To Measure or not to Measure: Geochemical Analysis of Siliceous Materials in the Interior Plateau of British Columbia

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ABSTRACT

Lithic sourcing studies remain one of the most effective ways to establish past trade networks and cross cultural connections within a region. The nature of trade within the British Columbian Interior Plateau may be assessed by analysing chert débitage excavated from Structure 109 at Keatley Creek and its archaeological and geological origins/quarries. This paper discusses both the potential and limitations of a current lithic sourcing study that is attempting to utilize petrographic and geochemical methods to characterize and correlate chert and chalcedony artefacts to their geologic sources.

As a multidisciplinary field archaeology draws from a wide range of methods and techniques. Although this is beneficial for the majority of archaeologists, it also has the potential to lead to the misuse of technology. There are limits to the usefulness of techniques used by natural sciences such as geology and chemistry to understand archaeological problems. The focus of this paper is to explore the capabilities and limitations of geochemical analysis. To do so, I will discuss geoarchaeology and its relevance to archaeological inquiry, the importance of geochemical characterization studies, the potentiality and constraints of geochemical analysis, and conclude with an in-progress case study from the Keatley Creek site, British Columbia, Canada.

Archaeology and Earth Sciences

Geoarchaeology represents the convergence of two disciplines, archaeology and geology. Gladfelter (1977:519) defines geoarchaeology “as the contributions of
earth science to the resolution of geology related problems in archaeology.” Hassan (1979:267) expands on this definition by explaining its wide breadth as it encompasses the following topics: locating archaeological sites; evaluating the geomorphic landscape for site catchment activities and site location; studying regional stratigraphic and microstratigraphic materials for relative dating and recognition of lateral and vertical distribution of activity areas; analyzing sediments for the elucidation of site-forming processes and quantification of microarchaeological (sub-macroscopic) remains; analyzing paleoenvironments; studying artefacts to determine manufacturing practices, procurement range, trade, and exchange networks; and modelling. While all these topics are relevant to geoarchaeology, this paper deals exclusively with geochemical methods related to determining procurement range, trade, and exchange networks.

Hassan’s (1979) definition is fitting since archaeology has a long history of association with geology especially in areas where they share commonalities; for example, environmental studies of the Pleistocene (which are particularly relevant in paleontology) rely on fundamental geological principles such as uniformitarianism and stratigraphy. These principles are also fundamental in determining site contexts in human evolutionary studies (Hassan 1979). An additional case can be made for geochemical characterization and sourcing studies, which identify rock types within artefact assemblages, and link these materials to quarry locations. These studies rely on complex geochemical analyses such as X-Ray Fluorescence (XRF) and Instrumental Neutron Activation Analysis (INAA) (Bakewell 1995; Glascock 2004).

Background to Geochemical Techniques

Geochemical techniques are frequently employed by geoarchaeologists interested in studying interactions between culture groups within a specific area. These researchers analyze trade and exchange items, and are largely concerned with the dynamic relationship humans have with each other and the environment. This leads to questions related to material procurement - such as “where did this stone material come from”? and “where was the source location”? Due to the poor preservation of organic materials in the archaeological record the majority of items eligible for geochemical analysis are stone tools. Consequently, archaeologists studying trade and exchange often engage themselves in different types of lithic analysis (Odell 2004).

Lithic analysis is divided into two main categories - microscopic and macroscopic. Microscopic analysis concerns itself with the elemental and structural components of culturally modified rocks (Andrefsky 2005). Macroscopic analysis focuses on visual aspects of stone tools that can be observed with the naked eye. Both of these categories have particular techniques suited to address concerns about procurement, manufacture, trade, and exchange strategies.
It is important to note that these techniques are research specific. Choosing an inappropriate technique can lead to poor and often costly results. Frequently archaeologists opt for techniques that are new and consequently, fashionable. Too often researchers will pursue unnecessary lines of evidence—a good example of this is the penchant for geochemical characterization and sourcing without first utilizing petrographic techniques. I do not intend to suggest petrographic techniques are superior to geochemical ones; however, to conduct a successful sourcing study, both petrographic and geochemical methods should be used when possible (Kempe and Harvey 1983). Depending on the stone material you are analyzing, and cultural sensitivity, complex and destructive geochemical techniques may not be necessary or acceptable.

Lithic sourcing is a complicated process involving a minimum of four steps: data collection I (excavation and raw material identification), data collection II (geochemical and petrographic testing), and data analysis and assessment of archaeological/cultural implications (Bakewell 1995). When using geochemical methods there is an unavoidable percentage of error. This is related to the selection of appropriate rare and trace earth elements, for example the selected trace elements should be found within the crystalline structure of all the samples (Bakewell 1995). Therefore, archaeologists should select elements that are fundamental to the structure of the rock type; for cherts, appropriate elemental selection should include Ca, K, Na, Mg, Al, and other light silicates.

**X-Ray Fluorescence (XRF)**

There are two primary techniques used for lithic sourcing, X-Ray Fluorescence (XRF) and Instrumental Neutron Activation Analysis (INAA). Fluorescence is the emission of characteristic X-rays from atoms that have absorbed X-rays by the photoelectric effect (Reed 1993). This effect is the process by which the whole energy of the incident X-ray photon is used to eject an atomic electron (Reed 1993). X-ray absorption is an alternative mode of producing the inner shell vacancies that precede characteristic X-ray emission. This method requires the sample to absorb a photon (light wave) so that electrons can be ejected from their atomic orbit. This causes an electron from a higher orbit to jump into the vacated spot circling the atom. This process creates another photon, whose energy is characteristic of the particular element whose orbit it has just left. For a particular wavelength of fluorescent light emitted, the number of photons per unit time is related to the amount of analyte in the sample. In this way elemental composition can be determined qualitatively and the concentration of these elements can be established quantitatively. The implications of this for archaeology are that the elemental composition of artefacts can be established and correlated to a geological source.
The strength of an XRF analysis is dependent on a clear understanding of intra and inter-source chemical variation, and statistical techniques for interpreting compositional data (Braswell et al., 2000). Appropriate statistical methods for sourcing studies are basic discriminate analysis, scatterplot matrices, and cluster analysis. Programs such as JMP and Statistical Package for the Social Sciences (SPSS) are both user-friendly and accessible programs. Though increasing in popularity, the use of XRF techniques has been limited in archaeology because the equipment for XRF is not always available or affordable (Neff and Glascock 1995). One advantage of XRF over some other geochemical techniques is that there are now non-destructive methods, which have made XRF a preferred option for some archaeologists and First Nation groups.

Instrumental Neutron Activation Analysis (INAA)

INAA is an analytical method that determines trace element concentrations with high precision and sensitivity; it allows for the determination of the concentration of a large number of inorganic elements in a wide range of archaeological materials (Pollard et al. 2007). Numerous chemical elements can be detected at the low parts per million (ppm) level and many can be detected well into the parts per billion (ppb) range (Rapp 2009). Wide ranges of elements can be measured simultaneously with no loss in precision. INAA requires a small sample (50 to 100mg), no complex sample preparation, and no extraction techniques. INAA is useful for qualitative and quantitative multielement analysis of major, minor, and trace elements in samples in virtually every field of scientific research (Glascock 2004).

A sample analyzed by INAA is subject to irradiation by slow (thermal) neutrons (Rapp 2009). A target nucleus is bombarded with neutrons resulting in a non-elastic collision forming a compound nucleus. The compound nucleus de-excites almost instantaneously, releasing gamma rays. The compound nucleus can also form a radioactive element that will have its own characteristic gamma ray decay. These emitted gamma rays are detected and counted; the numbers of gamma rays emitted are then used to determine element concentrations well into the ppb range. Thus, very specific and detailed compositional information can be derived using INAA - compositions that are unique to specific bodies of source material. This method has been employed in sourcing studies for obsidian (Braswell et al. 2000) and chert (Luedtke 1978, 1979, 1992), which are both materials commonly exploited for their knapping qualities. When this method has been successful, it is because various potential sources were easily differentiated from one another through their chemical compositions (Braswell et al. 2000; Glascock 2004). Chert is slightly more problematic than obsidian, because its chemical composition has the potential to vary within a single outcrop (Luedtke 1978). However, as Luedtke (1979) notes, trace elements reflect the original
sources of the sediments in which chert was formed, the conditions in the environment of chert deposition, and any post-depositional influences that may have affected the chert. Therefore, the proportions in which these elements are found should be specific to each formation or part of a formation. Intraformational variation is expected because the formation or depositional processes may have changed over time. For this reason, an analysis should include several samples from across a single outcrop or formation.

Geoarchaeologists have found INAA useful for lithic analysis, as one of the main advantages is samples can be analyzed and the results represent the analysis of the entire sample as a whole when irradiated (Pollard et al. 2007). This means that the entire sample is quantified (i.e., all elements within that sample are accounted for), in contrast to other techniques which test more localized areas of a single sample. One disadvantage of INAA is that it is destructive and once a sample is irradiated (bombarded by gamma rays), it is radioactive and will remain so for an unspecified amount of time (Pollard et al. 2007). The destructive nature of INAA is a major drawback, as archaeological artefacts are non-renewable, and generally considered to be property of the culture that created them. Furthermore, contamination can be an issue during the process of extracting a sample from the original archaeological material.

**Case Study: Keatley Creek Sourcing Study**

A current lithic sourcing study in the northwestern plateau of British Colombia, Canada (Figure 1) has the potential to shed light on past trade networks and cultural exchange, while also serving as a case study for the limitations of geochemical sourcing analyses. The purpose of the case study discussed here is to determine probable chert sources utilised by the inhabitants of ST 109, at the Keatley Creek site (Figure 2). To effectively link chert artefacts to a raw material source I selected samples from the lithic assemblage of ST 109 and chert deposits. Quarry areas were determined using Geologic Survey of Canada maps, literature, and a previous study by Rousseau (2000). The majority of the potential quarry areas are within reasonable travelling distance from the Keatley Creek site. Travelling distance was defined by the deposit’s accessibility; for example, the source being located on or near major water corridors, or along frequently used hunting/gathering trails for expedient collection. Remote source areas were also considered viable for this study, as these materials may have been acquired through trade or exchange.
Background: Keatley Creek Site and Structure 109

Keatley Creek is situated in the Clear Range mountains on the western edge of the northwestern plateau, near the Lillooet locality (Figure 2) (Hayden 2000, 2005; Hayden et al. 1996). The site sits on natural terraces in the Ponderosa Pine
Figure 2. Plan map of the Keatley Creek Site (Hayden 2000: 9) indicating the location of ST 109 and its associated features.

and Bunchgrass biogeoclimatic zones (Hayden 2000:7; Meidenger and Pojar 1991). Plants such as sagebrush, cactus and rabbit bush cover the present day landscape of the site (Hayden 2000:7). The site itself contains 119 house sized depression features and is over 19 hectares in size, making it the largest documented site on the British Columbia Plateau (Hayden 2000:7; Hayden and Adams 2004). The site was occupied from 7,000BP into the protohistoric period, with the climax of occupation between 3,500BP and 1000BP, during the Plateau
tradition. This cultural tradition is divided into three cultural horizons: the Shuswap (3,500-2,400BP), Plateau (2,400-1,500BP), and Kamloops Horizons (1,200-200BP) (Richards and Rousseau 1987).

ST 109 is a 9.5m diameter structure located on the periphery of the site, situated on the first terrace east of the core overlooking the entire site including the west terrace (Figure 2). Excavations conducted from June to August 2006 unearthed a large amount of lithic material consisting primarily of dacite, mica, and chert. 101 tools and 2662 pieces of debitage were excavated from ST 109; all of the formed tools were made from dacite (Muir et al. 2008: 23). The assemblage consisted of 1387 pieces of chert and 609 pieces of chalcedony; thus, the silicate materials comprised 75% of the débitage collected during excavations; making the relative abundance of chert in this structure atypical for Keatley Creek and other sites in this region. At Keatley Creek chert makes up less than 7% of the lithic débitage (Hayden 2004: 23; Morin 2006: 107). Therefore, in ST 109 chert is the dominant lithic material found in all of the strata with the exception of stratum VII, which consists mainly of dacite and basalt (Muir et al 2008: 23).

Geological Background

The main geologic features of the plateau region of British Columbia are the Thompson and Fraser rivers, which have cut deep valleys creating precarious cliffs. Over 12,000 years ago a large ice sheet exceeding depths of 2000 meters covered the entire surface of this region. When the Ice Age ended approximately 10,000 years ago and the glaciers melted, they deposited silt, sand, gravel and boulders on the landscape (Hayden 2005: 2-3). Using geologic classification, the bedrock of this area of the plateau is known as the Kamloops Group, with the Cache Creek group and Bridge River group in close proximity (Ewing 1981:1464; Rousseau 2000:166). The river valleys contain accumulations of Quaternary deposits. The Kamloops group is defined as an assemblage of Lower to Middle Eocene volcanic and sedimentary rocks found in south central British Columbia. Of particular interest is the type area west of Kamloops, which runs into the Lillooet and the vicinity of Keatley Creek. This area contains the basal Tranquille Formation consisting of 500 meters of lacustrine and deltaic sediments (Ewing 1981:1464-65).

The Cache Creek group is situated in the vicinity of Marble Canyon, which is southeast of the Keatley Creek site (Figure 3). According to Duffel and Taggart (1951), the bedrock is composed of chert, argillites, minor agglomerates and tuffs that are exposed along the Thompson River and Cariboo Highway from Martel to Cache Creek and north to Clinton (Rousseau 2000:166). A large component of this formation is the re-crystallized limestone exposed in Marble Canyon and the Pavilion Mountains. The limestone contains inclusions of chert, argillite and greenstone.
The Bridge River complex is a chert rich oceanic terrain located within the Canadian Cordillera; it abuts with the Cache Creek complex at the Fraser fault near Lillooet, British Columbia (Figure 3) (Cordey and Schiarizza 1993: 263). This complex is dated to the Triassic-Middle Jurassic (which is ~170 million years), and represents the longest known age range for chert sedimentation. This long period of chert sedimentation makes this region a high potential area for siliceous material deposits. Investigations by the Geological Survey of Canada have shown that this complex contains chert and greenstone, argillite, limestone, sandstone, conglomerate, serpentinite, and gabbro (Schiarizza et al. 1990).

**Sourcing in the Southern Interior Plateau of BC**

A considerable amount of research has focused on sourcing archaeological materials using dacite artefacts in the Mid-Fraser Region (Bakewell and Irving...
1994; Greenough et al. 2002; Greenough et al. 2004; Richards and Rousseau 1987). Bakewell (1995) used geochemistry to identify types of chert at Keatley Creek. There has been a substantial amount of research on chert artefact sourcing conducted throughout North America, most notably by Luedtke (1978, 1979, 1992), Glascock (2004), and Thacker and Ellwood (2002). These studies have provided critical information regarding the processes of determining viable methods for physical and geochemical sourcing of chert.

Collection of Geological Samples

Chert and chalcedony samples were collected from 11 source areas within 50 km of the Keatley Creek site and subjected to geochemical analysis. The majority of these source areas were situated on or near major rivers, or close to traditional hunting routes. Three to five samples were collected from each outcrop to compensate for the inter-variational qualities of chert. For the purposes of this research the majority of chert outcrops/deposits included were previously studied by Rousseau (2000:166) as part of the Fraser River Corporate Group Project. These included Ashcroft Blue chert, Moran chalcedony, Blue Ridge chalcedony, Glen Fraser silicate, West Fountain chert, Fountain white-pink speckled chalcedony, Rusty Creek Red chert, Upper Hat creek, Medicine creek, Lower Medicine creek and Maiden creek sources. I revisited these sources in the interests of confirming or disproving the past petrographic analyses conducted on this material by Rousseau (2000:166) through the application of geochemical and petrographic analysis. In addition, this study actively sought out previously undocumented chert sources based upon geological data from the Geological Survey of Canada, local knowledge, and the recommendations of Rousseau (2000:183). These resource areas included Bridge River Arbour, Applespring Creek, 23 Camels, and Yalakom River (Prentiss et al. 2008); however, this study revealed these source areas primarily contained dacite, poorly formed cherts and quartzites and were not included in geochemical testing.

Samples from the excavations of ST 109 were taken according to chert type and provenance. Chert type was determined based on the Keatley Creek lithic typology developed by Hayden and used in Bakewell’s (1995) chert geochemical characterization study. These archaeological samples were subject to the same analysis as the geologic samples.

Methods

Due to the high propensity of inter and intrasite variation within chert outcrops and deposits, the Keatley Creek sourcing study required a method which could test for trace elements and elemental density with high precision. Although all samples were analysed using a petrographic microscope, visual sourcing based on colour was not reliable for these samples, as not all properties could be identified
using this instrument. Prepared thin sections can be useful for identifying the presence/absence of fossils such as diatoms and radiolarians that can be used to correlate artefacts to their geological source, but thin sections are subject to individual interpretation, are difficult to properly identify in terms of context, and therefore, are not as precise as geochemical methods.

For geochemical analysis, the heterogeneity of chert and chalcedony requires a high precision instrument capable of measuring rare and trace earth elements. Each chert source can contain the same elements, but the composition percentage of each element varies (i.e., each chert outcrop has different amounts of trace elements and based on the variation detected by geochemical analysis, it is possible to identify where a specific piece was quarried). Because of the precision required for chert sourcing, INAA was selected over XRF for the Keatley Creek analysis. As previously explained, INAA is the most reliable and precise instrument for testing chert material due to chert’s heterogeneous nature. XRF is an acceptable candidate for material identification (characterization) studies, or for use in homogenous material (e.g. obsidian) studies, but INAA can reveal the variation in the trace elements found within a single outcrop of chert. XRF does not yet have this capability without sacrificing precision. There is however, a recently released S1 Turbo SD model for XRF analysis that is specifically designed for archaeometric applications and elemental analyses. Future sourcing studies should consider this technology for use in research and perform comparative studies with INAA.

78 geologic and archaeological samples from Keatley Creek and the surrounding area have been sent to McMaster University Reactor for analysis and are currently being measured for the following elements: Al, As, Au, Ba, Br, Ca, Ce, Cl, Cr, Cs, Co, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Nd, Sb, Sc, Sm, Sr, Tb, Th, Ti, U, V, and Yb. In total, concentration data on 32 elements will be reported upon completion of this geochemical sourcing study. The INAA analysis will be completed in August 2010, and the results may allow the ST 109 chert and chalcedony artefacts to be correlated with their geological outcrops/deposits.

In the event of no successful correlation, long-distance trade with other North American groups will have to be further examined. The southern Salishan cultures and eastern groups remain two likely candidates for long-distance exchange. It would have been unlikely for the Plateau cultures to trade with northern cultures, such as the Chilcotin. According to Teit and other early ethnographers, due to territorial and other disputes the Chilcotin were an unlikely partner for exchange with the peoples of the plateau. Future projects should also test more distant source areas, such as the Botanie Valley, Kamloops, Cache Creek/Ashcroft, and Clinton areas with an emphasis on tertiary deposits that might have also been a source for the chert artefacts recovered from Keatley Creek. However, because the Lillooet area is well known for its agates, cherts,
and chalcedonies by local rockhounds and lapidary enthusiasts who have heavily exploited deposits of these materials, it remains a possibility that the source areas used by First Nation groups in prehistory have been depleted. Thus, additional interviews and efforts should be made to contact these individuals to gather samples from private collections.

Conclusion

Although archaeology has a long-standing relationship with earth sciences and many of the principles and techniques are applicable to archaeological conundrums, geoarchaeologists should familiarise themselves with new technologies to ensure research produces accurate and reliable results. This is particularly relevant to sourcing and characterization studies, in which understanding the rock material is paramount. Techniques that are useful and effective for homogenous materials such as obsidian are often ineffective when dealing with heterogeneous materials such as chert. Geoarchaeologists can avoid wasting time and resources (including damage to archaeological materials) by understanding the geochemistry, theory, and application of available techniques. However, geoarchaeologists should also be aware that geochemical techniques do not guarantee an answer to the research questions asked. The Keatley Creak sourcing study discussed above reveals the problems of equifinality if no nearby source material for the ST109 chert artefacts is identified. Archaeologists are likely to default to explanations involving long-distance exchange, but direct long-distance foraging, the use of secondary deposits, and the depletion and invisibility of past sources remain alternative explanations.

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