Analysis of Chert by Particle Induced X-Ray Emission

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Jeanette E. Gibeson
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. BACKGROUND FOR THE STUDY</td>
<td>3</td>
</tr>
<tr>
<td>III. EXPERIMENTAL PROCEDURE</td>
<td>5</td>
</tr>
<tr>
<td>Initial Method</td>
<td>5</td>
</tr>
<tr>
<td>Target preparation</td>
<td>5</td>
</tr>
<tr>
<td>Beam line arrangement</td>
<td>6</td>
</tr>
<tr>
<td>Contamination problems</td>
<td>9</td>
</tr>
<tr>
<td>Revised Procedure: Hot Filament</td>
<td>11</td>
</tr>
<tr>
<td>Collection of Data</td>
<td>13</td>
</tr>
<tr>
<td>System Efficiency</td>
<td>15</td>
</tr>
<tr>
<td>IV. ANALYSIS OF DATA</td>
<td>18</td>
</tr>
<tr>
<td>V. RESULTS AND CONCLUSIONS</td>
<td>22</td>
</tr>
<tr>
<td>VI. BIBLIOGRAPHY</td>
<td>31</td>
</tr>
</tbody>
</table>
INTRODUCTION

The purpose of this study was to determine whether or not Particle Induced X-Ray Emission (PIXE) analysis is useful for fingerprinting chert. Particularly, samples from three chert sources were examined in an attempt to discover differences in trace element content. If trace element proportions were consistent within a particular source and different in samples from other sources, a useful fingerprint could be identified.

Chert is a rock composed of microcrystalline and cryptocrystalline quartz. It resembles flint or fibrous chalcedony. During this study chert samples from three chert sources were examined. Bayport and Deer Lick Creek are Michigan chert sources; Cobden chert is from Southern Illinois. Bayport chert is from a bedrock source, as is Cobden. The Deer Lick Creek samples come from a glacially deposited source. The work began with ten or more chert samples from each source and also some samples large enough that they could be broken into several fragments to examine the variability among several fragments from the same sample.

The WMU Tandem Van de Graaff Accelerator was used as a research tool for this analysis. The chert samples were mounted in the target chamber of the accelerator beam line. A beam of 3 MeV protons impinged on the target and the resulting x-ray spectrum was collected from each sample. Analysis of the spectrum provided information about the proportions of various trace elements in the sample.
Archaeologists are interested in being able to fingerprint chert. Artifacts found at a particular site may have been brought in from another region. The ability to match artifacts with their sources can lead to clues about trade routes or other interactions among the people in the region. Thus a study of chert sources using PIXE analysis was undertaken in an effort to find a non-destructive fingerprinting technique.
BACKGROUND FOR THE STUDY

During 1975, Dr. Stephen Ferguson, accelerator physicist, and Dr. Irwin Rovner, then with the Anthropology Department at WMU, were jointly working on PIXE analysis of obsidian from Central America. Preliminary results of that study were encouraging and Dr. Elizabeth Garland, from the Anthropology Department, expressed interest in beginning work on fingerprinting chert.

From an archaeological viewpoint, there are several reasons that a study of chert is important. Some of these are highlighted by Meyers^1. Chert was almost universally utilized as a raw material by prehistoric North American peoples. Because the chert-utilization processes require the incidental production of large amounts of waste flakes, there are quantities of chert debris on virtually every North American archaeological site. Furthermore, chert, unlike some other geologic materials found as artifacts, is universally well preserved. It is, because of its quartz composition, almost impervious to weathering and mild abrasion. It undergoes very little physical or chemical alteration once it has been deposited on a site. It should, therefore, be possible to make detailed physical and chemical comparisons between geological and artifactual cherts and thus locate the natural sources of the artifact cherts even if they were quarried thousands of years ago.

An additional reason for studying chert is that culturally modified chert, except for projectile points and a few other artifact

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1 Meyers, W. H. (19...
classes, is not systematically collected by relic hunters as are obsidian and certain other rare artifact materials. For this reason, it is likely that representative samples of both the types and quantities of chert originally deposited on any site should remain there. Thus comparisons of geologic cherts against cherts recovered from pre-historic cultural contexts may be useful to archaeologists.

A few previous studies of chert have been done. Meyers' publication provided some background information and he referred to the studies done by Maxwell and Wright which are listed in the Bibliography. Barbara Luedtke of the University of Massachusetts--Boston Harbor Campus, while working toward a Ph.D. at the University of Michigan, studied chert sources by neutron activation analysis. To my knowledge, no previous PIXE analysis of chert sources has been carried out.

The obsidian project underway provided guidelines for beginning the chert study. The obsidian samples were being analyzed by chipping off a tiny fragment, grinding it to a fine powder in a mortar and pestle, and then preparing a thin target by depositing a milligram of obsidian dust on Mylar backing.
EXPERIMENTAL PROCEDURE

Initial Method

Target preparation

Since PIXE analysis of obsidian was being done, first attempts at making chert targets followed the general methods used for the obsidian. The target chamber in the beam line was equipped with a two-frame target holder. Two targets could be inserted and run consecutively without breaking vacuum. The target frames were one inch squares of plexiglass, one-eighth of an inch thick, with a one-half inch diameter hole. Mylar polyester film was cut into squares and glued to the target frames using Duco cement. The Mylar thickness was $1.4 \times 10^{-4}$ inches and was obtained from E.I. Dupont De Nemours and Company. Small flakes of chert were chipped off a sample and ground to a fine powder in a porcelain mortar and pestle. In order to apply the chert powder to the Mylar backing, metal "jigs" were used. Two metal pieces and a polyethylene backing fit tightly around the target so that only the Mylar circle was visible. The opening in the jig above the Mylar backing formed a small cylinder over the target area. One milligram of chert dust was weighed out and poured into the cylinder. Using an eyedropper a few drops of denatured anhydrous ethyl alcohol were added, to fill the small cylinder. Covering the hole and shaking the jig suspended the chert powder in the alcohol. Then the jig was set aside where
it would be undisturbed as the chert particles settled and the alcohol evaporated. After evaporation, the Mylar backing had a reasonably uniform layer of dried-on chert powder. Once the jig was carefully loosened and removed, the target was ready for analysis.

Each target frame is numbered. As targets were prepared, the type of sample on each target was recorded for later comparison with the analysis results. Five jigs were used repeatedly, but the component parts of each jig were numbered and each jig was carefully washed with ethyl alcohol prior to each target preparation. Along with the frame number and type of chert powder, the jig number was also recorded for each target prepared. If any jig happened to show repeated contamination it could be more thoroughly cleaned or avoided in future target preparation. With each set of targets, a blank target was also made to test for contamination. The blank was treated the same as the other frames except that no chert powder was put on it.

**Beam line arrangement**

Figure 1

Beam line geometry for PIXE analysis

incident \(\rightarrow\) \(\rightarrow\) Target \(\rightarrow\) Faraday Cup

proton beam \(\rightarrow\) \(\rightarrow\) Collimators \(\rightarrow\) Si(Li) Detector
Figure 1 shows a basic diagram of the beam line geometry. A diffuse beam spot was desirable so that the incident protons would be spread over a reasonable amount of the chert powder. Extra collimators were inserted to keep the defocused beam centered on the target and prevent the beam from hitting the target frame.

The 80 square millimeter Si(Li) detector was positioned below the target chamber, 90° from the incident beam direction. Two absorbers were placed in front of the detector window, polyethylene of thickness 0.0104 ± 0.0001 inches and aluminum of thickness 0.0031 ± 0.0001 inches. Iron was an abundant element in all the samples. In fact, the iron line was so strong that it interfered with the detection of some weaker lines. The counting rate from the iron x-rays was so high that pile-up was also a problem. The absorbers knocked down the iron line and reduced the counting rate adequately for the system. However, the absorbers also blocked x-rays from the lighter elements so that the system was only sensitive for "heavy" trace elements, basically those with atomic number greater than iron.

Figure 2 on page 8 shows a block diagram of the electronics used to transmit the pulses from the detector to the PDP-15 computer. The system was designed to reduce pile-up. The response time of the spectroscopy amplifier was not fast enough to distinguish each pulse it received. Pile-up occurred when two pulses entered at nearly the same time and were transmitted as a single pulse. For example, an iron x-ray has a characteristic energy of 6.40 keV. If two such x-rays were detected within a 50 microsecond interval, their pulses
were transmitted as a single pulse corresponding to an energy of 12.80 keV. Since a large number of iron x-rays were detected, this pile-up occurred frequently enough to produce a pile-up peak at 12.80 keV. Pile-up from random x-ray combinations increased the background level. The increase in background level and existence of pile-up peaks could interfere with peaks of interest. Hence it was important to minimize pile-up.

Pile-up was reduced by examining the shape of pulses from the spectroscopy amp. The leading edge to crossover separation is different in a pile-up pulse than in a pulse produced by a single x-ray. The branch of the circuit labeled (1) looked at the leading edge of the pulse and provided the start signal for the Time to Pulse Height Converter.
Height Converter (TPHC). The Timing SCA in the branch labeled (2) was set on the crossover and provided the stop signal for the TPHC. The Timing SCA which then received the output of the TPHC was used to reject those pulses whose leading edge to crossover separation indicated that they were pile-up pulses. Using the system diagrammed in Figure 2, two x-rays must come within a 200 nanosecond interval in order for them to be transmitted as a pile-up pulse. Thus pile-up was significantly reduced.

**Contamination problems**

Several problems were encountered almost immediately. Although some blank targets showed very little background and a "clean spectrum," others had noticeable peaks. The clean spectra collected from some blank targets demonstrated that Mylar was a suitable backing material. A consistent zinc line was observed in all of the Mylar blanks. Evidently this contaminant was present in all the Mylar used. However, it was important to identify the source of contaminant and eliminate the other peaks. Study of more blanks revealed that the jigs and alcohol were clean, but that the particular sheet of Mylar used had been contaminated in some way. We had a "packet" of Mylar containing many sheets and by carefully removing an inner sheet and then guarding it from unnecessary exposure, consistently clean blanks were made. These struggles demonstrated the sensitivity of the technique. Even if the Mylar looked clean, trace elements were detectable.
The chert targets themselves posed some problems. Several attempts were made to find a simple, reliable way to make thin chert targets. Initially, one milligram of chert was deposited, producing a fine uniform film of chert powder on the Mylar. Unfortunately, the adhesion was not always good. The stress applied to remove the target frame from the jig sometimes caused the chert powder to flake off. Heat drying the targets rather than simply letting the alcohol evaporate was tried. The chert dust did adhere to the Mylar better, but the jigs also stuck to the target more often, so the dust flaking off was still a serious problem. Teflon "pads" were used inside the jigs to make removal easier. Different amounts of chert dust were applied, from about 0.75 mg to 2.00 mg, in an attempt to find the most consistently successful thickness of chert dust. Using a glue (Duco) and acetone mixture instead of the alcohol for suspending the chert powder in the jigs was also tried. The glued-on chert did not flake off, but the Duco cement added impurities. A few targets were made using Nuclepore (from Nuclepore Corporation, Pleasanton, California) backing on the target frames instead of Mylar. The Nuclepore did not display better adhesion than the Mylar.

Another contamination problem was traced to the mortar and pestle. Tiny flakes from the mortar and pestle could be mixed with the chert dust in the grinding process. To check on this, a test target was regularly made from the "mortar and pestle washings" with each set of targets prepared. After grinding chert, the mortar and pestle was carefully cleaned in the usual way, rinsing it with
alcohol and wiping it with tissues. Then to make the test target, some alcohol would be put into the mortar once again, the mortar and pestle would be ground together and the alcohol would be poured onto a blank Mylar target frame. During drying this test frame was handled the same as the others. The mortar and pestle washings showed several significant peaks. A new mortar and pestle made of alumina was ordered and there were high hopes that the contamination problems would be reduced or eliminated. Unfortunately, the targets made using the new mortar and pestle showed more severe contamination than the previous work! Perhaps strontium is used in polishing the mortar and pestle and some of that element remains on the finished product. Regardless of the source it was evident that the new mortar and pestle contributed significant amounts of strontium to the targets.

Revised Procedure: Hot Filament

In addition to trying a variety of target preparation methods, changes were also made in our beam line in an effort to find a reliable analysis technique. The problems with thin targets encouraged investigation of the use of solid targets. Initial attempts to collect data from solid targets were unsuccessful. The proton beam impinging on a solid target caused a charge to build up if the target sample was an electrical insulator. Subsequently, the discharge of the target sample produced Bremsstrahlung radiation which made the background so high that it interfered with several potentially useful peaks. This was not a problem with thin targets.
since a very small fraction of the beam was stopped and hence no charge build-up occurred on the target. The beam line change that was particularly useful was the inclusion of a hot filament in the target chamber.

The filament from a miniature six volt light bulb was mounted in the target chamber. When the target chamber was evacuated, the filament was turned on using a battery or power supply. The hot filament was then a source of free electrons which neutralized the charge deposited on the target sample by the proton beam. Since a charge does not build up on the target, Bremsstrahlung is reduced and a useful spectrum could be collected from a solid target.

Using solid targets had several advantages. Chances of contamination were minimized since grinding was eliminated. Required counting times for an adequate number of counts was cut down. Frequently, with thin chert targets a single target would require about four minutes of beam time to collect an adequate spectrum. Also thin targets required that the beam current be kept at or below 100 nanoamps to avoid burning through the Mylar backing. With solid targets the beam current could be adjusted according to the counting rate that could be handled by the system, and each target only required about two and a half minutes of beam time. Target preparation changed drastically. For analysis of solid targets, the only restriction is that the sample be of an appropriate size and shape to fit into the target chamber.

The target ladder was also revised to hold six target frames at a time. Six consecutive samples could be run without breaking
vacuum. The solid targets were carefully taped to the target ladder using tiny strips of masking tape. The target ladder was designed to hold six one inch target frames. It was six inches long, one inch wide and had six circular holes evenly spaced. Thus, an ideal solid target would be a fairly flat chert fragment approximately one inch in diameter.

Larger samples could be run by allowing them to cover more than one target position. Smaller fragments could be mounted on Mylar before being positioned on the target ladder, so there was quite a bit of flexibility in appropriate target sample size and shape. If a sample was too large to fit conveniently into the target chamber, a chip could be removed and mounted on Mylar for analysis. However, in nearly all cases, samples could be mounted without modification. This is a major asset of the solid target technique. Samples may be analyzed without being destroyed.

The hot filament—solid target technique was also appropriate for obsidian and this method was used on the obsidian artifact analysis that was continuing during the time this chert study was being done. The obsidian blades being analyzed fit conveniently into the target chamber and the analysis proceeded more efficiently than was formerly possible with the tedious thin target preparation methods.

**Collection of Data**

The WMU model EN Tandem Van de Graaff was the source of 3 MeV protons. The samples for analysis were sorted and catalogued so that
each chert fragment had a unique label. Six samples were mounted on
the target ladder and inserted into the target chamber. With beam
on target, the electronics were monitored and the spectra being
collected were observed. The CRT display on the PDP-15 computer
terminal allowed integration of any peaks of interest to determine
the number of counts collected. When a sufficient number of counts
had been collected, the beam was shut off, the spectrum was recorded
on magnetic tape, and the sample's label was recorded in the log book
along with count time, beam current, and total x-ray values for that
run. Any peculiarities or special observations were noted. After
the spectrum was recorded, the data collection region was erased.
By advancing the ladder to the next frame, a new sample was posi-
tioned in the beam line.

While six samples were run consecutively, the next set of chert
fragments was mounted. Two target ladders were available so that
one could be in preparation while the other was in use. This, of
course, saved considerable time since the change-over to a new
target ladder could be made without the delay of carefully remounting
new samples on the target ladder. The change-over process involved
isolating the target chamber from the rest of the beam line vacuum
system and letting air into the target chamber, then removal of the
target ladder, exchange with the new set of samples and insertion
into the target chamber. Pumping the air out and reconnecting the
vacuum systems completed the change-over. When using the hot fila-
ment technique, care must be taken to shut off the light bulb before
letting air into the target chamber to avoid burning out the filament.
Once the vacuum was achieved again with the new target ladder in place, the light bulb was turned back on.

System Efficiency

During the PIXE analysis work several methods of determining the system efficiency were investigated. Although the efficiencies are not needed for compiling results from this study, it is necessary to know the system efficiency in order to compare the results with work done at other labs. A group of three elements that has been particularly useful in comparing trace element content is strontium, rubidium, and zirconium. This threesome is referred to as the Magic Triplet (MT).

The relative efficiency for the MT was first approximated by dropping standard solutions on Mylar backing to make thin targets. The standard solutions, prepared by Dr. Dale Warren, Department of Chemistry, WMU, contained known concentrations of various combinations of the MT elements. When a large drop of a solution was deposited on Mylar and allowed to dry, the concentration of elements near the edge of the drop was, perhaps, different than the concentration near the center. Also, in handling the targets, some of the deposits could flake off the Mylar. Thus the results would be dependent on which portion of the target was covered by the beam spot. Targets were also made with many tiny droplets on Mylar backing in an attempt to produce a more uniform distribution. Results from this attempt indicated that if the factor for Rb is defined to be one, our peak totals for Sr should be multiplied by 1.15 and Zr totals should be

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multiplied by 2.10.

As solid target work began, efficiency studies also shifted to solid targets. Tests of solid and powdered obsidian targets from the same sample indicated that the MT efficiency factors were not dependent on the type of target. Using plaster of paris and the standard solutions, disc-like "artificial rocks" were made. Unfortunately, plaster of paris contains Sr, so no information about the Sr efficiency factor could be gained from these samples. For Zr, an efficiency factor of 2.10 was determined. Also, comparison with results from the University of California for analysis of green obsidian from Cerro de Navajas, Mexico confirmed the Zr factor of 2.10.

A set of trace element standards was purchased from the National Bureau of Standards. It consists of a set of wafers containing known trace elements distributed in a glass matrix. However, these were hard to use because there were too many elements present. Zr was included, but its concentration has not been certified. An efficiency factor of $1.58 \pm 0.10$ was determined for Sr.

The article by Stross et al. enabled comparison with results for obsidian from El Chayal, Guatamala. Efficiencies of $1.34 \pm 0.10$ for Sr and $1.90 \pm 0.14$ for Zr were determined. Thus efficiency factors of 1.50 for Sr and 2.10 for Zr were adopted for this study.

Current work involves using a "funny filter". This change was made in an effort to include more elements. The funny filter—a small hole punched in the aluminum filter—allows some sensitivity for elements lighter than iron while still suppressing the iron
count rate sufficiently for the system. Using comparison with El Chayal obsidian results, the efficiency factors are adjusted to 1 for Rb, 1.5 for Sr, and 2.3 for Zr. In using additional elements in the analysis, efficiency factors are also needed for those elements. El Chayal results are used to obtain a first approximation. Better methods of measuring system efficiency are still being investigated.
ANALYSIS OF DATA

The spectra collected were recorded on magnetic tape using the WMU on-line PDP-15 computer. During a day of data collection, several tapes could be filled, each holding twenty spectra. Data analysis was a separate process that could be carried on at a later time. The tapes were transferred to the PDP-10 computer. Dr. Stephen Ferguson wrote a program for use in analyzing the obsidian data. The same program was used for the chert analysis. Using a graphics terminal (TEK - 4010 or TEK - 4002) each spectrum was recalled and any portion of it could be printed on the CRT display. Figure 3 shows a typical spectrum.

The iron line was much stronger than the other peaks. The program always plotted the channel with the most counts as full scale on the display screen of the terminal. If the entire range of interest (say from channel 100 to channel 700) was plotted, the iron line dominated and the other peaks looked insignificant. A more useful way to examine the spectrum was to plot the low energy region separately from the high energy region. Plotting channels 100 to 400 allows examination of iron and near-by peaks. Then a plot of channels 350 to 700 allows a more distinct look at trace element peaks in that region.

An energy calibration was established based on the x-ray energy of two elements and the location of the center channel of their peaks. To sum a peak the terminal operator used the cursor to mark
the boundaries of a peak and indicated the region of average background. An "S" command, i.e., typing an S on the teletype, then instructed the computer to sum the peak. A background line was drawn in so that the operator could observe that a reasonable background level had been used in the calculations.

The program had access to files containing information about the x-ray energy and appropriate line shape of various elements. By using these files the program could "strip-off" a peak that had been summed. This stripping also removed associated peaks, so that the iron $\beta$ peak was stripped along with the iron $\alpha$. If an iron x-ray spectrum were examined, the two peaks labeled in Figure 3 would be observed. When an incident proton produced a vacancy in the K shell and an electron from the L shell filled it, an iron K$\alpha$ x-ray was produced. If the K shell vacancy was filled by an electron from the M shell, an iron K$\beta$ x-ray was produced. For heavier elements, such as lead, L transitions produced x-rays whose energies were in the region of interest. For each element that may be useful, a single element target was analyzed to measure the relative peak intensities. Thus by storing on computer files spectra from the single element targets, the appropriate relative peak intensities were available to the analysis program.

This was especially important for revealing "hidden" peaks. A particular example of this problem involved the strontium and zirconium peaks. Strontium's $\beta$ peak was at nearly the same energy as the zirconium $\alpha$ peak. Thus it was certainly inappropriate to sum the entire peak and attribute those counts to zirconium. Instead
the strontium \(\alpha\) peak was summed first and in stripping the appropriate number of counts were subtracted from all strontium peaks. The remaining peak reflected the zirconium content as confirmed by its own \(\beta\) peak occurring at a slightly higher energy.

Each peak could be summed and stripped in this way. Furthermore, the series of commands could be stored so that the summing procedure was repeated automatically on each spectrum, requiring only that the operator input the name of each spectrum and supervise the analysis to watch for any unusual or unexpected results. After all of the spectra had been analyzed, a line-printer copy of the results was requested from the terminal. This output listed in tabular form the totals for the peaks, the level of the background, the peak center channel, and the range of channels over which the summing was carried out. If the peak was stripped out, the printout also listed the element that was matched up with the peak.

The magnetic tapes from the PDP-15 may be kept to retain the spectra for later reference or erased for re-use.
RESULTS AND CONCLUSIONS

The line printer output from the data analysis provided the necessary information for comparison of trace element content. For each sample, the number of counts in the Magic Triplet peaks were added and then the fraction of this total that could be attributed to each of the three elements was calculated. This type of analysis considered the relative concentration of the elements rather than absolute amounts. This calculation was carried out for each sample, and the relative percentages of rubidium, strontium, and zirconium were recorded. For example, one sample from the Cobden source (labeled CDi3) had the following peak totals:

\[
\begin{align*}
\text{Rb} & : 708 \\
\text{Sr} & : 13713 \\
\text{Zr} & : 167 \\
\hline
14588 & \text{Magic Triplet Total}
\end{align*}
\]

Which indicated: 4.9% Rb, 94.0% Sr, 1.1% Zr.

The peak totals were not multiplied by the system efficiency factors.

A useful way to compile the results was to plot the ratios for each sample on a triangle diagram. Figure 4 displays a triangle diagram for Bayport Chert. The vertex labeled Sr means that a point at that vertex would indicate a sample containing 100% Sr, 0% Rb, and 0% Zr. Likewise, the Zr vertex means 100% Zr and the Rb vertex means 100% Rb. As can be seen from Figure 4, the Bayport Chert samples were high in Sr; nearly always 70% or more of the Magic
Triplet total was from Sr.

Figure 5 displays the results of Magic Triplet analysis for Deer Lick Creek Chert. In this source the Sr content was usually below 70%, and the spread of the data points toward the right hand side indicated that the Rb content is greater than the Zr content. Figure 6 is a composite of Bayport and Deer Lick Creek data points. The solid black circles indicate data points from Bayport Sample "N". A single Bayport source rock, labeled "N" for analysis identification was split into a number of fragments. Analysis of each fragment then resulted in the spread of solid black circles displayed on the diagram. The multiple analysis of a single source rock gives an indication of the variability of chert. Bayport is a bedrock source. The Deer Lick Creek source is glacially deposited, so it is not too surprising that it shows even greater variability in Magic Triplet ratios. Figure 6 illustrates that Magic Triplet ratios provide an adequate way to sort Bayport and Deer Lick Creek samples.

The other source examined was Cobden Chert. Figure 7 shows the Magic Triplet triangle diagram from the Cobden samples. This source, like Bayport, was consistently high in strontium. A composite of Bayport and Cobden data points is shown in Figure 8. This illustrates that the Magic Triplet ratios are inadequate for sorting samples from these sources. However, recall that several peaks other than Rb, Sr, and Zr are present in a spectrum. After some calculations and comparisons involving other elements, bromine content was found to be useful. To make the comparison, I computed the ratio of the number
of counts in the bromine peak to the number of counts in the Magic Triplet total. The results are displayed in a histogram, Figure 9. The Cobden samples consistently showed an absence of bromine, or only a minute amount. The Bayport chert has more significant amounts of Br as displayed on the histogram. Thus, even though Bayport and Cobden sources have approximately the same trace element composition in terms of Magic Triplet ratios, bromine content provided a way to sort samples from these sources.

The usefulness of the technique increases as more sources are fingerprinted. Currently work is underway with additional sources. The use of bromine as a distinguishing element was especially encouraging. As the study continues additional elements may also contribute useful clues. Manganese content looks like a possible means of differentiation. During this study absorbers were used in front of the detector to cut down the count rate from iron x-rays. This was necessary to avoid pile-up, but the use of the absorbers had the unfortunate effect of also interfering with detection of all lighter elements. Current investigations are underway using a "funny filter," that is, an aluminum absorber with a small hole in it. The aperture permits us to get better sensitivity for the light elements, while still knocking down the iron line.

The information compiled may now be used as a basis for distinguishing samples from the three sources examined. The objective of this study has been achieved. The results from non-destructive PIXE analysis provide a way to fingerprint chert from Bayport, Cobden, and Deer Lick Creek sources.
Figure 5

Deer Lick Creek Chert

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Figure 6

- Bayport Chert
- Bayport Sample "N"
- Deer Lick Creek

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BROMINE CONTENT IN CHERT

A COMPARISON OF BAYPORT AND COBDEN

Numbers computed \(\{\text{Br/Magic Triplet Total}\} \times 100\)

X BAYPORT
O COBDEN

Number of Samples

| 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 | 0 0 |
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