

Using Instrumental Neutron Activation Analysis (INAA) to test the validity of current field methods of chert identification in archaeological projects

Kostalena Michelaki¹, Ron Hancock^{1,2}, Alice Pidruczny³, Brandi Lee MacDonald^{1,3}, and Phil Woodley⁴

1. Anthropology, 2. Medical Physics and Radiation Sciences, 3. McMaster Nuclear Reactor, 4. New Directions Archaeology, Ltd.

INTRODUCTION

In Ontario, stone tools are ubiquitous in archaeological sites, from prehistoric through to historic times. Although a great variety of stones were chosen for the manufacture of such tools, chert was the predominant material. Chert was, therefore, important in the lives of First Nations people, who used it to make chipped lithic tools, such as projectile points, bifaces, drills, scrapers, or wedges.

Chipped lithic tools and their source materials are also of interest to archaeologists who use them to comprehend Ontario's past. Understanding the sources of the cherts found archaeologically has been paramount in attempts to understand how First Nations groups used the resources in their natural environment, as well as how far they were willing to travel for them, and whether they engaged in long-distance exchange with other groups to acquire such materials.

Currently, the assignment of archaeological chert tools to different chert sources is based primarily on the macroscopic consideration of the tools' colours and textures. Two assumptions underlie this method: 1) that cherts with the same colour/texture come from the same source, and 2) that cherts with different colour/texture come from different sources. These assumptions have not been tested systematically.

The colours of rocks and minerals are determined to a great degree by their chemical composition. By using a technique such as Instrumental Neutron Activation Analysis (INAA) that allows one to chemically fingerprint material like chert, we can test whether the assumptions behind archaeological analytical techniques are valid and, thus, whether

the techniques and the interpretations drawn from the data collected using such techniques, are reliable.

The purpose of the present project is threefold:

- 1) To test whether cherts from different known local (and neighbouring) sources, which are often cited in the archaeological literature as the sources of archaeological material, can be chemically distinguished.
- 2) To test whether cherts from the same known source are more similar to each other than to cherts from other known sources.
- 3) To test whether the archaeological grouping of cherts based on a consideration of colour/texture coincides with their chemical grouping, based on INAA.

METHODOLOGY

Phil Woodley, of New Directions Archaeology Ltd., collected chert samples from 26 distinct chert sources in Ontario, 7 in New York, 4 in Michigan and 1 in Ohio. Each piece of chert was labelled, cleaned, photographed and its colour was recorded following the Munsell Soil Colour Chart guidelines (*Table 1*). Specimens weighing approximately .5 g were sawed off the bulk samples. In some cases, samples that exhibited more than one colour were sub-sampled (e.g. samples with MNR-ID: 3-5, 3-8 and 3-10 are sub-samples of the same piece, as are 3-6 and 3-9 and finally 4-4, 4-6, 4-7 and 4-8). By selecting multiple samples from within each region and sub-sampling particular samples, we prepared a final assemblage of 50 samples that we submitted for Instrumental Neutron Activation at the McMaster Nuclear Reactor (see *Table 1*).

Analytical procedures and Irradiation Protocols

Instrumental Neutron Activation Analysis is a method where specimens are bombarded with neutrons from a nuclear source. A tiny fraction of the nuclei from each element within the sample is transformed into unstable radioisotopes that decay with characteristic half-lives. These radioisotopes emit gamma ray with energies that are characteristic of each isotope. These energies are measured by a high-purity germanium (HPGe) gamma ray spectrometer and are converted into channels along an electromagnetic spectrum measured in kiloelectron volts (keV). The peaks that form as a result are the spectrometric end-products of elements that produce radioisotopes.

One irradiation was performed at the McMaster Centre for Neutron Activation Analysis (CNAA) to acquire concentration data on elements that produce short-lived radioisotopes. Samples of prepared chert specimens were weighed to approximately 0.5 g each in polyethylene vials. They were run, along with standards, through a pneumatic tube system and were subjected to a 180-second thermal irradiation with a neutron flux of $5 \times 10^{13} \text{ n cm}^{-2} \text{ s}^{-1}$. After a 10-minute decay, each sample was measured by a high-purity germanium (HPGe) detector for 3 minutes. The elements measured include: Al, Ba, Ca, Co, Cl, Dy, K, Mg, Na, S, Ti, U and V. After a further decay of approximately 24 hours, a 5-minute count was performed to collect data on Eu, K, La, Mn, Na, Sm and Sr, ***Reference Standards***: For this analysis, the following standard reference materials were used: SRM 1632b Coal, SRM 1633b Fly Ash, SRM 688 Basalt, SRM 278 Obsidian Rock issued by the National Institute of Standards and Technology (NIST).

RESULTS

The initial concordance and descriptions of the samples analyzed are presented in the Appendix as Table 1. Preliminary chemical groupings of the samples are presented as Table 2. The analytical data are presented as Table 3, sorted by general chemical compositions.

Questions arising:

1) Are cherts from different known local (and neighbouring) sources chemically distinguished from each other?

To understand whether our samples from Northern Ontario, Ontario, New York, Michigan and Ohio could be chemically distinguished we ran a discriminant analysis using all our samples and all the measured elements in parts per million (ppm), grouping them by State and Province. As *Figure 1* shows, the samples from Northern Ontario and from Vera Cruz, Jasper Park were considerably different from all the rest of the samples. Following the recommendation of Baxter (1999) about detecting and dealing with multivariate outliers in artifact compositional data, we excluded the Northern Ontario and Vera Cruz samples and ran the analysis again. As seen in *Figure 2*, the majority of the New York samples became distinct. Thus, we excluded the clearly distinct New York

samples and ran the analysis yet again. As seen in *Figure 3*, the remaining New York samples continued to be distinct. Furthermore, the Ontario samples were themselves distinct. However, the Michigan and Ohio samples remained indistinguishable. To ensure that the presence of elements in minor (rather than trace) concentrations was not affecting our analysis, we re-ran the same analysis including the weight % of Al, Mg and Ca rather than their ppm concentrations. Our results were identical, making us confident that the difference in the magnitudes of specific elemental concentrations was not affecting our analysis.

We can thus conclude that the cherts from different known regional sources may indeed be distinguished chemically. In the case of the Michigan and Ohio cherts that appear indistinguishable one must not forget that our sample sizes are very small (n=4 and n=1 respectively), and we have avoided drawing firm conclusions before further samples are analyzed.

2) *Are cherts from the same known source more similar to each other than cherts from other known sources?*

Based on the same figures as above (*Figures 1-4*) it is clear that samples from the same region cluster together consistently and remain different from the clusters of other regions. The only exception is, as mentioned above, the samples from Michigan and Ohio, which were indistinguishable from each, possibly because we only analyzed 1 sample from Ohio and 4 from Michigan.

3) *Does the archaeological grouping of cherts based on a consideration of colour/texture coincide with their chemical grouping, based on INAA.*

Finally, seeing that the provenance postulate does hold and thus cherts from the same location are more similar to each other than to cherts from different locations, we wanted to check whether our chemical groupings would match the chert types recognized by archaeologists. For that purpose we focused only on the Ontario samples, which were the most numerous, and ran a discriminant analysis considering all the elements in ppm, while grouping our samples by Chert Type (see *Table 1*).

As can be seen in *Figure 5*, the samples from Gordon Lake and Kettle Point were significantly different from all the rest of the Ontario samples. Following Baxter's (1999) advice again, we excluded those samples and ran the analysis again. This time the Fossil Hill Formation became quite clearly distinct (*Figure 6*). After excluding the Fossil Hill Formation samples we could see that all the archaeologically recognized chert types were chemically distinct, except for the Collingwood and Reynales samples, which remained indistinguishable (*Figure 7*). It is possible that those samples would become distinct if we continued excluding clearly distinct samples, such as the Till or Selkirk. However, by now each of our chert type categories had 2-3 samples, making the pattern we see in *Figure 7* at best a hypothesis that should be tested with greater numbers of samples.

DISCUSSION – Meeting project milestones, addressing difficulties and successes of the project

This was overall a very successful project for a multitude of reasons. Firstly, it provided the opportunity for Cultural Resource Management (CRM) and academic archaeologists to collaborate (a feat rarely if ever achieved in Ontario) to test the validity of widely used field methodologies by CRM archaeologists. Although our sample size was small, our results are suggesting that, with a few minor exceptions, field methods for the provenancing of chert are successful and, thus, so are the social interpretations based on them. Although the field identification of chert based on colour and texture is common, it had not been systematically tested until now.

This project also gave the opportunity for two undergraduate archaeology students at McMaster University to be involved in a research project at the McMaster Nuclear Reactor. Both students are now considering graduate studies in archaeology.

This project and its results will also be showcased at the upcoming Developing International Geoarchaeology conference organized by the Anthropology and the Geography and Earth Sciences departments, and the McMaster Nuclear Reactor at McMaster University (May 25-30, 2009; <http://socserv.mcmaster.ca/dig/>). This

international conference will be attended by graduate students, academics and CRM archaeologists alike, providing the fastest venue for the wide dissemination of our results.

At the same time, as with all interdisciplinary and collaborative projects, we did face difficulties and set backs, the most severe of which was the difficulty of communication between all the participants who often had conflicting schedules. Although we met almost all our milestones, we lagged in the timing of our data correlation and, as a result, also in the production of the final report. However, our collaboration remained smooth throughout the whole project and we can definitely envision working together again in the future.

References Cited

Baxter, M.J.

1999 Detecting multivariate outliers in artifact compositional data. *Archaeometry*, 41: 321-338.

APPENDIX