electrons requiring this high amount of thermal excitation to migrate have remained in traps since first they were dislodged from their atoms. The photons measured at low temperature are the measurement of an unknown percentage of the electrons originally displaced by radiation bombardment.

The crystals in the temper of each artefact can be different. Therefore we must determine which temperature represents a stable trap condition for each of the crystals being analyzed. This is done by a so called 'Plateau test'. The shape of the natural glow curve for a sample which has just received radiation during burial is compared with the artificial glow curve obtained after bombarding the same material with a known γ radiation source. It will become apparent that the ratio of natural to artificial T-L obtained rises from a very low value, below 200 deg. C., to a steady value or plateau which occurs after 300 deg. C. (Figure 13). In the latter zone the traps are sufficiently deep to prevent leakage and therefore data obtained from this region yields a true indication of the radiation absorbed during the lifetime of the artefact.

The reason for trying to determine whether a plateau zone exists instead of just analyzing the glow curves arbitrarily above 300 deg. C. is to ensure that the results have not been affected by a number of phenomena such as anomalous fading or the original firing of the pottery at too low a temperature. The former refers to the trap stability of different crystals. The latter would result in the incomplete releasing of all trapped electrons during original artefact manufacture. Both would result in the lack of a steady region in the glow curves.

Another problem that can affect the results of thermoluminescence analysis is the different impact of α , β and γ radiation on electron migration and trapping.



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Figure 15

The main effect is due to α radiation. In fact these particles have an extremely short travel range. This means that the larger crystals will have an inner core region that is never subjected to bombardment by α particles (Figure 14). Furthermore the efficiency of α radiation is far lower than that of β particles and γ rays (Fleming, 1979: 18 - 23; see also Aitken, 1985: 11). Therefore the amount of electrons trapped due to natural α , β and γ radiation will not be proportional to the amount trapped as a result of the γ source laboratory irradiation, thus not permitting the direct calculation of age outlined above. This problem can be eliminated by using relatively large crystals of approximately 100 μ in diameter which are chemically etched to remove the portion of the crystal affected by α radiation but not so large that the effects of β attenuation are critical (Figure 15) (Fleming, 1979: 23 - 30 and 40; Aitken, 1985: 18).

A further problem is the impact of groundwater in the soil in which the artefact is buried on the amount of natural radiation absorbed by the temper in pottery. The presence of water in the soil and therefore in the ceramic will reduce considerably the path length of the radiation. In the case of α particles, for example, the effectiveness of water in stopping radiation is close to 50 per cent greater than that of the natural clay or quartz (Fleming, 1979: 32). Water can also leach out some of the radioisotopes. In contrast the absence of water will permit radioactive radon gas to escape (Fleming, 1979: 14 - 16; Aitken, 1985). In both instances the result over the burial time would reduce the amount of radiation which would reach the pottery temper (Fleming, 1979: 31 - 37; Aitken, 1985: 76 - 82; Winter, 1971: 132 - 133). A more detailed discussion on this area will be carried out in the results section of this thesis.

Results of studies carried out on relatively recent pottery have been reported by Fleming (1979: 195 - 203) for various world wide locations, with ages ranging from AD 1220 to AD 1867. The Balsam Lake material falls well within these dates. Fleming's

research produced dates with uncertainty ranges from +/-8 to +/-65 years at the 95 percent confidence level. The material analyzed included pottery buried between 0.2 and 1 metre below surface, sherds recovered from graves, fragments of buried moulds, fragments of bricks and samples of unburied terracotta.

Provenancing

The problem of identification of sources of human artefacts is at the basis of much archaeological research. Patterns of routine activities, trading patterns and the development of cultural influences can be inferred from the presence or absence of pottery types. However the identification of these types is often based on stylistic analysis exclusively. "Very often sherds of different provenance have similar appearances although, conversely, different manufacturing techniques can produce a wide variety of pottery from the same clay. Therefore a classification of sherds based solely upon microscopic and stylistic grounds can lead to serious mistakes. Physicochemical techniques could contribute more substantial evidence" (Gancedo et al., 1985: 75).

The advent of new chemical technologies has permitted archaeologists to probe deeper into the nature of artefacts, beyond a study of their surficial attributes. One of the approaches which permit such an analysis is the rigorous determination of the chemical composition of the material fabric. While at times some general conclusions can be drawn based on the identification and quantification of major constituents (Mahaney et al., 1991: 81 - 92), different types of ceramics tend to have similar concentrations of major constituents (Frana et al., 1987: 69). Therefore, in spite of the apparent incentive in determining the provenance of artefacts, there are some limitations to discrimination by gross chemical analysis of major components of clay in the ceramic fabric. Clay is widely distributed through south-central Ontario in scattered deposits mainly of the low grade illite types (Ontario Department of Mines, 1967). Geologically the clay deposits which would have been used by the Native population of this region were formed in the glacial and interglacial stages of the Pleistocene epoch and even now occur near the surface of the ground (Mahaney et al., 1991: 90).

Clay deposits are composed of secondary materials resulting from the weathering of aluminous minerals such as feldspar or mica which form hydrous aluminium silicate compounds like, for example, Kaolinite clay (Al₂O₃.SiO₂.2H₂O). The ice movements which were instrumental in the formation of the south-central Ontario clay beds were persistently oriented east-west (Ontario Department of Mines, 1967: 116) and would have tended to generate deposits which are relatively homogeneous in composition throughout their thickness. The Provincial Industrial Minerals Report (Ontario Department of Mines, 1967) shows the clay soils in this region to be in fact relatively uniform so that differentiation amongst them would not be possible at the gross chemical component level. Furthermore, element concentrations in soils can be considerably affected by leaching either via surface run-off or by water percolation (Mahaney et al., 1991). However trace elements, particularly those of low solubility, are believed to reflect more closely the original deposit composition (Williams-Thorpe, 1988; Mahaney et al., 1991).

To ensure a clear discrimination, the analysis must be carried out at the trace element level. A technique which permits such a study is Instrumented Neutron Activation Analysis (INAA). The procedure relies on the transformation of the natural elemental nuclei in the sample fabric into radioactive ones allowing the subsequent measurement of the γ radiation which emanates from them. This permits the detection of concentrations down to 10⁻⁶ µ. grams. Neutron activation for quantitative elemental analysis was proposed as early as the 1930s. However practical applications were not possible until

the advent of operational nuclear reactors in the 1950s. Currently the determination of provenance of materials through the identification of their trace elements composition is a well established procedure (Pavlish et al., 1985; Glascock et al., in press; Volterra et al., 1994).

Neutron activation relies on the bombardment of samples with neutrons. In this case slow thermal neutrons, produced by a SLOWPOKE reactor, are captured by the nuclei of stable isotopes present in the sample. The resulting compound nuclei have the same atomic numbers but a larger mass than before bombardment. This renders them unstable. These radioactive nuclids de-excite by emitting β particles followed by γ rays which have characteristic energy levels for each element contained in the sample. The amounts of γ ray decay products are proportional to the quantity of each element present. By measuring the former we can identify and quantify the elements composing the samples. The basic activity equation is:

$A = Nfo(1-e^{-\lambda t})$

where:

A = the number of disintegration per second

N = the number of atoms of the target element present in the sample

 \mathbf{f} = the neutron flux of the reactor

 σ = the cross section of the target sample

 $\lambda = \ln 2/\text{half life of the isotope}$

t = the time duration of the bombardment

The original procedure involved "a purely radiochemical analysis using Geiger or scintillation counters after separation of components into radio-chemically pure forms" (Hoste et al., 1971: 139). This presented considerable drawbacks since a large number of subsamples had to be analyzed serially. Such a procedure was very cumbersome particularly since short lived isotopes often cannot be separated readily after irradiation.

The current approach uses nuclear reactors with high, reliable neutron fluxes and advances in high resolution γ ray spectrometry, with detecting apparatus close-coupled

to computer-driven counters run with sophisticated software. Such instrumented analysis permits the automatic conversion of the radiation spectra into meaningful digital results, making INAA a most productive archaeometric technique for the measurement of a wide array of trace element compositions when a large number of archaeological samples are involved. (see J.S. Morris, in press). Another advantage is that only very small samples are required to obtain a positive identification and quantification of elemental compositions.

The manufacturing of ceramics, including the firing process, does not alter the mineral elemental composition of the original clay. Therefore, through elemental analysis one would not only be able to discriminate between different fabrics, but also, theoretically, to identify the natural source of the clay.

All the samples were analyzed using the T-L laboratories of the University of Toronto Geophysics Department and the University of Toronto SLOWPOKE Reactor Facility. Thirty-five sherd samples were processed initially and four additional units from the Hardrock site were processed at a later date to provide confirmatory data. Clay and soil samples were analyzed after completion of the work on the ceramic material.

Details of the laboratory procedures are included in appendix A.

5 - DISCUSSION OF RESULTS

Instrumented Neutron Activation Analysis

General

Results for sherds and clays are reported on Tables 1 to 5. As indicated in Appendix A, to ensure successful analysis, the mass of all our samples was kept in excess of 750 mgms. However, as noted by Hancock et al. (1991: 72), the detection limits are related to γ ray energy and radioactive half life as well as to sample mass, and can be seen to vary up to an order of magnitude depending on the properties of the isotopes used for analysis of each element.

All elements in our analyses fall within detection limits with few exceptions (chlorine, dysprosium, gallium, arsenic, gold, antimony and nickel). The former twentynine elements are deemed more than sufficient for provenancing analysis. Also important for T-L determination, concentration of uranium, thorium and potassium were , determined for all samples.

Detection limits for trace elements varied from an average of 40 ppm for barium (average concentration 910 ppm) with an average precision of +/- 12.5 ppm (e.g. +/- 1.4%) to 0.03 ppm for scandium (average concentration 15 ppm) with an average precision of +/-0.024 (e.g. +/- 0.2%) and are within the 95 per cent confidence limit.

The average repeatability is over 95 percent as exemplified by the results for the element sodium which is counted three separate times.

In all cases the elements which appeared to be more powerful for discriminating between different provenances were Ce, Lu, Rb, Sc, Sr, Tb, Yb. In the case of the Kirche and Coulter sites Ba and K were useful as were Th, Al and V for the Coulter site.

HARDROCK SITE - INAA DATA

| AI | Ba | Ca | CI | Dy | Mg | Mn | Na | Т | iι | v v | Eu | Ga | к | i |
|---|--|--|--|---|--|---|--|--|--|--|--|---|--|-------------------------------------|
| .94 .69 .49 .00 .68 '.58 | 861. 852. 0.00 0.00 0.00 0.00 | 2.06 1.76 2.68 1.43 1.79 1.56 | 0.00 3 0.00 4 0.00 0 0.00 3 0.00 2 | 3.1 2 3.3 2 0.0 2 3.7 2 0.0 1 2.6 2 | .40 74 .33 68 .46 90 .32 39 .88 36 .22 38 | 1.0 1 7.0 1 3.0 1 9.0 2 5.0 1 5.0 1 | .67 .67 .82 .06 .99 .94 | 411 398 407 290 374 290 | 1.63 1.80 0.00 0.00 0.00 | 3 90.40) 69.80) 92.00) 57.90) 62.70) 53.50 | 1.38 1.69 0.00 0.00 0.00 0.00 | 48.60 12.50 0.00 0.00 .0.00 0.00 | 3.55 3.10 2.65 2.56 2.90 3.85 | 0.0 0.0 0.0 0.0 0.0 |
| В | r Fe | La | Sb | Sc | Sm | и Үр | | Ca | Со | Cr | Qs | Hf | Lu | N |
| 2.7 0.0 0.0 0.0 0.0 | 5 3.65 0 3.83 0 0.00 0 0.00 0 0.00 0 0.00 | 34.1 44.1 0.00 0.00 0.00 0.00 | 0.00 0.00 0.00 0.00 0.00 | 12.90 13.00 0.00 0.00 0.00 0.00 | 5.53 7.01 0.00 0.00 0.00 | 3 2.80 3.62 0.00 0.00 0.00 0.00 | 88 106 0 0 0 | .50 .00 .00 .00 .00 | 15.30 14.20 0.00 0.00 0.00 0.00 | 78.5 80.3 0.00 0.00 0.00 0.00 | 3.21 2.55 0.00 0.00 0.00 0.00 | 7.50 7.19 0.00 0.00 0.00 0.00 | 0.43 0.51 0.00 0.00 0.54 0.55 | 23.7 26.9 0.0 30.5 39.1 |
| 137. 122. 0.0 0.0 0.0 | 0 306.0 0 216.0 0 0.00 0 0.00 0 0.00 | 0 0.85 0 0.96 0 0.00 0 0.00 0 0.00 0 0.00 | 0.79 1.10 0.00 0.00 0.00 0.00 | 11.3 14.8 0.00 0.00 0.00 . 0.00 | | | | | | | | | | |

TABLE 1

JAMIESON SITE - INAA DATA

| | Al | Ba | Ca | CI | Dy | Mg Mr | n Na | Ti | U | v | Eu | Ga | к | |
|-----------|--------------------------------------|----------------------------------|------------------------------|--------------------------------------|---|---|---|------------------------------------|--|------------------------------|------------------------------|----------------------------------|------------------------------|-------------------------------|
| | 8.25 8 8.84 9 8.37 7 8.81 5 | 89. 95. 80. 86. | 2.23 1.27 2.10 1.79 | 0.00 4 0.00 5 0.00 0 0.00 0 | 1.0 2. 5.9 2. 0.0 2. 0.0 2. | 21 558.0 19 1046 52 669.0 35 778.0 |) 1.52 . 1.21) 1.49) 0.98 | 373 391 452 360 | 0.00 7 0.00 1 0.00 8 1.94 6 | 6.40 02.0 5.60 6.20 | 2.02 2.10 1.40 1.51 | 25.00 14.00 27.20 26.30 | 2.96 3.28 2.88 2.83 | 0.(0.(0.(3.; |
| L | Br | Fe | La | Sb | Sc | Sm | Yb | Qa | Co | Cr | Os | Hf | Lu | N |
| 2 2 2 4 2 | 0.00 3.62 0.00 2.54 | 3.77 4.16 3.36 3.40 | 48.7 58.5 35.6 36.8 | 0.00 0.00 0.00 0.00 | 13.10 15.30 12.00 11.10 | 6.91 8.51 4.84 4.85 | 4.48 10 5.18 12 2.54 8 2.36 74 | 1,0 1 6.0 1 3.50 1 4.40 1 | 5.00 75 7.40 87 4.40 78 3.90 85 | .0 .4 .9 .1 | 3.08 4.20 2.36 7.54 | 7.69 7.98 6.49 6.93 | 0.61 0.67 0.37 0.37 | 30.3, 40.6 22.6 21.8 |
| 11 | Rb | Sr | r Ta | Tb | Th | | | | | | | | | |
| 00000 | 126.0 153.0 105.0 155.0 | 323.0 270.0 282.0 195.0 | 0.93 1.13 0.69 0.81 | 1.10 1.29 0.58 0.67 | 12.4 16.1 9.57 13.8 | | | | | | | | | |

TABLE 2

KIRCHE SITE - INAA DATA

| Al | Ba | Ca | CI | Dy | Mg | Mn | Na | Ti | U | v | Eu | Ga | К | 1.1 |
|--|---|--|--|---|--|---|---|---|--|---|--|---|--|--|
| 1.78 8 1.38 1 1.02 6 1.34 9 1.02 7 3.67 9 3.34 1 | 99, 686 20. 73. 24. 29. 04 | 1.90 1.98 1.71 1.52 2.34 1.89 2.36 | 0.00 3 0.00 4 0.00 3 0.00 4 0.00 3 0.00 3 0.00 5 | .1 2 .4 2 .6 2 .2 2 .2 2 .8 2 .0 2 | .22 68 .23 61 .11 38 .79 89 .25 44 .35 73 .23 88 | 1.0 1 9.0 1 1.0 1 7.0 1 8.0 1 3.0 1 6.0 1 | .32 .86 .09 .74 .16 .43 .65 | 382 409 361 378 331 441 0.00 | 1.72 0.00 1.83 0.00 1.74 1.98 2.13 | 81.60 78.20 56.00 87.50 63.40 77.90 79.60 | 2.02 2.22 1.62 1.53 1.72 1.62 2.10 | 34.50 15.90 19.20 40.90 14.80 21.00 18.40 | 3.00 3.18 2.36 3.95 2.82 2.64 2.47 | 0.0 0.0 0.0 0.0 0.0 0.0 0.0 |
| Br | Fe | La | Sb | Sc | Sm | Yb | l | Cæ | œ | Cr | Qs | ·- Hf | Lu | N |
| 2.72 0.00 2.57 3.46 2.66 2.36 3.96 | 3.60 3.31 2.44 3.71 2.83 3.73 3.85 | 47.5 56.5 33.1 57.1 56.3 52.2 62.9 | 0.00 0.00 0.00 0.00 0.00 0.00 0.00 | 12.70 13.00 10.80 12.70 11.00 13.20 13.60 Th | 6.37 8.91 5.04 7.70 6.28 7.19 8.50 | 3.34 4.17 3.00 3.51 2.87 3.58 4.84 | 9: 11 67 10 10 10 10 | 3.40 1 0.0 1 7.80 1 2.0 1 3.0 3.0 1 0.0 1 | 5.80 1.50 0.40 6.30 8.90 5.10 2.80 | 91.0 118. 77.4 90.9 79.6 84.1 70.1 | 2.64 3.52 5.10 3.02 5.55 2.70 2.01 | 6.87 9.18 7.92 5.86 9.24 9.08 9.55 | 0.47 0.56 0.41 0.45 0.40 0.52 0.69 | 30.5 39.8 20.0 34.7 28.8 31.0 43.4 |
| 127.0 136.0 127.0 153.0 108.0 114.0 86.20 | 301.0 330.0 -225.0 372.0 227.0 261.0 -308.0 | 0.78 1.32 0.87 1.06 0.80 0.77 0.77 | 0.95 1.30 0.72 1.02 0.81 1.04 1.34 | 11.7 12.1 11.1 10.2 13.0 12.4 12.3 | | | | | | | i. | | | |

TABLE 3

COULTER SITE - INAA DATA

BARLIN PRODUCTION

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| | | | | | | | | | ti i | | | | | | | | 1 - 1 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - | A Stand |
|-----|------|----|------|------|-----|-------|-----|------|------|------|------|-------------------|--------|----|------|-------|---|---------|
| AI | Ba | | Ca | CI | ۵ |)y | Mg | N | /In | Na | · T | 'i , , , , | U | ۷ | Eu | Ga | к | A |
| 55 | 913. | 2 | .31 | 0.00 | 3.7 | 2 | .29 | 791 | .0 | 1.21 | 354 | 0.0 | 0 76.9 | 0 | 1.91 | 3.34 | 2.29 | 0.0 |
| 32 | 975. | 2 | .76 | 0.00 | 4.3 | 3 2 | .12 | 817 | .0 | 1.33 | 416 | 0.0 | 0 89.1 | 0 | 1.97 | 20.50 | 2.80 | 0.0 |
|)6 | 737. | 2 | .45 | 0.00 | 4.0 |) 2 | .25 | 448 | .0 | 1.31 | 406 | 1.8 | 2 71.0 | 0 | 1.83 | 14.90 | 2.98 | 0.0 |
|)0 | 826. | 2 | .60 | 0.00 | 3.7 | / 2 | .59 | 662 | .0 | 1.25 | 370 | 1.6 | 8 82.3 | 0 | 2.05 | 22.00 | 3.27 | 0.00 |
| 74 | 101 | 2 | .27 | 0.00 | 4.6 | 3 2 | .82 | 114 | 6. | 1.15 | 487 | 0.0 | 0 87.8 | 0 | 2.14 | 24.90 | 2.70 | 0.0 |
| 14 | 894. | 3 | .53 | 0.00 | 0.0 |) 2 | .87 | 116 | 3. | 1.28 | 529 | 1.5 | 9 118 | .0 | 2.31 | 9.88 | 2.91 | 0.0 |
|)1 | 100 | 1 | .81 | 0.00 | 4.0 |) 2 | .63 | 846 | .0 | 1.48 | 422 | 1.8 | 8 81.7 | 0 | 1.89 | 42.50 | 2.97 | 0.0 |
| 74 | 975. | 2 | .06 | 0.00 | 0.0 |) 2 | .14 | 747 | .0 | 1.43 | 463 | 1.5 | 1 94.2 | 20 | 1.92 | 35.20 | 2.80 | 0.04 |
| 58 | 935. | 2 | .24 | 0.00 | 4.0 |) 2 | .96 | 607 | .0 | 1.47 | 442 | 2.3 | 2 81.7 | 0 | 1.87 | 35.90 | 2.89 | 0.0 |
|)2 | 108 | 2 | .13 | 0.00 | 3.9 | 9 2 | .61 | 853 | .0 | 1.43 | 384 | 0.0 | 0 81.8 | 0 | 2.62 | 24.40 | 3.48 | 0.0 |
| 11 | 890. | 2 | .26 | 0.00 | 3.3 | 3 2 | .48 | 462 | .0 | 1.47 | 366 | 1.5 | 7 79.5 | 50 | 1.50 | 16.60 | 2.48 | 0.00 |
| 35 | 100 | 2 | .19 | 0.00 | 4.4 | 1 2 | .03 | 687 | .0 | 1.41 | 358 | 1.6 | 6 89.8 | 0 | 1.65 | 18.20 | 2.90 | 0.00 |
| | | | | | | | | | | | | | | | 14.2 | | | 11.00 |
| | | | | | | | | 5 | | | | | | | | 6.2 | | 1 |
| | | | | | | | | | | - 14 | | | | | | | | |
| В | r | Fe | La | | Sb | Sc | | Sm | | ſb | Ca | 60 | Cr | | Cs | Hf | Lu | Nd |
| 2.9 | 74. | 06 | 56.3 | 0.0 | 00 | 13.40 | 7 | .51 | 3.2 | 9 10 | 0.0 | 15.20 | 84.7 | 4 | 3.41 | 9.06 | 0.94 | 37.4 |
| 1.7 | 4 4. | 20 | 63.4 | 0.0 | 00 | 14.30 | 8 | 1.41 | 3.6 | 0 12 | 20.0 | 16.50 | 93.5 | | 3.17 | 8.98 | 0.54 | 39.7 |
| 1.7 | 1 2. | 75 | 42.6 | 0.0 | 00 | 12.80 | 7 | 1.11 | 3.5 | 7 8 | 6.70 | 11.40 | 79.3 | | 4.52 | 10.7 | 0.56 | 28.3 |
| 1.0 | 0 4. | 13 | 52.7 | 0.0 | 00 | 13.80 | 7 | .22 | 3.2 | 1 11 | 0.0 | 15.80 | 90.2 | | 2.78 | 9.05 | 0.47 | 32.2 |
| 1.0 | 0 4. | 43 | 56.8 | 0.0 | 00 | 15.10 |) 8 | 1.00 | 3.4 | 8 11 | 5.0 | 18.90 | 102. | | 3.34 | 6.82 | 0.56 | 197. |
| 1.2 | 8 4. | 53 | 56.2 | 0.0 | 00 | 16.40 | 5 | .48 | 3.9 | 1 11 | 6.0 | 20.60 | 98.1 | | 3.16 | 6.89 | 0.58 | 41.7 |
| 1.0 | 0 4. | 03 | 53.7 | 0.0 | 00 | 13.70 | 8 | 8.08 | 3.6 | 4 11 | 5.0 | 16.90 | 93.0 | | 2.97 | 8,60 | 0.54 | 36.3 |
| 1.2 | 5 4. | 57 | 46.3 | 0.0 | 00 | 15.10 | 6 | 3.85 | 3.2 | 3 10 | 0.70 | 18.30 | 101. | | 2.97 | 8.00 | 0.49 | 28.8 |
| 1.0 | 0 4. | 08 | 40.2 | 0.0 | 00 | 15.70 | 6 | .64 | 4.1 | 9 7 | 7.80 | 14.90 | 92.1 | | 3.40 | 8.74 | 0.66 | 27.9 |
| 1.0 | 0 4. | 07 | 63.4 | 0.0 | 00 | 13.90 | 8 | 1.14 | 3.0 | 6 12 | 23.0 | 17.70 | 99.3 | | 3.32 | 9.43 | 0.50 | 165. |
| 1.0 | 0 3. | 09 | 52.1 | 0.0 | 00 | 12.20 | e | .72 | 3.3 | 5 8 | 4.10 | 11.40 | 93.0 | | 3.01 | 6.88 | 0.47 | 26.1 |
| 2.7 | 1 3. | 97 | 47.0 | 0.0 | 00 | 13.00 | • • | .83 | 3.5 | 2 10 | 2.0 | 16.20 | 90.0 | | 3.00 | 7.94 | 0.49 | 25.1 |
| | | | | | | | | | | | | | | | | | | 1 |

| Rb | Sr | Та | Tb | Th | | |
|--------|-------|------|------|------|--|--|
| 24.0- | 291.0 | 0.94 | 1.09 | 11.4 | en e | |
| 25.0 | 334.0 | 0.96 | 1.15 | 12.9 | | |
| 17.0- | 271.0 | 1.03 | 113. | 12.4 | | |
| 25.0 | 248.0 | 0.95 | 1.10 | 12.7 | | |
| 35.0 - | 276.0 | 0.91 | 1.17 | 12.7 | | |
| 21.0 | 255.0 | 0.96 | 1.22 | 11.1 | | |
| 20.0 | 229.0 | 0.99 | 1.17 | 12.7 | | |
| 29.0 | 322.0 | 0.99 | 0.91 | 14.5 | | |
| 9.0 | 273.0 | 0.99 | 1.02 | 11.6 | | |
| 35.0 | 274.0 | 0.93 | 1.10 | 13.1 | | |
|)9.0 | 275.0 | 0.79 | 1.06 | 10.9 | | |
| 20.0 | 299.0 | 0.89 | 0.97 | 12.1 | | |

TABLE 4

BENSON SITE - INAA DATA

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| AI | Ba | Ca | Cl | Dy | Mg | Mn | Na | Т | i l | J V | Eu | Ga | к | A |
|---|--|--|--|---|--|---|--|---|--|--|--|--|---|--|
| .79 1 .07 1 .52 1 .18 1 .97 9 .01 1 .71 9 .93 1 .37 7 .62 1 | 10 25 07 23 83. 04 54. 07 26. 06 | 2.80 2.19 2.08 2.34 1.94 2.00 2.07 1.99 1.93 2.11 | 0.00 3 0.00 4 0.00 3 0.00 4 0.00 3 0.00 3 0.00 3 0.00 3 0.00 3 | 3.3 2 4.0 2 3.5 2 4.9 2 3.9 2 3.2 2 3.7 2 2.8 2 3.5 2 | .95 88 .63 88 .12 27 .85 12 .58 71 .75 12 .26 67 .44 81 .11 26 .58 74 | 30.0 34.0 75.0 266. 16.0 212. 70.0 13.0 57.0 16.0 | 1.35 1.30 1.36 1.67 1.47 1.45 1.53 1.36 0.94 1.48 | 376 395 363 417 402 434 412 286 243 389 | 0.00 2.00 2.07 0.00 2.05 1.89 1.72 2.37 1.89 | 77.50 87.30 757.10 96.90 78.30 93.00 86.80 77.40 40.00 82.50 | 1.81 1.84 1.63 2.80 1.87 2.08 1.82 1.92 1.68 1.84 | 11.50 30.50 32.40 42.80 29.80 15.50 17.30 34.40 17.50 30.70 | 3.08 2.99 3.04 3.44 3.30 2.82 3.05 3.58 2.67 2.90 | 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 |
| Br | Fe | La | Sb | Sc | Sn | n Yl | D | Cə | ထ | Cr | Os | " "Hf | Lu | Nd |
| 0.00 0.00 0.00 0.00 0.00 0.00 2.76 3.04 3.45 Rb | 4.01 4.08 1.90 4.44 3.88 4.57 3.74 4.17 2.40 4.07 | 60.3 56.7 44.7 71.4 47.2 72.7 44.2 52.0 46.4 51.3 Ta | 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0 | 14.20 13.70 11.10 15.10 14.00 14.50 12.50 14.40 12.30 13.70 Th | 7.82 7.75 5.98 8.89 6.69 6.91 6.95 | 2 4.3 5 4.2 9 4.5 9 4.5 9 4.1 9 4.3 1 3.4 1 3.4 1 4.0 7 3.7 3 3.8 | 6 11 6 11 2 85 3 12 7 10 0 12 6 92 1 95 5 86 6 98 | 5.0 0.0 5.70 6.0 2.0 4.0 2.20 9.60 5.80 3.40 | 19.00 17.70 9.00 19.20 16.90 17.60 15.00 16.70 8.56 16.10 | 100. 98.0 70.1 91.8 86.9 88.3 78.2 87.2 83.7 84.3 | 3.21 3.16 5.44 2.94 2.98 2.97 2.47 2.70 5.94 2.49 | 8.17 7.59 7.19 7.93 7.58 7.56 7.45 7.72 7.70 8.20 | $\begin{array}{c} 0.57 \\ 0.56 \\ 0.44 \\ 0.58 \\ 0.54 \\ 0.55 \\ 0.45 \\ 0.53 \\ 0.47 \\ 0.50 \end{array}$ | 37.5 36.4 88.1 42.3 30.5 39.1 26.3 31.7 26.1 29.7 |
| 139.0 134.0 115.0 137.0 136.0 116.0 116.0 117.0 154.0 144.0 120.0 | 376.0 294.0 -447.0 276.0 286.0 290.0 302.0 262.0 284.0 | 0.91 0.96 0.96 0.94 0.88 0.86 0.86 0.89 0.94 | 1.13 1.05 0.82 1.22 1.01 1.13 0.81 0.98 0.80 0.91 | 13.0 13.1 13.7 12.8 11.8 12.8 11.3 12.0 14.2 10.8 | | 2 | | | | | | | | |

TABLE 5

Major components of clay are quite uniform and, as discussed earlier, it is the trace elements that one must rely on for discriminant analysis (Cuomo di Caprio, 1985: 256 - 259). In overall concentration of major components, our results from the analyses of clay samples were reasonably similar to the results obtained for southern Ontario soils by Mahaney et al. (1991: 87). Differences were instead evident in the concentrations of trace elements for both clays and ceramic samples. A comparison with the results obtained by Trigger et al. (1980) for Benson sherds and by Birgul et al. (1977) for Ontario clays is also positive. Comparison with the clay at the Beaverton quarry shows the calcium and sodium to be much higher than for our clay samples but other major elements are comparable (Figure 44, page 77).

Discriminating diagrams have been produced for each site comparing local clays with sherd samples (Figures 28 to 42). These will be reviewed by site in chronological order from earliest to latest.

Local clay samples

The Native populations manufacturing pottery from local clay deposits in the Balsam Lake area would have obtained raw materials from surface deposits. While the levels of the various bodies of water in the area are somewhat higher now than they were in the sixteenth and seventeenth century, as a result of the canalization of the Trent River, the genesis and distribution of clay resources as outlined in current mineralogical surveys (Ontario Department of Mines 1967) indicate that such sources as were available in earlier periods would still be accessible to-day.

It is likely that weathering and erosion will have destroyed the actual surfaces exploited by Balsam Lake people. However as discussed earlier, the composition of clay bodies in the area is relatively uniform (Mahaney et al., 1991). This is confirmed by the INAA results as evidenced by samples 37, 61, 62, 68 and 70. Samples 38, 63, 72 and 73 were obtained from ditches close to roadways in open cuts which crossed clay deposits. The fine material collected would have been redeposited by water from the main clay bodies. A considerable amount of leaching appears to have taken place since in all cases both major and trace element concentrations are much lower than for the other samples. This phenomenon is consistent with the findings of Mahaney et al. (1991, 1993) and accounts for the high values of calcium measured in the samples. The proximity of roadbeds can also account for a portion of the higher calcium. Calcium hydroxide is sometimes used in summertime in the area to suppress dust on unpaved roads.

It is reasonable to assume that the material used by the Balsam Lake tribes would be quite similar to the clay samples collected. In fact, as indicated previously, elements are not affected by the pottery firing process and therefore isotopic ratios are essentially the same for ceramics as for the raw clay from which they are manufactured, though there is an irreversible chemical transformation of the clay matrix (N. Cuomo di Caprio, 1985: 123 - 124, 130; Gogte, 1989: 102; C. M. Sinopoli, 1991: 27 - 31).

After firing, the elements are locked into the pottery matrix with little subsequent leaching or absorption in spite of taphonomy. In addition, since native ceramics in this area are manufactured without slip or glaze, there is no possibility of confusion with the basic body clay matrix.

During the firing process however the loss of material on ignition is of the order of 5 to 15 percent of the mass (Mahaney et al., 1191: 90; Cuomo di Caprio, 1985: 215). The Beaverton clay, which is the commercially exploited quarry currently closest to the Balsam Lake area, has been reported as having a loss on ignition of 13.06 to 21.24 percent (Ontario Department of Mines, 1967: 127). Thus we could expect that the analysis of ceramic samples would show somewhat larger concentrations of trace elements than would be present in the raw clay from which they are produced. This appears to be so in our case. One can compare values of most trace elements for samples 37, 61, 68 and 70 with comparable values for sherds such as samples 1 to 10 (Figure 43, page 76).

More importantly, it would be reasonable to expect to see on discriminating diagrams different clustering by elemental concentrations for locally manufactured Huron material and imported ceramics. As well results obtained for artefact samples should cluster in the same area as the results for the clay from which they are produced. This is to say that, regardless of style and form, pottery manufactured using the same source materials would have similar elemental concentrations and, if their elemental concentrations match those of local clay sources, the ceramics would have been produced locally.

The Hardrock site samples

The pertinent scatter diagrams for the Hardrock site are shown on Figures 28 and 29.

In all the diagrams there appears to be a reasonable clustering of results. The Ce vs. Lu particularly shows that the clays from which samples 37, 68, 70 and possibly 61 have been obtained could indeed be the source of the raw materials for the pottery whose sherds were analyzed. Sample 70 comes from a location marginally closer to Hardrock, while all the others are found in the same general area south west of Balsam Lake and within reasonable travelling distance from the Hardrock site. Each of these sources, or a mixture of the three to balance clay and mineral content, could have been used to manufacture the Hardrock ceramics. The fact that the deposits of raw clay used by the people at Hardrock appear to have been more

Hardrock site

Cerlum vs Lutetlum



o Huron style sherds + Clays

Figure 28

Hardrock site

Strontium vs Terblum



O Huron style sherds +

+ Clays

Figure 29

remote than the sources utilized at Kirche, Coulter and Benson may be in effect the archaeological proof that at this time there was considerable security in the region and people did not fear being ambushed. Since Hardrock is a non-palisaded site this would also give weight to the suggestion by Heidenreich (1971: 139) and Trigger (1976, vol. 1: 44) that palisades at Ontario Iroquoian sites were erected for defensive purposes.

The Jamieson site samples

The pertinent scatter diagrams for this site are shown on Figures 30, 31, 32 and 33.

It is evident from these diagrams that there is a definite cluster separation between the samples of Huron style ceramic and St. Lawrence Valley style pottery. These differences recur in all the diagrams regardless of bi-variants chosen. Therefore it seems reasonable to infer that the ceramics identified stylistically as St. Lawrence indeed represent pottery of foreign manufacture and got to the site through trade or other form of importation.

Some clustering of clays with the Huron sherds also appears, particularly in Figure 30 [Sc vs Ce]. In this diagram the Eldon Station Road West source (sample 68) appears to coincide with the locally manufactured pottery. The sample that is consistently closest to the Huron pottery is number 61 on all diagrams. This is a clay sample obtained along the edge of the creek which runs at the south edge of the site. It is reasonable to accept that the Jamieson people utilized the material closest at hand for the manufacture of their pottery. The deposit which surfaces now and from which the sample was collected appears to be small; however it is probable that a larger exploitable source of the same clay may have been missed during site surveys.





Figure 30

• Huron style sherds D St. Lawrence style sherds + Clays

Strontium vs Terbium



Figure 31

3

•.

• Huron style sherds b St Lawrence style sherds + Clays

Rubidium vs Ytterbium



Figure 32

O Huron style sherds

erds 🗆 🗄

D St. Lawrence style sherds

+ Clays

Cerlum vs Lutetium



Figure 33

O Huron style sherds D St. Lawrence style sherds + Clays

Kirche site

Barium vs Potassium



Figure 34

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o Huron style sherds D St. Lawrence style sherds

Clays +







□ Huronstyle sherds ○ St. Lawrence style sherds + Clays

X
The Kirche site samples

Discriminating diagrams for the Kirche site are shown on Figures 34 and 35.

Some differential clustering of points between stylistic Huron and St. Lawrence sherd samples appears on these diagrams. However one of the St. Lawrence style samples (sample 15) associates most readily with the Huron style material. Drawings of this artefact and field notes indicate that its attributes were clearly diagnostic and definitely in the St. Lawrence style (P. Ramsden, personal communication). The sherd was recovered inside the village palisade and it seems to have been made locally in contrast to the rest of the St. Lawrence pottery.

This is the first occurrence within the apparent chronological sequence of the sites examined that we find evidence of local production of non-Huron style ceramics. Ramsden believes that in fact some of the houses located outside the Kirche palisade were occupied by visitors to the village (1988b: 181). He speculates that this may have been a first step in the process of immigration towards the long term goal of eventual incorporation into the community. "Such activities as trade and intermarriage may have formed part of the negotiations toward such incorporation" (Ramsden, 1988b: 181). According to this hypothesis, a reasonable explanation for the presence of a foreign style sherd made of local clay inside the palisade at the Kirche site is that it had been manufactured by a St. Lawrence woman living within the community (Trigger et al., 1980: 120). Interestingly the individual age determined by T-L for this sample places it very late in the occupational date range for the site. This would place it within the period during which, according to Ramsden (1988b), the absorption of the St. Lawrence Iroquois by the Huron was taking place.

Some of the clay results (specially those for samples 37 and 68) show association with Huron material. These samples were collected either relatively close to the site at Eldon Station Road west (sample 68) or immediately south of the site itself (sample 37). A review of all the trace element analysis results shows that there is the least amount of variance between these two samples. Considering the proximity of the areas where they were collected this is not entirely surprising. However while the Eldon material is essentially pure clay, the Kirche material is very high in mineral content and may not have been suitable by itself to produce acceptably durable ceramics. It is therefore reasonable to theorize that Kirche people admixed Eldon clay to the local material to produce their artefacts.

The Coulter site samples

Discriminating diagrams pertaining to the Coulter site are shown on Figures 36, 37, 38, 39 and 40.

It is very clear from the diagrams that in all cases both styles of ceramics cluster together and no clear distinction can be made between the two. Accordingly it seems reasonable to infer that all items were manufactured from the same raw material sources and that all artefacts were produced locally and not imported into the area. This result supports the suggestion that toward the latter occupational period of the Balsam Lake region Huron and St. Lawrence Iroquois lived together in the same sites (Ramsden, 1978). Ramsden (1988b: 177) and Damkjar (1990) report that the Coulter site had undergone a series of major expansions and Ramsden states that in fact people travelled long distances to join such expanded villages (1978: 104).

Figures 36 [Yb vs Lu] and 37 [Ba vs K] show also a close relationship between the data for the pottery and the data for clay samples 37, 61, 68 and 70. However it is





Figure 36

o Huron style sherds D St. Lawrence style sherds + Clays





Figure 37

o Huron style sherds 🛛 🗆 St. Lawrence style sherds

2.5

+ Clays

Vanadium vs Aluminum



O Huron style sherds

12

St. Lawrence style sherds + Clays

Thorium vs Scandium



Figure 39

o Huron style sherds

 $\mathbf{\hat{z}}$

□ St. Lawrence style sherds + Clays



Scandium vs Cerium





Huron style Sherds 0

St. Lawrence style sherds +

Clays

Benson site

Rubidium vs Ytterbium



Figure 41

O Huron style sherds () Hybrid sherds I St. Lawrence style sherds + Clays

1 2



Cerium vs Lutetium



Figure 42

OHuron style sherds()Hybrid sherds□St. Lawrence style sherds+ Clays

difficult to discriminate between the separate clay deposits. Samples 37 and 68 are most consistently closer to the results for ceramics as shown in Figures 38 [V vs Al], 39 [Th vs Sc] and 40 [Sc vs Ce].

The Benson site samples

Discriminating diagrams pertaining to the Benson site are shown on Figures 41 and 42.

It is clear from the diagrams that in all cases the results of the analyses for both styles (as well as for "hybrid" samples) of ceramics cluster together and no clear distinction can be made between them. This is similar to the results obtained for the Coulter site. We can therefore infer again that all the artefacts were manufactured locally from the same raw material sources. All the diagrams also show a close relationship between data for clay samples 37, 68 and 70 and the pottery data.

Sample 37 was collected near the Kirche site. The sample collected at the Benson site itself (sample 70) contained a large percentage of clay, yet perhaps it was not adequate to manufacture reasonably durable ceramics because the mineral content was also high. In light of this, it does not seem likely that Benson people would have travelled to the Kirche site to collect material that was inferior to that available in their own area. However it appears reasonable to hypothesize that, as at Kirche, local material was admixed to the pure clay available at the Eldon Station Road West deposit.

It is interesting to note that Trigger et al. (1980) tested a number of sherds from Ontario sites including Benson. The results obtained by the current research fall within the element concentrations reported by Trigger et al. (1980: 133) for this site (Table 6).

| Geometric Means of the Concentrations of Selected Elements | | | | | | |
|--|-----------|---------|------------|---------|-----------|-----------|
| Element | K% | Ca% | Ti% | Fe% | Rb ppm | Sr ppm |
| Trigger Group "W" | 3.3+.65 | 1.8+.54 | 0.47+.0706 | 3.8+.65 | 121+36-28 | 303+55-46 |
| Current Analysis | 3.86+/1 | 2.12+/2 | 0.37+/06 | 4.0+/01 | 131+/-2 | 308+/-17 |

TABLE 6

Thermoluminescence analysis

The radiation dose affecting the temper crystals in archaeological pottery sherds results, as indicated above, from the disintegration of the natural isotopes of potassium, uranium and thorium contained within the clay matrix. The same isotopes are also present in the surrounding burial medium and additional radiation exposure results from cosmic rays, while the quartz component of the ceramic temper is entirely free of internal radioactivity.

It was not possible to ascertain dose rate contributions from the environment by direct site dosimetry. However it can be reasonably assumed that the level of all soil radiation, including clay, should be essentially uniform in the small geographical region from which the sherds originate. Since local populations would not travel significant distances to collect raw materials for standard ware pottery making (Arnold, 1985: 58), it can be expected that the amount of radiation from the clay matrix will not vary significantly from that produced by the ground in which the sherds were buried, in spite of the fact that, as indicated in the previous section, pottery is expected to have slightly higher concentrations of trace elements than are present in the raw clay. This is confirmed by the analyses of soil collected from the Benson, Kirche and Jamieson sites and clays collected at various locations around Balsam Lake. Thus a differential contribution to yearly dose rate for buried sherds due to surrounding soils would be at best negligible. Furthermore it is generally accepted (Fleming, 1979: 3) that roughly 80 percent of typical ceramics dose rates come in fact from radioactivity contained within the ceramic itself, while only 20 percent comes from the environment.

Given the above consideration, it is feasible to make allowance for the lack of site dosimetry when determining the overall age calculation error. With regard to the

component of environmental dose rate due to cosmic radiation, the typical value quoted in the literature of 15 millirads per year (Fleming, 1979) is considered normal for south-central Ontario and was used for calculations.

Determination of concentration of the radioactive isotopes present in each sample was made by INAA as discussed in the previous pages. Uranium and thorium each contribute different yearly doses of radiation due to α and β particles and γ rays. Potassium does not contribute any radiation due to α particles and its radiation due to β particles and γ rays is also different from the two other isotopes. Typical values are quoted in the literature (Fleming, 1979, Aitken, 1985) and were used in the calculations. These dose rates must be modified by a number of assumptions dealing with the effect of crystal size on radiation attenuation and with the radiation efficiency of α and β particles and γ rays. Literature quoted coefficients (Fleming, 1979) have been used in our calculations. Attenuation curves are shown in Figures 14 and 15.

An additional factor must be considered in the process of determination of artefact age. Radon and thoron radioactive gases are produced in the decay of uranium and thorium during the lifetime of the pottery. If they are free to migrate, the total radiation absorbed by the crystals in the ceramic is reduced. For one hundred percent radon/ thoron loss, typically 57 percent of α , 60 percent of β and 95 percent of γ energy associated with the entire decay chain is lost (Fleming, 1979). Therefore loss of radon and thoron have a significant impact on the amount of yearly dose rates.

Gas migration is connected with the effect of water uptake in buried materials. As already indicated, the presence of water shortens the path lengths of radiation thus inhibiting it but, more significantly, it also prevents the migration of radon and thoron gases and therefore increases the amount of radiation which would be absorbed by the artefact in its lifetime. The effect of water on radiation path lengths is taken into consideration

in the calculation of dates in the form of systematic error equivalent to 7 percent (Fleming, 1979: 121). The problem associated with gas migration is complex and must be evaluated on a site by site basis. We can expect that all the sherds recovered from the Balsam Lake area would have in fact been saturated with water during burial by different degrees depending on the site. For example, finds from the Hardrock site were recovered from excavations in sandy soil very close to the shore of Balsam Lake (Wright, 1964: 167). They would therefore be expected to be wet for significant periods of each year because of the proximity of the water table. Thus we can assume in this instance that radon and thoron losses have been close to zero.

In the calculation of T-L dates, a number of random errors must also be accounted for, including the error which could arise from potential supra-linearity in the glow curves, the α radiation efficiency, etc. Typical contribution from random error for the quartz extraction method used in these analyses is quoted in literature at 7 percent (Fleming, 1979: 121) and has been used in our age calculations. An example of the calculations required to achieve an age determination using the T-L dating technique is shown in Figure 45. Natural dosage determinations for all samples are tabulated in Figure 46.

The average repeatability of the glow curves at the plateau zone of 375 deg. C. is 96 percent. It varies from sample to sample and ranges from a high of 100 percent for two thirds of the curves to a low of 76 percent for 1.5 percent of the curves. Repeatability is highest for the natural dose curves at 100 percent for 84 percent of the cases and averaging 98 percent. T-L dates could not be calculated for all of the sherd samples analyzed. In a number of cases, data obtained from the glow curves could not be utilized. It is to be noted also that not all glow curves exhibited plateaus.

Out of 39 samples satisfactory results were only obtained for 24. Some of the crystals showed poor sensitivity to radiation and the glow curves did not yield plateaus or straight line correlations for increasing radiation doses. The percentage of rejects is

| | | | | | | | | | | | | | | 76 | | inter. |
|-----------|------|------|-------|-------|------|------|-------|------|------|-------|-------|-----|------|-------|------|--------|
| 1 + + 11. | AI | Ba | Mn | ٧ | ĸ | Fe | Sc | Sm | Yb | Ca | Q | Qs | Lu | Rb | Тъ | |
| | 8.79 | 110 | 880.0 | 77.50 | 3.08 | 4.01 | 15.50 | 7.82 | 4.36 | 115.0 | 19.00 | 3.2 | 0.57 | 139.0 | 1.13 | - |
| 2 | 9.07 | 125 | 884.0 | 87.30 | 2.99 | 4.08 | 14.90 | 7.75 | 4.26 | 110.0 | 17.70 | 3.1 | 0.56 | 134.0 | 1.05 | |
| 3 | 8.52 | 107 | 275.0 | 57.10 | 3.04 | 1.90 | 11.30 | 5.98 | 3.42 | 85.70 | 9.00 | 5.4 | 0.44 | 115.0 | 0.82 | |
| Ļ. | 9.18 | 123 | 1266. | 96.90 | 3.44 | 4.44 | 15.60 | 8.89 | 4.53 | 126.0 | 19.20 | 2.9 | 0.58 | 137.0 | 1.22 | |
| , | 8.97 | 983. | 716.0 | 78.30 | 3.30 | 3.88 | 14.90 | 6.69 | 4.17 | 102.0 | 16.90 | 2.9 | 0.54 | 136.0 | 1.01 | |
| ; | 8.01 | 104 | 1212. | 93.00 | 2.82 | 4.57 | 14.90 | 9.19 | 4.30 | 124.0 | 17.60 | 2.9 | 0.55 | 116.0 | 1.13 | |
| , | 8.71 | 954. | 670.0 | 86.80 | 3.05 | 3.74 | 12.70 | 6.41 | 3.46 | 92.20 | 15.00 | 2.4 | 0.45 | 117.0 | 0.81 | |
| ţ. | 8.93 | 107 | 813.0 | 77.40 | 3.58 | 4.17 | 14.60 | 7.31 | 4.01 | 99.60 | 16.70 | 2.7 | 0.53 | 154.0 | 0.98 | |
|) | 4.37 | 726. | 267.0 | 40.00 | 2.67 | 2.40 | 12.70 | 6.07 | 3.75 | 86.80 | 8.56 | 5.9 | 0.47 | 144.0 | 0.80 | |
|) | 9.62 | 106 | 746.0 | 82.50 | 2.90 | 4.07 | 13.90 | 6.93 | 3.86 | 98.40 | 16.10 | 2.4 | 0.50 | 120.0 | 0.91 | |
| | | | | | | | | | | | | | | | | |
| 7 | 7.65 | 813. | 640.0 | 63.30 | 2.25 | 2.57 | 9.76 | 5.34 | 3.30 | 69.60 | 9.58 | 0.9 | 0.52 | 70.90 | 0.76 | |
| 3 | 4.57 | 513. | 548.0 | 48.40 | 1.37 | 1.70 | 5.68 | 3.52 | 2.02 | 44.00 | 5.93 | 0.0 | 0.31 | 40.90 | 0.52 | |
| 1 | 6.29 | 652. | 526.0 | 37.20 | 2.04 | 2.36 | 7.49 | 4.10 | 2.92 | 46.50 | 5.62 | 1.5 | 0.49 | 72.20 | 0.67 | |
| 2 | 4.40 | 451. | 557.0 | 52.50 | 1.36 | 2.48 | 9.49 | 4.11 | 2.15 | 50.10 | 8.14 | 1.6 | 0.32 | 56.70 | 0.66 | |
| 3 | 2.95 | 341. | 419.0 | 25.90 | 1.11 | 1.48 | 4.86 | 2.88 | 1.59 | 33.50 | 4.31 | 0.9 | 0.23 | 40.40 | 0.41 | |
| 3 | 7.79 | 841. | 615.0 | 66.50 | 1.93 | 2.41 | 10.70 | 6.26 | 4.03 | 76.80 | 9.02 | 1.4 | 0,56 | 64.10 | 0.86 | |
|) | 6.27 | 821. | 738.0 | 51.30 | 1.63 | 2.84 | 9.05 | 5.41 | 3.20 | 69.80 | 8.28 | 0.4 | 0.45 | 53.10 | 0.82 | |
| 2 | 2.12 | 249. | 565.0 | 0.00 | 0.88 | 1.52 | 3.19 | 1.67 | 0.73 | 23.20 | 4.73 | 2.3 | 0.10 | 43.00 | 0.18 | |
| ł | 2.12 | 222. | 556.0 | 19.90 | 0.88 | 1.30 | 3.15 | 1.77 | 0.78 | 23.50 | 4.78 | 2.3 | 0.11 | 43.70 | 0.18 | |

Figure 43

| B | BEAVERTON CLAY QUARRY | | | | | | |
|--------------------------------|-----------------------|-----------|-------------|--|--|--|--|
| Chemica | Analysis | Elemental | Composition | | | | |
| AL O | 10.31 | Al | 5 36 | | | | |
| Fe ₂ O ₃ | 3.59 | Fe | 2.51 | | | | |
| CaO | 22.56 | Ca | 16.11 | | | | |
| MgO | 2.61 | Mg | 1.57 | | | | |
| Na ₂ O | 1.11 | Na. | 0.81 | | | | |
| K ₂ O | 2.34 | К | 1.94 | | | | |

Figure 44

| A - Calcul | A - Calculation of effective radiation | | | | | |
|---|---|--------------------|-----------------|---------------------|--|--|
| Since the samples were etched, α radiation will not have affected electron trapping in | | | | | | |
| the portion | of the crystals and | lyzed | | | | |
| and P | | | Actual | Effect of | | |
| β radiation | rads/y_conc.* | Attenuation factor | attenuation | thoron/radon loss** | | |
| U | 0.01460 | 0.90 | 0.013158 | 0.00526 | | |
| Th | 0.00286 | 0.85 | 0.002431 | 0.00097 | | |
| K | 0.06960 | 0.97 | 0.067512 | 0.67512 | | |
| γ radiation | | | | | | |
| U | 0.01148 | 1 | 0.01148 | 0.00057 | | |
| Th | 0.00514 | 1 | 0.00514 | 0.00026 | | |
| K | 0.02092 | 1 | 0.02090 | 0.02090 | | |
| Total Radia | tion | | | | | |
| U | | | 0.0246 | 0.0058 | | |
| Th | | | 0.0076 | 0.0012 | | |
| K | | | 0.0884 | 0.0884 | | |
| B - Age calculations for sherd #2 | | | | | | |
| Natural radi | Natural radiation absorbed = 125 rads | | | | | |
| For no rado | n/thoron loss: | | For 100% rado | n/thoron loss: | | |
| Uppm | $2.0 \ge 0.0246 = 0$ | .0493 | U ppm 2.0 x 0. | 0058 = 0.0117 | | |
| Thppm | $13.1 \ge 0.0076 = 0$ | .0992 | Th ppm 13.1 x | 0.00123 = 0.0161 | | |
| K % | $2.99 \times 0.0884 = 0$ | .264 | K % 2.99 x 0.0 | 884 = 0.264 | | |
| | (|).413 | | 0,292 | | |
| Cosmic radi | ation (| 0.015 *** | Cosmic radiati | on <u>0.015</u> *** | | |
| Tot. yearly | dose (|).428 rads | Tot. yearly dos | 0.307 | | |
| Age = 125/0 | .428 = 292 BP = 1 | 701 AD | Age = 125/0.30 |)7 = 407BP = 1586AD | | |
| | | | | | | |

Benson is a well drained site, most likely there will not have been any radon/thoron loss.

C - Calculation of uncertainty

Calculation of systematic error: % difference rads/year @ 100% radon/thoron loss vs. no loss = 0.292/0.413 = 29%Resulting systematic error = +/-7% (Fleming, 1987: 21)

Random error = +/-7% (Fleming, 1987: 67) Calculation of INAA error

| | Count uncertainty | %Contrib. to tot. radiation | Weighted count error |
|-------|---|--|----------------------|
| U | 16.4 | 5.8 | 0.95 |
| Th | 4.7 | 9.1 | 0.43 |
| Κ | 0.15 | 85.1 | 0.13 |
| Com | bined INAA error $= (0.9)$ | $5^{2}+0.43^{2}+0.13^{2})^{1/2} = 1.1$ | |
| Total | $Prror = (1 \ 1^2 + 7^2 + 7^2)^{1/2} =$ | +/- 9 9% | |

Date assigned to sherd #2

3 2

Uncertainty in years = $407 \times 0.099 = +/-40$ Therefore date = 1566 +/- 20

* For U and Th concentration is in ppm, for K it is in %. **Effect of radon and thoron loss is equivalent to a reduction in radiation of 60% for β and 95% for γ . *** Fleming, 1987: 67.

Figure 45

| SAMPLES NATURAL DOSE FROM GLOW CURVES | | | | |
|---------------------------------------|--------------|--------|--------------|--|
| Sample | Natural Dose | Sample | Natural Dose | |
| 1 | na | 20 | 160 | |
| 2 | 125 | 21 | 190 | |
| 3 | 125 | 22 | 150 | |
| 5 | 125 | 22 | 150 | |
| 4 | 170 | 23 | 170 | |
| 5 | 110 | 24 | 95 | |
| 6 | na | 25 | 360 | |
| | | | | |
| 7 | 135 | 26 | 140 | |
| 8 | 90 | 27 | 400 | |
| 9 | 120 | 28 | na + | |
| | | | | |
| 10 | 250 | 29 | na | |
| 11 | 170 | 30 | na | |
| 12 | 90 | 31 | 200 | |
| | | | | |
| 13 | 85 | 32 | na | |
| 14 | 200 | 33 | 180 | |
| 15 | 170 | 34 | 510 | |
| | <u>.</u> | | | |
| 16 | 175 | 35 | 170 | |
| 17 | na | 64 | 400 | |
| 18 | 170 | 65 | na | |
| | | | | |
| 19 | 290 | 66 | na | |
| | | 67 | 220 | |
| | | | | |

Figure 46

normal for this type of material. The positive results obtained produce dates which are in reasonable agreement with each other and are sufficient to establish chronologies for their respective sites. The accuracy of results compares favourably with previous dates obtained for Davey, Fournier and Train site ceramics (Volterra et al., 1991). Also there was good general agreement in the chronology of the Balsam Lake sites between the results of T-L and stylistic analyses (Figure 47). T-L results produce dates which are consistently marginally later than stylistic ones with the exceptions of Benson, where the former are earlier by less than a decade.

T-L results also compare favourably with some recently obtained radiocarbon dates for the Balsam Lake sites (Table 7, Figure 47). Discrepancies occur in the case of samples for the Benson, Coulter and Kirche sites, where ¹⁴C results indicate dates consistently older (early seventeenth century). However the material subjected to radiocarbon tests consisted of organic residues scraped from pottery sherds and was somewhat contaminated with ceramic. This rendered the analysis complex and the results suspect. Furthermore, as noted previously, all ¹⁴C dates for this period of time require large corrections and are inherently inaccurate. It is also known from historical sources (Champlain, 1929: 59) that when Champlain travelled through the area in the early 1600s the entire region had already been abandoned by Native people in favour of Huronia.

Details of the dates for each site are outlined below.

The Hardrock site

Only two samples had been selected initially for the Hardrock site. These were intended to act as "checks" and confirm the hypothesized chronological order of the Balsam Lake sites. As discussed previously the Hardrock location is considered essentially to be one where no radon and thoron losses would have occurred during

| SITES IN ABSOLUTE CHRONOLOGICAL ORDER | | | |
|---------------------------------------|-------------|--|--|
| SITE | T - L DATE | | |
| Hardrock | 1467 - 1561 | | |
| Jamieson | 1499 - 1569 | | |
| Kirche | 1541 - 1589 | | |
| Coulter | 1550 - 1582 | | |
| Benson | 1555 - 1599 | | |
| | | | |

Table 7

THERMOLUMINESCENCE DATES



the disintegration process of the radioactive isotopes. Dates were therefore calculated on this basis. The two results obtained, while just overlapping, were quite different from the data obtained from stylistic analysis, though the latter were reasonably consistent with a radiocarbon date obtained some time ago from organic remains recovered at the site. The T-L date obtained was AD 1529 +/- 11 versus a stylistic date of AD 1450 +/- 15 and a ¹⁴C date of AD 1482 +/- 70 (J. Reid, personal communication). Accordingly four additional samples were tested. The new data obtained, when combined with the previous results, show that in fact two separate components could be proposed for this site. The earlier one, estimated as AD 1514 +/- 47, is later than the stylistic date of AD 1450 +/- 15 but overlaps well with the radiocarbon date. The later date is estimated as AD 1597 +/- 41.

A possible explanation for the two results could be that Hardrock was not occupied continuously and that its traces disappeared rapidly. Other people may have visited and utilized the site temporarily long after abandonment, to take advantage of its location. It is possible that testing of additional sherds might yield other occupational dates.

The Jamieson site

Three of the samples selected for the Jamieson site produced meaningful results. There are water springs in the area of this site and a number of small creeks. Accordingly this area was considered one where radon and thoron losses most likely did not occur. The date estimated is AD 1534 +/- 35. This date fits within the site sequence proposed for the Balsam Lake area and is only a decade older than the stylistic date. There is a radiocarbon date, based on a wood charcoal sample, for the Jamieson site (L. Pavlish, personal communication). This is AD 1505 +/- 75 and would appear to support an earlier occupational period than hypothesized even by stylistic analysis. The T-L date is considered valid.

The Coulter site

Six of the twelve samples selected for the Coulter site yielded meaningful results. Though this is only fifty percent of the material tested this is not unusual in thermoluminescence and the results are considered valid. Unfortunately it is difficult to determine what amount of radon and thoron loss may have occurred at this site and it is possible that different sections of the area may have been affected differently. However the results calculated for either 100 percent loss and no loss appear to be in reasonable agreement. The date obtained by this method (AD 1566 +/- 16) is the same as the date assigned to the site by stylistic analysis (AD 1565 +/- 15). The recent corrected radiocarbon date for the Coulter site of AD 1639 +/- 20 (TO-3636) is quite different from two previous ones from the Archaeological Survey of Canada (1447 +/- 80: S-1536 and 1177 +/- 60 : S-1537). Such wide discrepancies are not unexpected. As indicated above ¹⁴C dates for this period are unreliable. All ¹⁴C results are outside the possible date range. With regard to the most recent one, the historical record indicates that by the second decade of the seventeenth century the Balsam Lake area had been abandoned.

Another interpretation can also be made from the data. If the two results at the low age end are separated from the five at the high age end they would produce two different occupational dates (see Figure 47), though the upper and lower end overlap. One would be AD 1520 +/- 33 and the other AD 1581 +/- 31. Since we know that the palisades at Coulter had been expanded several times (Ramsden, 1988b; Damkjar, 1990), this could be an indication of occupation of the site over a longer period than usual. Additional testing on Coulter material would have to be carried out for a more appropriate determination.

The Kirche site

Four of the seven samples chosen for the Kirche site yielded meaningful results. As indicated above this is not unusual for thermoluminescence analysis and the results are considered valid.

The date obtained for the site (AD 1565 +/- 24) is somewhat later than the one obtained by stylistic analysis (AD 1550 +/- 20) but does overlap with it. A recent corrected ¹⁴C date obtained from material collected at the site is AD 1639 +/- 20 (TO-3633). This does not agree with an earlier corrected radiocarbon date of AD 1505 +/- 75 (S-1538; C. Ramsden, 1989). The discrepancy is not unexpected. As indicated above ¹⁴C dates for this period are unreliable. Accordingly the T-L date is considered a more reasonable one for the Kirche site.

Accepting a date of AD 1565 +/- 24 as the correct one would make the Kirche site contemporary with Benson and Coulter as well as Jamieson. The evidence from trace element analysis could support such an interpretation.

The Benson site

Six of the ten samples chosen for the Benson site yielded meaningful results. However two of them are considerably outside the chronological range of the other four. One is much later and one much earlier. The date range obtained by using the four similar results is more consistent with the general chronology of occupation of the <u>Balsam Lake region</u>.

The site is well drained and on a slight rise located away from bodies of water Accordingly in the calculations it has been assumed that radon and thoron losses are 100 percent. The date obtained for the site (AD 1577 +/- 22) is almost identical to the stylistic date (AD 1580 +/- 20) but is considerably different from the recent radiocarbon date of AD 1610 +/- 25 (TO-3635) and two previous ¹⁴C results (1547 +/- 80 : S-1535 and 1357 +/- 70 : S-1539).

Thermoluminescence and trace element analyses: additional inferences

i Temporal relationship between indigenous and immigrant communities: Kirche vs. Jamieson

The results of T-L analysis strongly support the archaeological evidence that the Kirche village was inhabited while the earlier indigenous Jamieson site was still occupied.

The average dates obtained from the samples of the two sites (AD 1565 and AD 1534) are just outside the normal span of duration of occupation for Huron sites. However their uncertainty ranges overlap for 28 years; the earliest Kirche date of AD 1541 compares with a latest date for Jamieson of AD 1569.

ii Contemporaneity of Benson with the Coulter site

If we accept the possibility that the dates for the Coulter site can be interpreted as representing different times of occupation, the T-L evidence then supports the development sequence proposed by Ramsden (1988b) which envisages this as a site which underwent a number of expansions during its occupation. The average for the latest of the Coulter dates, estimated at AD 1581, would be still earlier than the latest possible calculated Benson date of AD 1599.

iii T-L vs. stylistic analysis

The T-L results produce dates which, though confirming the archaeological sequence of events, place them in some instances at slightly later times. They vary somewhat from radiocarbon dates for these sites, though, as stated above, radiocarbon determinations for this time period are generally unreliable. Overall the results are considered quite satisfactory and prove the validity of thermoluminescence as a technique to be utilized in archaeological research involving Native Ontario ceramics. They also confirm the superiority of thermoluminescence over radiocarbon when applied in dating material from a time period for which the radiocarbon results require always considerable corrections and are often suspect.

6 - CONCLUSION

The research program set out to demonstrate that the use of thermoluminescence and trace element analysis is relevant to the archaeological hypothesis of the historical sequence of events and cultural development of the people which inhabited the Balsam Lake region in the sixteenth century proposed by Ramsden (1988a). He suggested an increase in contacts between the local populations and the St. Lawrence Iroquois and the eventual absorption of the latter by the former. My research proposed to achieve its objectives by determining whether dates obtained independently from stylistic consideration are consistent with the hypothesis and by discriminating, also independently from stylistic considerations, between locally manufactured pottery and ceramics of external provenance. The results of my research I believe have sachieved the goals originally established.

The chronological sequence developed via thermoluminescence for site occupations ranges from the second half of the fifteenth century to the late sixteenth century. While it is somewhat narrower than that postulated by stylistic analysis, it confirms that Iroquoian people lived in the area of Balsam Lake for over a century prior to the consolidation of the Huron in Simcoe County.

By combining the results of T-L and trace element analysis it was possible to discern a change in the social interactions between the local population and the St. Lawrence Iroquois. At the earlier Jamieson site there is a discernible difference in the composition of the fabric between ceramic artefacts of Huron style and St. Lawrence style. This would suggest contacts between the two people in which the latter style of artefacts were imported onto the site perhaps as a result of trading visits. At the Kirche site, whose occupation ends after Jamieson, in addition to Huron style material, two different ceramic types appear, both made in St. Lawrence style. The examination of one of these samples revealed it to be made locally, while the others were imported from elsewhere. This could be hypothesized as indicating a shift in the relations between the two people and could support Ramsden's suggestion of intermarriages (1988b: 181; see also Trigger, 1985: 106). At the Coulter and Benson sites, which are the most recently occupied, no distinction can be made between the fabric of any of the sherds analyzed regardless of their stylistic differentiation. Both artefacts are made of local materials and this provides strong support for the hypothesis that at the time the St. Lawrence and Huron lived together (Ramsden, 1978; 1988a; Wright, 1966; Damkjar, 1990).

Thus the results of this research are important for Northeastern prehistory. They make a positive contribution to the ongoing debate regarding the movements of people in and out of the Trent Valley and the uncertainty about the demise of the St. Lawrence Iroquois who had vanished by AD 1603 (Trigger, 1985: 62).

Trigger hypothesizes that these people were destroyed by the Mohawks who wished to acquire directly European axes and other iron implements (1985: 147). However, the absorption of at least some of the St. Lawrence into the Balsam Lake settlements would have been consistent with the accepted practice among Native Americans for a winning group to incorporate the losers into their own communities (Richter, 1986: 105, 108, 113). If we assume then that this is the sequence of events which took place, as suggested by Wright (1966: 58) and by Ramsden (1988a), the current research would confirm that the conflict between the two occurred in the second half of the Sixteenth century and not earlier as suggested by Trigger (1985: 144).

The results obtained via thermoluminescence yield a much more dramatic impression of the changes which affected the Balsam Lake sites than the dates obtained by stylistic analysis. The new chronology is much narrower and therefore developments appear to have taken place much more rapidly than was assumed earlier producing greater impact on people who were used to relatively stable conditions over a long period of time. Similarly the results of trace element analysis provide a better perspective of the Balsam Lake society because, by discriminating between local and imported artefacts, they confirm a potential change in the relationship between Huron and St. Lawrence which could only be assumed before.

7 - CAN A STORY BE TOLD ?

Though both history and archaeology deal with the same general subject (the past), archaeological reports appear to be significantly different from historical works. I find this an intriguing situation and would like to provide a closing for my thesis that might attempt to bridge the gap between the two.

To achieve this, since the material remains left behind by the people who lived in the upper Trent region during the sixteenth century have been interpreted as belonging to tribes of the Huron family, I believe that some background exposition regarding our knowledge of them is necessary. I believe that it is also necessary to place the direct evidence of the material culture recovered in the context of the time sequences which affected these people. The idea of time sequences is borrowed from the French historian Fernand Braudel (1958, 1980). He suggests that it is not only the occurrence of single events which forms the fabric of history but a combination of these, the structure of everyday life and the conjuncture of long term developments over long periods of time, which he calls *la longue durée* (Braudel, 1958;727). Events are part of long term processes and are influenced by them and by beliefs that have coalesced over long periods.

Finally it will be necessary to write something simple that attempts to connect all this material together.

Some historical context

The Huron occupy a special position in the history of Canada for their support of the early French traders and their impact on the fur trade. Their demise at the hands of the League Iroquois in 1649 closed a cycle of human development that had begun centuries

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8 ---

earlier as part of the evolution of the Eastern Woodland Indians. Their history is tied closely to the migratory tribes of the Montagnais, Algonquin and Chippewas and to the other agriculturalists who lived at the same time in southern Ontario: the Neutral, Petun and Iroquois (Reaman, 1967:5).

Little is known of the origins of the Huron outside the archaeological domain. The Ouendat or Wendat, as they called themselves (Heidenreich, 1971:21), appear to have arisen from the amalgamation and then the separation of the people associated with the Pickering and Glenn Meyer stylistic horizons (Wright, 1966: 94 - 98). "The theory that Wendat meant 'a land apart' and was considered an 'island' by the Huron, is reinforced by a reference to a conversation between the Jesuits and Native people, in which the latter refer to themselves as 'inhabitants of the island''' (JR 15: 21, 33: 237 - 239, c.f. Heidenreich, 1971: 22).

The name Huron first came into usage among the French settlers sometime prior to 1623 (Champlain 5: 100 c.f. Scott, 1966: vii; JR 16: 231 - 233 c.f. Heidenreich, 1971: 21), but the first contact between the two appears to have taken place in 1609. This occurred when Champlain went to St. Eloi in Quebec to help the Algonquin and their confederates on a major raid against the Mohawk (Champlain 2: 67 - 71, c.f. Heidenreich, 1971: 49).

White believes that the Huron had been introduced to European trade by their traditional northern trading partners the Algonquin and Nipissing by 1603 (1985: 41). However the first direct trade between Huron and French, according to Heidenreich (1971: 49), did not occur until June 13, 1611. Further direct contacts continued with Champlain's visit to the west in 1615-1616 and with the brief incursion of the Recollet Fathers. These were followed by the more stable and significant missions of the Jesuits, which culminated with the founding of Sainte-Marie among the Huron. Most of the data regarding their customs and habits and about their destruction by the

League Iroquois has come to us from the Jesuit Relations. While other sources exist, our information on the Huron has been acquired only through the perspective of foreigners, strangers to the established American customs which had evolved over long periods. The French settlers and their priests, steeped in the European cultural tradition, had different human values and different concepts of space and time. Their preconceptions and the limitation of sources have tended to bias somewhat at least the early interpretation of the Ontario archaeological material. Furthermore the Europeans do not seem to have had any contacts with the people who inhabited the Balsam Lake area. This also complicates our analysis because no direct chronological references are available.

Trends and the impact of time

The people who lived in south central Ontario were, to paraphrase Braudel (1958: 725 - 753): "weighted down by their own ponderous inheritance". They were hemmed in by the shores of Lakes Ontario, Erie and Huron and the Ottawa River. These Farmers of the North (Trigger, 1969) could not move further north (even if their friends the Algonquin had allowed it) because the environment there would not support the growing of corn which had become such an integral part of their subsistence. We were also tied to a very strong tradition of trading (Bonvillain, 1989: 26 - 27) which was necessary to support their lifestyle and which was in fact continually expanding through the Northeast, particularly as population increased.

The cultural "structures" (Braudel, 1958: 731) based on trade and agricultural development had become, over a long time span, stable elements of the Huron life pattern, but while they provided support for the development of the Balsam Lake people, they also produced constraints. The reality was one of confronting the difficulty, at times even the impossibility, of breaking out of geographical frameworks, biological realities and

limits of productivity. 'For centuries man has been a prisoner of climate, of vegetation, of the animal population, of a particular agriculture, of a whole slowly established balance from which he cannot escape without the risk of everything being upset" (Braudel, ibidem). Mental frames developed through a static tradition can also form traps which are difficult to evade.

Suddenly the Huron culture, based on the long trend of a northern agricultural development and of an increased trade as a way of life, met the European culture which was based on a long trend of mercantilistic expansion and aspirations to supremacy. The Huron in general and the Balsam Lake tribes specifically were not just passive victims of this conjuncture. It is indeed their active participation in it that precipitated the conflict with the St. Lawrence Valley Iroquois and eventually the terminal struggle with the League.

The Balsam Lake Huron at first would have pursued aggressively the rich trade opportunities offered by the new intruders in the American continent. The first evidence that a change in the pattern of life had occurred outside their territory would have reached them through the St. Lawrence Iroquois with whom the Balsam Lake people had traded for a long time.

European trade was indeed sought after since it offered a prime way to acquire the goods that built prestige and influence (Courtin, 1984: 227). It was not unusual for local people to travel hundreds of miles in search of the tools and weapons which the European could provide. These led to "social and political changes, one of the most immediate of which was to create new ways of working out economic and military rivalries within Indian society" (Courtin, 1984: 220).

Courtin explains that "cross- cultural trade before and after the European arrival ran a broad gamut of possible relationships, from mutual raiding and plain robbery, through a variety of ritual ceremonial exchanges with important social and political

functions" (1984: 225). Therefore it is not surprising that trade competition should have culminated in the conflict which was part of the wider Franco-Algonquin-Iroquois struggle and which ended in the defeat and dispersal of the St. Lawrence. The absorption of at least some of them into the Balsam Lake settlements was consistent with the accepted practice among Native Americans for winners to incorporate the losers into their own communities (Richter, 1986: 105, 108, 113).

The span of occupation of the sites studied is a mere 63 years +/-, if we accept the thermoluminescence dates for the Balsam Lake sites. For those people that occupied south central Ontario and had to contend with late and early frosts, with crops which were not originally intended for a northern climate and with animal herds which were moving away from the traditional hunting grounds this was at once a circular and a struggling time. For those people this should have been static time, never ending, continuous, during which they had always occupied the continent, during which the same events were repeated in accordance with the seasons and things changed only very slowly if at all. Yet this was sufficient time for one or many of the cycles which take place in the history of the human race, a time sufficient to overturn the previously accepted reality. The developments that resulted in the material record recovered at Balsam Lake took time, but the changes occurred at a rate which was outside of the experience of the local people.

Which of these concepts of time represents the reality that we are attempting to reconstruct? Which of these do we consider when we write about the development of real people whose past life we can see in the present only through a few sherds of pottery? The choice is not important provided we keep in mind that they all represent a form of reality, that events are overlaid on cycles which in turn are affected by long term trends.

A story

During the continuing search for a better environment in which to settle, the Balsam Lake region must have looked attractive to the people that settled there for a period which probably spanned three or four generations. The rolling hills were easily traversed, the main lake provided a steady supply of fish and the network of streams permitted them to maintain those contacts already established with other groups.

Of the sites analyzed, Hardrock is the oldest. This was possibly a semi-permanent base occupied only for part of the year. It is also possible that the ceramic recovered was not all manufactured locally but some of it may have been made at the various temporary sites in which the people lived in summer time. These ceramics were made from clay found in the region south west of the site itself, obtained from one of the few beds widely scattered in the region.

Even the first occupiers of Hardrock must have been living in the region for some time prior to the earliest date ascertained from the ceramic samples, since it would have taken them some time to explore for and discover mineral resources in an area which •must have been heavily wooded at the time.

It is more than likely that by the early 1500s a number of sites around Balsam Lake, such as Jamieson, were already occupied. People had found a sheltered area close to springs with a terrain that, though relatively meagre, could be cleared and cultivated easily as it sloped gently between the site and the lake. A source of clay existed nearby which eliminated the need for long excursions in search of raw material. A village had been built and the normal cycle of occupation had become well established.

Expanding contacts with the people of the St. Lawrence Valley had resulted in the presence at the site of foreign ceramic either imported or used by visiting traders.

The traders who came after 1534 brought the news of encounters with strange new people with new tools and new goods.

This information spread rapidly throughout the existing tribal network, so that in time the inhabitants of Jamieson must have become aware that other people from the lands to the west had started migrating into the Balsam Lake area to be closer to the potential new sources of trade (see Ramsden 1988a).

However they must have been surprised when one of these tentatively settled in the 1550s less than a kilometre away from their village at the Kirche site. These were not enemies, yet the people of Jamieson were not inclined to let the newcomers have access to their fields and their clay and so decided to erect ramparts and a partial palisade. The newcomers had to utilize other resources as we can see from the material they employed for their ceramic.

The people who had settled at Kirche had moved in search of trade and they pursued it more aggressively than their neighbour. Their contacts with their trading partners, the St. Lawrence Iroquois, were so frequent that the latter were permitted to erect some houses outside the village palisade. These were used during trading visits. One of the

St. Lawrence women ended up living at the site participating in the seasonal chores and producing the ceramic whose shattered remains were found and analyzed. Her presence there was due either to an intermarriage arrangement between the two groups or as a result of an eventual raid by the Huron, when relationships with the St. Lawrence deteriorated. Skirmishes with the latter became frequent and the escalation of violence, affected in a very disruptive way the pattern of life which had been established so painstakingly in the Balsam Lake region, a pattern repeated throughout southern Ontario over
the centuries after the introduction of agriculture. The pervasive insecurity and the resulting threat to crop recovery and of food gathering convinced some of the Kirche inhabitants to move away from their village and settle with the people who had recently built the larger Coulter centre. Ceramics made from their traditional clay sources and found at this site attest to this movement.

The closer integration of all the Balsam Lake people in response to the constant and escalating friction with their former trading partners gave support to those who were in favour of a decisive action for the control of the trade with the Europeans. The St. Lawrence were attacked, their villages destroyed and the people dispersed. Some of the defeated survivors were absorbed into the victors' communities, not an unusual occurrence in the tradition of the Northeast, and ended up living in the Benson and Coulter villages as confirmed by the pottery which they manufactured from local clay and which has been found there.

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APPENDIX A

SAMPLE IDENTIFICATION

| Site | Sample number | Site number |
|----------|---------------|------------------------|
| Benson · | 1 | 9835 |
| | | 9074 |
| | 3 | 4601 |
| 8 | 4 | 7721 |
| | 6 | 12893 |
| | 7 | 12550 |
| | 8 | 13637 |
| | 9 | 13564A |
| | 10 | 13600 |
| | 10 | 13000 |
| Kirche | 11 | 2050 |
| | 12 | 2257 |
| | 13 | 3672 |
| | 14 | 2946 |
| | 15 | 8583 |
| | 16 | 8645 |
| | 17 | 8694 |
| Jamieson | 18 | 56 |
| | 19 | 242 |
| | 20 | 30 |
| | 21 | 288 |
| Coulter | 24 | 5374 |
| | 25 | 6743 |
| | 20 | 7004 |
| | 27 | 5795 |
| | 29 | 4984 |
| | 30 | 21682 |
| | 31 | 21655 |
| | 32 | 11828 |
| | 33 | 11400 |
| | 34 | 16269 |
| | 35 | 6035 |
| Hardrock | 22 | H15580 I |
| | 23 | H1755165 |
| | 64 | H20.5.5.55 I |
| × | 65 | H131.1.110 I |
| | 66 67 | H20555 I H-30 175Bc |

Figure 16

DESCRIPTION OF ANALYSIS

Thermoluminescence

All the sherds were catalogued and properly identified with their individual project sample numbers and cross-referenced to their catalogue number (Figure 16). All ceramic material was photographed with a Canon FTb camera using an FD 50mm 1:1.8 S.C. lens under artificial lights (Figures 6 and 7). Sherds were washed in distilled water, scrubbed with a nylon bristle brush and then rinsed in double distilled water. The samples were then air dried at ambient temperature in the laboratory.

The complexity of pottery dosimetry (Fleming, 1979: 18 - 30) places some restrictions on the size of the crystals which can be used for T-L analysis. This complexity is the result of the different behaviour of α , β and γ radiation already outlined. Accordingly a number of T-L techniques can be applied to temper (Fleming, 1979: 40 - 119) to determine the date of the ceramic from which it originated.

When a sufficient quantity of relatively large crystals are present, the quartz inclusion method of analysis is preferred since, by chemical treatment, the effect of the erratic α radiation can essentially be eliminated. This technique has been used with success for dating Ontario ceramics (Volterra et al., 1991) and therefore has been chosen for my research.

The use of the quartz inclusion method of analysis makes it necessary to extract and select temper grain sizes sufficiently large to ensure that the effect of α dosage would be eliminated. The 75 to 125 μ crystal fraction of the pottery temper, when properly treated, fulfils this requirement and yet is sufficiently small in size to ensure that β attenuation effects are not significant (Figure 15).

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| SAMPLE COLOUR AFTER GRINDING | | | | | | |
|------------------------------|--------------|-----------|--|--|--|--|
| Sample No. | Style | Colour | | | | |
| 1 | St. Lawrence | umber | | | | |
| 2 | St. Lawrence | umber | | | | |
| 3 | Huron | umber | | | | |
| 4 | Huron | sienna | | | | |
| 5 | Hybrid | umber | | | | |
| 6 | Hybrid | umber | | | | |
| 7 | Huron | umber | | | | |
| 8 | Huron | sienna | | | | |
| 9 | St Lawrence | black | | | | |
| 10 | St. Lawrence | sienna | | | | |
| 11 | St. Lawrence | dark grey | | | | |
| 12 | St. Lawrence | dark grey | | | | |
| 13 | Huron | black ** | | | | |
| 14 | St. Lawrence | black | | | | |
| 15 | St. Lawrence | dark grey | | | | |
| 16 | Huron | sienna | | | | |
| 17 | Huron | sienna | | | | |
| 18 | St. Lawrence | sienna | | | | |
| 19 | St. Lawrence | sienna | | | | |
| 20 | Huron | umber | | | | |
| 21 | Huron | umber | | | | |
| 22 | Huron | umber | | | | |
| 23 | Huron | umber | | | | |
| 24 | Huron | umber | | | | |
| 25 | St. Lawrence | dark grey | | | | |
| 26 | Huron | dark grey | | | | |
| 27 | St. Lawrence | umber | | | | |
| 28 | Huron | sienna | | | | |
| 29 | St. Lawrence | umber | | | | |
| 30 | Huron | sienna | | | | |
| 31 | St. Lawrence | sienna | | | | |
| 32 | Hurons | ienna | | | | |
| 33 | St. Lawrence | umber | | | | |
| 34 | Huron | umber | | | | |
| 35 | St. Lawrence | umber | | | | |
| 64 | Huron | umber | | | | |
| 65 | Huron | umber | | | | |
| 66 | Huron | umber | | | | |
| 67 | Huron | umber | | | | |

Figure17

.

2.7

To obtain the desired grain size, the sherds were washed and dried then processed through a Cook and Son crushing roller apparatus, with the gap between the rollers being reduced progressively. The crushed material from each sample was collected into properly labelled polyethylene beakers. Some of the crushed material for each sample was separated, weighed on a Mettler AJ 100 balance and stored in appropriately labelled polyethylene capsules to be used for Neutron Activation Analysis. The remaining material was then separated into fractions by using stacked Edincotts screens for 500, 210, 125 and 74 μ mesh sizes and then processed through a Central Scientific Meinze sieve shaker model 18480. Shaking time for each sample was five minutes at a frequency setting of6.5. A test sample was run to confirm optimum machine settings (Volterra et al., 1991: 5). Longer shaking periods and higher and lower frequencies were tried but did not yield different amounts of the individual fractions.

The 74 - 125 μ fraction was collected separately for each sample. The remaining material was stored in properly labelled polyethylene bags one for each sample. Colour of the crushed samples varied from sienna to charcoal gray (Figure 17) however there was no apparent association between colour and the purported tribal origin of the ceramic samples.

Yields of the selected fraction, though varying from sample to sample, remained relatively uniform. The separated 75 - 125 μ fraction was then processed through a Franz Isodynamic separator model L-13668. Here separation was achieved by exploiting the paramagnetic properties of various materials. Quartz crystals are quite refractory and with the proper settings they can be easily removed from the remainder of the sample. The material to be separated was inserted via a funnel at the top of a chute placed between powerful electromagnets. The lower end of the chute is divided into two channels. The non-magnetic material collects into the lower of the two and moves downward along

it. The tilt and the yawl angles of the chute can be adjusted as can the magnetic field surrounding it. To suit the different materials to be handled, a motorized variable frequency vibrator is attached to one end of the chute to facilitate the flow of the material. The magnetic and non-magnetic fractions were collected separately in aluminium containers placed at the end of each channel.

Several runs were made with a test sample to determine optimal machine settings. These were selected as a tilt angle of fifteen degrees, a yawl angle of twelve degrees, magnet current setting of 1.6 amps. and shaking frequency at maximum. The test was repeated twice, after a number of samples had been run, to confirm the settings.

Each sample was run once through the machine. The magnetic material was rerun at the same machine setting to attempt to separate any residual quartz which had been retained in the reject. The latter was the added to the quartz already separated and also rerun through the Franz apparatus, at the same settings, to remove impurities which might have been entrapped.

while the rest was added to the containers into which the previously sorted material had been placed.

The quartz fractions were weighed using a Mettler AJ 100 balance (Figure 18) then washed with isopropyl alcohol and finally air dried at ambient temperature in the laboratory. Each sample was then chemically treated in hydrochloric acid for two and one half hours. The beakers were stirred after 120 minutes. At the end of the treatment the hydrochloric acid, originally colourless, was bright yellow. The acid was drained and each sample was thoroughly washed with double distilled water. The material was rinsed until all acidity was removed as verified with the use of pH paper.

UNTREATED QUARTZ - 75 - 125 µ FRACTION

| Sample No. Weigh mgs. | | Sample No. | Weight mgs. |
|-----------------------|--------|------------|-------------|
| 4 | 004.4 | 04 | 004.0 |
| 1 | 834.4 | 21 | 624.6 |
| 2 | 526.8 | 22 | 767.0 |
| 3 | 968.3 | 23 | 576.4 |
| 4 | 182.3 | 24 | 683.9 |
| 5 | 784.8 | 25 | 1035.8 |
| 6 | 435.2 | 26 | 408.9 |
| 7 | 939.8 | 27 | 900.1 |
| 8 | 1094.3 | 28 | 262.5 |
| 9 | 216.3 | 29 | 535.7 |
| 10 | 370.9 | 30 | 288.0 |
| 11 | 447.8 | 31 | 466.7 |
| 12 | 483.4 | 32 | 757.0 |
| | | | |
| 13 | 282.2 | 33 | 1404.8 |
| 14 | 108.5 | 34 | 398.5 |
| 15 | 336.4 | 35 | 489.5 |
| 16 | 451.9 | 64 | 1545.4 |
| 17 | 156.4 | 65 | 1247.9 |
| 18 | 543.4 | 66 | 1225.4 |
| 19 | 293.6 | 67 | 1257 2 |
| 20 | 274.8 | 0, | 1407.4 |
| | | Sec. B. | |

Figure 18

 Σ

| SAMPLE COLOUR AFTER CHEMICAL TREATMENT | | | | | |
|--|---|---|--------|--|--|
| | Stylistic attribution | | | | |
| Colour | St. Lawrence | Huron | Hybrid | | |
| White | 10, 19, 33 | 4, 8, 16, 17, 22, 28, 30, 32, 34, 64, 65 | | | |
| Light grey | 18, 25 | 20 | 5, 6 | | |
| Grey | 1, 2, 9, 11, 12, 14, 15, 27, 29, 31, 35, 66, <mark>67</mark> | 3, 7, 13, 21, 23, 24, 26 | | | |

Figure 19

Samples were again air dried in the laboratory and re-weighed. The dried samples ranged from white to grey in colour. Again there was no apparent association between colour and purported tribal origin of the ceramic samples (Figure 19).

Samples were then etched with full strength hydrofluoric acid for sixty seconds followed by five rinses with double distilled water. Elimination of residual acidity was verified with pH paper. Some samples showed greater reactivity than others, most likely due to the presence of calcite and feldspar crystals. Etched crystals for all samples were essentially uniform in colour.

Hydrofluoric acid etching is a very time consuming and complex exercise. Material must be handled inside fume hoods and crystals must be thoroughly neutralized after treatment to ensure there is no residual acidity which is harmful to people and apparatus. However the benefits are significant. A one minute etch is sufficient to remove the outer layer of each crystal thus eliminating the impact of α radiation (Volterra et al., 1991: 6, 9). With such short treatment time β dose degradation is not considered significant. The hydrofluoric acid treatment also helps to smooth the T-L glow curves by removing the surface impurities which were diffused during kiln firing from the clay matrix of the sherd onto the crystal cortex.

After etching, the crystals were again air dried at ambient temperature and then weighed. It is interesting to note that there appears to be some correlation in weight loss as a result of hydrofluoric acid treatment between the 75 - 125 μ crystal fractions from Balsam Lake sherds which were assigned different tribal origins. Though the difference in weight loss between materials from sherds originally identified as Huron or St. Lawrence Iroquois varies between sites, at both site the difference is consistent (Figure 20).

Each of the samples of chemically treated 75 - 125 μ quartz fraction was then divided into three portions. Two of the portions were placed into appropriately labelled

| SITE | SAMPLE# | STYLE | %LOSS | | |
|------------------|---------|-------|----------|---|--|
| Benson (North Ea | ast) 1 | S | 39 | | |
| | 2 | S U | 59 | | |
| | 4 | Ĥ | 64 | | |
| Benson (South Ea | ast) 5 | В | 51 | | |
| Benson (South) | 6 | В | 54 | | |
| | 7 | H | 44 | | |
| | 8 | Н | 49 | | |
| | 9 | S | 58 | | |
| | 10 | S | 48 | | |
| Kirche (outside) | 11 | S | 77 | | |
| | 12 | S | 71 | | |
| | 13 | Н | 55 | | |
| Kirche (inside) | 14 | S | 74 | | |
| | 15 | S | 50 | * | |
| | 16 | H | 47 | | |
| | 17 | н | 51 | | |
| Jamieson | 18 | S | 36 | | |
| | 19 | S | 47 | | |
| | 20 | н | 50 | | |
| | 21 | Н | 51 | | |
| Hardrock | 22 | Н | 59 | | |
| | 23 | H | 64 | | |
| | 64 | H | 73 | | |
| | 65 | H | 56 | | |
| | 66 | H | 58 | | |
| | 07 | н | 50 | | |
| Coulton | 24 | ч | 49 | | |
| Comier | 25 | Ŝ | 40 58 | | |
| | 26 | Ĥ | 53 | | |
| | 27 | S | 58 | | |
| | 28 | H | 52 | | |
| | 29 | S | 58 | | |
| | 30 | н | 53 | | |
| | 31 | S | 58 | | |
| | 32 | н | 47 | | |
| | 33 | S | 64 | | |
| | 34 | Н | 56 | | |
| | 30 | 3 | 54 | | |
| | | S | | | |

Figure 20

small polyethylene capsules in preparation for irradiation. One of the two portions was irradiated using the University of Toronto Chemical Engineering Laboratories Cobalt 60 gamma ray cell #220 for one minute and the other for two minutes. At current source strength, the resulting laboratory doses to which these samples were subjected were 286 Rads and 572 Rads respectively. The choice of irradiation duration was based on past experience for the material being analyzed (Volterra et al., 1991). It was expected that the amount of natural radiation absorbed by the ceramic sherds over their lifetime would have been in the range of 100 to 150 Rads. The effects of radiation doses are additive. Hence the laboratory doses selected for the analysis were expected to result in electron trappings which were approximately three and five times higher respectively than those produced by natural irradiation through the ceramic's life. This spread allows for a clear distinction between the various glow curves to be produced. The higher of the two laboratory doses was expected to be well below saturation. As indicated above, recent irradiation produces a build-up of electrons in shallow unstable traps which appear as very high low temperature peaks in the glow curves. Accordingly, samples subjected to laboratory doses are normally stored for a period of time prior to testing. Alternatively the samples can be appropriately pre-heated.

All the samples, including those subjected to laboratory irradiation, were "glowed" using a Harshaw model 2000 A/B apparatus consisting of an oven and counter section (Figure 21). The output signal was fed into a Hewlett-Packard 7044 B plotter.

The oven was continuously purged by means of a pure, dry nitrogen stream. Its temperature was controlled to rise to approximately 450 deg. C. at a constant rate of five deg. C. per second. The heating cycle could be started, interrupted and restarted at will by means of a push button interrupting contacts to the oven heater. The sample was heated over a nichrome metal strip whose temperature is monitored by a thermocouple.







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A photomultiplier and appropriate filters are mounted over the sample and detect light emission as the temperature increases. Its output drives the vertical scale of the plotter while the current produced in the thermocouple drives the horizontal scale of the plotter (Figure 22). Both signals are indicated on dials on the Harshaw apparatus also. A number of trial runs were carried out to determine optimum settings for the T-L apparatus and the plotter. For details on use of filters to cover the range of T-L emission spectra see Fleming, 1979: 6 - 9.

Photomultiplier range was set at 10⁻⁹ picoamps, while plotter scales were varied to suit individual samples. In turn five milligrams of sample were introduced into the oven and pre-heated to 60 deg. C. Oven temperature was then allowed to rise to 250 deg. C. to eliminate the typical low temperature peaks due to shallow traps.

This pre-heating to 250 deg. C. prevents the plotter from going off-scale at the low temperature end when processing laboratory irradiated material and produces neater glow curves. Pre-heating to such temperature does not affect the 325 to 375 deg. C. peaks (Volterra et al., 1991: 10) which represent the stable plateau area described above. The temperature was then reduced again to 60 deg. C. and the heating process restarted. At this point the plotter was turned on and the glow curves for the sample were obtained. After cooling below 60 deg. C. the spent sample was removed and a new one introduced. The process was repeated twice for each of the high laboratory dose samples, the low dose laboratory samples and the natural samples. This is done to confirm the repeatability of the procedure which was in fact better than +/- 2% variance. (See also Volterra et al., 1991: 9). After the last glow curve for the natural crystal sample from each sherd was plotted, the material was allowed to cool to 60 degrees C. and then immediately reheated at the standard rate to 450 deg. C. with the plotter on. This was to produce







a curve showing the "background" radiation inherent in the apparatus and sample. For an example of glow curves see Figures 22 to 24. The net T-L output over background was obtained directly from the glow curves. The natural energy dose absorbed over the life of the artefact was then calculated graphically and confirmed algebraically from these data.

Instrumented Neutron Activation Analysis

Clays and soils collected in the field were oven dried in air at 250 deg. C. for 24 hours. Samples from each were weighed and placed in 1.2 mL polyethylene capsules. Sherd samples had already been separated during the preparation process for T-L analysis. Since there is no way of foretelling the levels of elements present in the samples, samples of between 750 and 1200 mgms. were utilized for the analysis. They were then processed at the University of Toronto SLOWPOKE Reactor Facility. This laboratory consists of a small pool type atomic reactor using enriched uranium fuel pencils housed in a cylindrical case surrounded by a beryllium reflector. Light water is used as moderator. Production of the neutron flux is controlled by a centrally located cadmium control rod (Figure 25). The thermal flux range is 0.5x10¹¹ to 1.0x10¹² n.cm⁻².s⁻¹. Access to the irradiation area is via up to ten pneumatic transfer systems. The facility is also provided with appropriate γ ray counting and analysis equipment.

The samples were introduced sequentially into the reactor and, after the appropriate delay time they were placed in front of a detecting target of germanium doped with lithium and cooled with liquid nitrogen. Delay times after irradiation are required for two reasons. One is to ensure that the activity of the irradiated material is reduced to a level

which is not deemed hazardous for handling. The other is to ensure sufficient decay of the isotopes to permit the reading and counting of selected γ ray peaks without masking effects. γ rays interact with the detector to produce photoelectrons and these are then amplified and sorted according to energy levels. The detector's output was fed into analyzer/counters. Peaks and backgrounds for the selected γ ray emission energy levels were counted over varying durations and accumulated totals were recorded on BM printers after a preset count period. The area under each γ ray peak corresponds to an absolute disintegration rate of the induced radioisotopes and therefore represents the net γ ray felement present in the sample.

INAA via the SLOWPOKE Reactor facility permits the analysis of samples for elements which produce radioisotopes of different lives, allowing the quantification of a wide array of elements. To take full advantage of this feature, the procedure was repeated for all samples in four cycles. The first cycle took place after irradiation at a neutron flux of $2x10^{11}$ n.cm⁻².s⁻¹ for five minutes and after a time delay of eight minutes with a count period of five minutes. This allowed the examination of the elements Al, Ba, Ca, Cl, Dy, Mg, Mn, Na, Ti, U, V. The second count took place after a time delay of 24 hours following the same irradiation, with a count period of five minutes. This allowed the examination of the elements Eu, Ga, K, Na.

At the end of the first two cycles, the samples were re-packaged into small polyethylene sheet bags so that all samples could be subjected to the same long term irradiation at a neutron flux of 5×10^{11} n.cm⁻².s⁻¹ for 16 hours.

The third count took place after a time delay of seven days, with a count period of ten minutes. This allowed the examination of the elements Sm, U, Yb, La, As, Sb, Br, Sc, Fe, and Na. The last count took place after a time delay of fourteen days with a count

period of one hundred minutes. This allowed for the examination of the elements Ba, Co, Cr, Cs, Eu, Fe, Hf, Lu, Nd, Ni, Rb, Sc, Sr, Ta, Tb, Th, and Yb. Thirty six elements in total were analyzed for. Some of the elements were counted more than once to ensure consistency of procedure and repeatability of analysis. A sample printout is shown on Figure 26.

A program utilizing the formula on page 28 was used to determine the quantity of each element present in each sample. Copy of a typical program output is shown on Figure 27.

The data were then fed to the Panorama spreadsheet program and discriminating diagrams (bi-variate scatter plots) were generated for a combination of elemental compositions. Typical diagrams are shown on Figures 28 to 42. The discriminating diagrams of element concentration show clustering of data points.

The concentrations of K, U and Th determined via INAA were utilized also in the determination of correct age via T-L.





CRITICAL ASSEMBLY & REACTOR VESSEL

Figure 25

2.7

| 0203 | 000000 | 118973 | 0213 |
|------|---------|--------|-------|
| 0214 | 000000 | 028409 | 0224 |
| 0454 | 000000 | 007279 | 0460 |
| 0462 | 000000 | 006660 | 0468 |
| 0553 | 000000 | 005299 | 0559 |
| 0571 | 000000 | 004556 | 0377 |
| 0789 | 000000 | 005618 | 0798 |
| 0799 | .000000 | 003693 | 0808 |
| 0821 | 000000 | 002385 | 0827 |
| 0834 | 000000 | 002212 | 0840 |
| 0970 | 000000 | 023342 | 0981 |
| 1003 | 000000 | 003528 | 1014 |
| 1096 | 000000 | 002158 | 1103 |
| 1116 | 000000 | 002366 | 1123 |
| 1125 | 000000 | 002625 | 1133 |
| 1135 | 000000 | 002596 | 1143 |
| 1551 | 000000 | 001933 | 1558 |
| 1564 | 000000 | 001494 | 1571 |
| 1772 | 000000 | 025209 | 1786 |
| 1789 | 000000 | 003240 | 1803 |
| 2193 | 000000 | 008704 | 2206 |
| 2209 | 000000 | 002108 | 2222 |
| 2731 | 000000 | 019425 | 2749 |
| 2753 | 000000 | 001344 | 2771 |
| 0006 | 00 | | |
| { | | | |
| 0203 | 000000 | 142390 | 0213 |
| 0214 | 000000 | 031741 | 0224 |
| 0454 | 000000 | 008291 | 0460 |
| 0462 | 000000 | 007594 | 0468 |
| 0553 | 000000 | 006187 | 0359 |
| 0571 | 000000 | 005309 | 0577 |
| 0789 | 000000 | 006556 | 0798 |
| 0799 | 000000 | 004236 | 0808 |
| 0821 | 000000 | 003023 | 0827 |
| 0834 | 000000 | 002645 | 0840 |
| 0970 | 000000 | 028374 | 0981 |
| 1003 | 000000 | 004069 | 1014 |
| 1096 | 000000 | 002562 | 1103 |
| 1116 | 000000 | 002905 | 1123 |
| 1125 | 000000 | 003159 | 1133 |
| 1135 | 000000 | 003102 | 1143 |
| 1551 | 000000 | 002350 | 1558 |
| 1564 | 000000 | 001748 | 1571 |
| 1772 | 000000 | 029576 | 1786 |
| 1789 | 000000 | 003885 | ,1803 |
| 2193 | 000000 | 010015 | 2206 |
| 2209 | 000000 | 002546 | 2222 |
| 2/31 | 000000 | 023901 | 2749 |
| 2/35 | 000000 | 001629 | 2771 |
| | | | |

Figure 26

Data is for GROUP: 9vclay2 Sample #1, ID: 64 Power: 5.00 kW Irrad. Time: 57600s Count Time: 6000s Delay time: 1264896s Sample Mass: 945g Counter: 2 Position: 1

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| Elem | Gamma | En | Concentration | 5. x | Precision | Detection Limit |
|--------|--------|------|---------------|--------|--------------|-----------------|
| Nd | 91 | | 40.50ppm | +/- | 0.610ppm | 1.870ppm |
| Ce | 145 | | 104ppm | +/- | 0.366ppm | 0.924ppm |
| Lu | 207 | | 0.541ppm | +/- | 0.00699ppm | 0.0209ppm |
| Ba | 216 | | 928ppm | +/- | 12.60ppm | 37.80ppm |
| Th | 312 | | 10.40ppm | +/- | 0.0477ppm | 0.117ppm |
| Cr | 320 | | 89.50ppm | +/- | 0.659ppm | 1.780ppm |
| Yb | 396 | | 4.090ppm | +/- | 0.0630ppm | 0.184ppm |
| Hf | 482 | | 6.740ppm | +/- | 0.0593ppm | 0.159ppm |
| Sr | 515 | | 291ppm | +/- | 14.10ppm | 44.50ppm |
| Cs | 796 | | 2.740ppm | +/- | 0.0955ppm | 0.298ppm |
| Ni | 811 | | 29.70ppm | +/- | 6.710ppm | 21.90ppm** |
| Tb | 879 | | 1.030ppm | +/- | 0.0414ppm | 0.130ppm |
| Sc | 889 | | 16.20ppm | +/- | 0.0216ppm | 0.0296ppm |
| Rb | 1077 | | 125ppm | +/- | 1.670ppm | 4.380ppm |
| Fe | 1099 | | 4.910% | +/- | 0.0122% | 0.0161% |
| Co | 1173 | | 1.250ppm | +/- | 0.0546ppm | 0.200ppm * * * |
| Ta | 1222 | | 0.845ppm | +/- | 0.0368ppm | 0.107ppm |
| Eu | 1407 | | 1.810ppm | +/- | 0.0329ppm | 0.0763ppm |
| | | | | | | • |
| | | | | | | |
| | | | | | | |
| Data | is for | GI | ROUP: 9vclay2 | | | |
| Samp | Le #2, | ID | : 65 | | | |
| Pouros | | 1 41 | Turned Time | . 5760 | On Count min | C000- |

Power: 5.00 kW Irrad. Time: 57600s Delay time: 1270944s Sample Mass: Counter: 2 Position: 1

Count Time: 6000s 939g

| Elem | Gamma | En | Concentration | | Precision | Detection Limit | 2 |
|------|-------|------|---------------|-------|------------|-----------------|---|
| Nd | 91 | 10 T | 28.40ppm | +/- | 0.587ppm | 1.840ppm | |
| Ce | 145 | | 75.50ppm | +/- | 0.337ppm | 0.893ppm | |
| Lu | 207 | | 0.657ppm | +/- | 0.00681ppm | 0.0197ppm | |
| Ba | 216 | | 803ppm | +/- | 11.70ppm | 35.20ppm | |
| Th | 312 | | 12.50ppm | +/- | 0.0478ppm | 0.107ppm | |
| Cr | 320 | | 53.70ppm | +/- | 0.571ppm | 1.620ppm | |
| YD | 396 | | 4.700ppm | +/- | 0.0596ppm | 0.167ppm | |
| Hf | 482 | | 6.200ppm | +/- | 0.0537ppm | 0.139ppm | |
| Sr | 515 | | 203ppm | +/- | 12.30ppm | 38.80ppm | |
| Cs | 796 | | 3:490ppm | +/- | 0.0850ppm | 0.256ppm | |
| Ni | 811 | | 4.450ppm | +/- | 5.730ppm | 18.90ppm*** | |
| Tb | 879 | | 0.836ppm | +/- | 0.0356ppm | 0.111ppm | |
| Sc | 889 | 1.1 | 11.20ppm | +/- | 0.0181ppm | 0.0254ppm | |
| Rb | 1077 | | 123ppm | +/ | 1.530ppm | 3.800ppm | |
| Fe | 1099 | | 3.720% | +/- | 0.0106% | 0.0137% | |
| Co | 1173 | | 11.50ppm | +/- | 0.0935ppm | 0.170ppm' | |
| Ta | 1222 | | 1.570ppm | +/- ' | 0.0373ppm | 0,0936ppm | |
| Eu | 1407 | | 1.350ppm | +/- | 0.0277ppm | 0.0626ppm | |



APPENDIX B



EFFECT OF TEMPER IN THE CERAMIC

Ceramic fabric contains temper as well as clay. The trace element composition determined for the sherd samples tested therefore will be a combination of the elements of each of these two components.

This is obviously not a problem when using the data to discriminate between origins of artefact since pottery which has been manufactured locally will contain both clay and temper obtained from local sources. The converse is true for ceramics which have been imported into a site.

A problem arises however when utilizing the results of the trace element analysis to identify the potential sources of clay used in the manufacture of the pottery. The elements contained in the temper will have a dilution effect on the elemental composition of the clay. The separation of the sand and clay components of ceramics cannot be readily achieved as it presents a series of complex practical problems. Such work is outside the scope of this thesis and would require considerable additional research.

Without separating the clay and the temper which form the ceramic it is not feasible to ascertain the actual impact of the latter on the former. As a result, in most cases it is possible only to make general statements about the likelihood of any of the clay deposits analyzed being the potential source of the material used for the artefacts tested. In the instance of the Balsam Lake material, however, the data obtained for specific clay samples are sufficiently similar to the results of specific ceramic samples that, taking into account loss on ignition, the source identifications proposed can be considered reasonably correct.