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Determining the Source of Lithic Artifacts and Reconstructing Trade in the Ancient World

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Introduction

The study of prehistoric exchange systems is a fundamental topic of archaeological research, as the successful reconstruction of trade may illuminate not only economic aspects of ancient societies, but also the social and political climate in which it operated. While changing theoretical emphases in recent decades have affected the interpretation of archaeological data relevant to exchange systems, technological advancements in our ability to determine the source of archaeological materials have greatly enhanced the quantity and quality of this data. This is reflected in the goals, design and implementation of modern provenance studies.

After a brief review of trade and exchange studies, I focus on the principles and prerequisites of a successful provenance study; the lithic and other materials for which source determination is possible; the analytical methods available; and sampling procedures and other considerations. Recent research on Mediterranean obsidian sources illustrates the potential of lithic provenance studies for reconstructing trade. Although such studies are the focus herein, it is recognized that “characterization alone is not enough” (Renfrew 1993:15). Determining the source of lithic artifacts is only the first link in a *chaîne opératoire* that also includes mechanisms of procurement, transport, manufacture, use, and disposal. The reconstruction of this entire sequence of activities is necessary for a full understanding of the human motivations and behaviors involved.

Trade and Exchange

Archaeologists commonly use the concepts of “trade” and “exchange” to explain the presence of non-local raw materials or artifacts on archaeological sites. In

formal economics, trade may be defined as “the mutual appropriative movement of goods between hands” (Polanyi 1957b:266). In the archaeological record, however, it is the movement of the goods themselves, rather than their ownership or possession, which is immediately recognizable (Renfrew 1993), and somewhat broader definitions have often been adopted, e.g., “reciprocal traffic, exchange, or movement of materials or goods through peaceful human agency” (Renfrew 1969:152) or “procurement of materials from a distance, by whatever mechanism” (Renfrew 1977:72). Anthropologists ultimately require a methodology for establishing a cultural biography for goods starting with the procurement of their raw materials and ending only with their final disposal.

Interpreting the social context of various modes of exchange in prehistoric societies has been the subject of considerable research in recent decades, beginning with Grahame Clark’s (1952) work on prehistoric Europe, and blossoming after the publication of Karl Polanyi’s (1957a) influential work which emphasized a substantivist (institutionally determining) rather than formalist (individually optimizing) approach. The possibility of equating certain modes of trade with particular levels of social complexity (Service 1962) was of central interest to the “new” processual archaeology and its goal of achieving higher planes of inference from static archaeological data (Adams 1974; Renfrew 1972; Sahlins 1972; Wilmsen 1972). As Baugh and Ericson (1992:4) have noted, “Exchange is not simply an economic transaction but a series of transactions involving social relationships that form the central component of the action. From an archaeological perspective, these social ties can be measured in terms of content, magnitude, directionality, and the diversity of items being traded through time and space.” While it seemed apparent that exchange could only be fully understood within *both* social and economic contexts relevant to the society in question, these constructs remain difficult to establish without historical or ethnographic data (Akalu and Stjernquist 1988; Dalton 1975, 1977; Meijer and van Nijf 1992; Plattner 1989).

In the past two decades, scholarly interest in trade and exchange has remained keen, especially since technical advances have made it possible to determine the source of materials such as pottery, jade, turquoise, amber, marble, copper, lead, and obsidian (Figure 5.1). Numerous works have been devoted to this subject (see individual articles in edited volumes by Baugh and Ericson 1994; Brumfield and Earle 1987; Earle and Ericson 1977; Ericson and Baugh 1993; Ericson and Earle 1982; Fry 1980; Hårdh et al. 1988; Knapp and Stech 1985; Oates 1993; Polanyi et al. 1957; Sabloff and Lamberg-Karlovsky 1975; Scarre and Healy 1993; *The Ancient World* 10[1-2] 1984). In addition to specific case studies, the literature includes a number of essays that discuss the nature of production, trade and exchange, and review the history of their archaeological interpretation (Baugh and Ericson 1992; Brumfiel and Earle 1987; Earle 1982, 1985, 1994; Earle and Ericson 1977; Ericson 1984; Ericson and Baugh 1994; Hodder 1980; Knapp 1985; Renfrew 1993).

Many studies in the 1970s and 1980s made use of generalizing, heuristic mathematical models to interpret the distribution patterns of traded artifacts. Among the best known are the gravity model (Bradley 1971; Chappell 1986),

used to describe interaction zones in which different sources “compete” for market share, and fall-off curves (Hodder 1974, 1978; Hodder and Orton 1976; Renfrew 1975, 1977; Warren 1981) of artifact frequency vs. increasing distance from their source.

Stone	Metals
obsidian	copper and copper alloys
flint and chert, jasper, quartz	lead
soapstone (steatite and chlorite)	gold
greenstone (jadeite and nephrite)	silver
basalt, granite, rhyolite	Glass
turquoise	glass and glass beads
schist	faience
sandstone and quartzite	Other Materials
limestone and marble	amber
hematite and magnetite	bitumen
alabaster	ivory
Ceramics	bone
pottery	antler and horn
other clay objects	

Figure 5.1. Archaeological materials that can be sourced.

The shape of the fall-off curve is determined by particular exchange mechanisms, and the slope by factors such as demand, transportation costs, and the availability of alternative materials. Sidrys (1977), for example, found a strong correlation between obsidian frequency and ranking of Maya centers, while Fulford and Hodder (1974) identified mode of transport as the prime factor in determining the percentage of Oxford pottery at Romano-British sites.

There are a number of inherent problems in these models. Ammerman (1979; Ammerman et al. 1978; Ammerman and Andrefsky 1982) in particular has noted that these models assume exchange was *not* sporadic, was *not* disrupted, and that they do *not* take into consideration dynamic time behavior, population growth, changes in settlement size, and the heterogeneity of “dropping rates” (Ammerman and Feldman 1974, 1978). There are also variables such as differential participation in exchange networks, seasonal activities, and the likelihood that several exchange mechanisms were in effect at the same time, that need to be taken into consideration. Objects may have moved alone (by trade or gift exchange); along with individuals (traders, craftspeople, brides); or with groups of people (migration, colonization, war, foraging). In some cases, the idea alone, rather than the physical object, may have been transmitted (Olausson 1988). Local variation in resources, transportation, population density, and social organization would have produced regionally distinct situations which may be amplified by differences in archaeological fieldwork methods, sampling strategy and sample size (Clark 1979; Hodder 1980; Knapp 1985). Lastly, the problem of equifinality, that different exchange mechanisms may have resulted in the same

distribution of artifacts, has also been recognized. Despite these considerations, few have made an explicit interpretive connection between Polanyi's oft-cited modes of exchange (reciprocity, redistribution, and market exchange), the multiple mechanisms characteristic of each, and their manifestations in the archaeological record (Sheridan 1982). These problems, along with the uneven quality of most archaeological data, has led some scholars to reassert that quantification of existing data was a higher priority than the elaboration of theoretical models (Bietti Sestieri 1985).

More recent lithic studies have turned their focus to procurement (Andrefsky 1994; Bamforth 1990; Jeske 1989; Kuhn 1989; Montet-White and Holen 1991; Morrow and Jefferies 1989; Shackley 1990; Torrence 1986), production (e.g. Ammerman and Andrefsky 1982; Andrefsky 1991; Arnold 1992; Bradley and Edmonds 1993; Carr 1994; Ericson and Purdy 1984; Gibson 1986; Torrence 1981a, 1981b, 1982, 1984, 1986), and use (Grace 1996; Hurcombe 1992a, 1992b; Shea 1992; Vaughan 1985, 1990) rather than distribution of artifacts. Use of lithic raw materials by hunter-gatherers is frequently determined to have been economizing in a formalist sense, while embedded in subsistence-related activities. For production, the social constraints of economic behavior are directly explained using the *chaîne opératoire* approach (Cresswell 1983; Dobres 2000; Lemonnier 1976, 1990; Leroi-Gourhan 1964, 1965; Phillips, this volume; Schlanger 1994). After procurement from a particular source, the subsequent behaviors involved in exchange, use and deposition are much more variable, particularizing, and difficult to infer from the archaeological record.

Lithic materials are among the most common artifacts in the archaeological record, and are the product of several distinct behaviors: acquisition of the raw material; preparation of a core for flaking; primary trimming; secondary trimming and shaping; use; maintenance or modification; and disposal (Collins 1975). Gero (1989) has defined five axes of variability which must be controlled for in order to understand the social processes involved: the rarity of the raw material; the size of artifact produced; the number of production stages necessary; the restrictiveness of production; and the longevity of the item. Some of these activities may have been part of rather complex behaviors. Raw nodules, pre-formed cores, or finished tools may have been acquired from distant sources, and labor specialization may have been involved in these processes. Finally, the movement of the lithics found in the archaeological record may have been non-economic in purpose, or have been secondary to the movement of primary resources including animals and animal products, agricultural produce, salt, etc., of which there would be little trace in the material record.

The identification of the geological source of lithic artifacts establishes both beginning and end points in the *chaîne opératoire*, while the analysis of geographic and chronological patterns of source exploitation complements lithic reduction and use-wear studies in elucidating the intervening behavioral links and in answering questions about exploitation. As often the most visible indicator of prehistoric human activity, lithic use is also relevant to discussions of adaptations to local climatic and ecological systems, long-distance exchange networks, craft specialization, and the development of social differentiation.

Principles and Prerequisites of Provenance Studies

In order for a provenance study of lithic artifacts to be successful, there are several prerequisites: (1) all relevant geological sources must be known; (2) these sources must be characterized for the physical properties or parameters (e.g. color, density, mineralogic, elemental or isotopic composition) which will be measured for the artifacts; (3) one or more properties must be homogeneous within an individual source; (4) measurable, statistically valid differences between sources must exist for one or a combination of these parameters; and (5) they must be measurable using analytical methods appropriate for archaeological artifacts.

Many provenance studies have been attempted when not all of the prerequisites have been met. In some cases, not all of the possible sources were known, so not all of the artifacts tested “matched” a known source. In others, intra-source variability and inter-source differences have not been well established because only a small number of geological specimens have been tested; this makes source attributions of artifacts, even when they match one source, unreliable, since some specimens from other sources might also have the same measured values. A sufficient number of well-selected samples from each source are required to make such “overlaps” statistically unlikely. Locating and characterizing all of the geological sources may be difficult for lithic types that occur in multiple, small outcrops; some rocks are more likely than others to form in dispersed patterns yet still have the same physical characteristics.

In general, provenance studies have been most successful when the number of possible geological sources is naturally limited. While many potential sources may be effectively excluded because of geographic distance (especially in certain time periods), we must avoid a tautological situation in which artifacts from “unlikely” sources are never identified as such—often the exception to the rule is the most significant finding. With fewer natural sources, there is less chance of additional sources remaining unknown, a smaller total number of specimens must be characterized (advantageous for time and cost reasons), and the likelihood of finding some parameter that meets prerequisites 3-5 above will be much greater. The characterization of obsidian in the Mediterranean, the Near East, and elsewhere is the classic success story for just these reasons. Provenance studies of other stone materials (e.g. chert/flint, steatite, greenstone, marble, basalt, granite) also have been successful when the above criteria were satisfied.

The efficacy of many techniques for provenance studies of certain lithic materials has been demonstrated. Even though the use of some techniques may be successful in a scientific sense, they may not be readily applicable to all archaeological studies because of sampling requirements, cost, or availability.

Analytical Methods and Procedures

For stone materials, characterization begins with “macroscopic” observations and measurements of properties such as color, luster or other aspects of appear-

ance, density, hardness, and refractive index. There are few examples where these properties have been sufficient by themselves to distinguish reliably among lithic sources (e.g., in Malta and the south central Mediterranean dark green obsidian is from Pantelleria and black/gray obsidian is most probably from Lipari). Caution is especially warranted for lithics that at first appear to be identifiable based on color, which may be influenced by depositional circumstances, weathering, natural or intentional heat treatment, etc.

The next step is microscopic examination, typically in thin section using a petrographic microscope by which the mineral grains and inclusions may be identified using natural, polarized, and/or cross-polarized light. Petrographic analysis is destructive to a lithic artifact since a thin section of at least 1 cm² is required. However, it is not an expensive or difficult procedure and a number of archaeologists have been suitably trained to make and interpret their own thin sections; thin section equipment and petrographic microscopes are available at just about any university with a geology department. In many cases petrographic analysis alone has been enough to distinguish lithic sources, for example "greenstones" in the Alpine region (Ricq-de-Bouard 1993; Ricq-de-Bouard and Fedele 1993; Ricq-de-Bouard et al. 1990) and in southern Italy (Leighton 1992; Leighton and Dixon 1992). Some success has also been achieved in sourcing flint in northern Italy using a combination of macroscopic and microscopic analysis (Barfield 1999).

In many cases, however, measurements of physical properties and/or petrography cannot distinguish among all possible lithic sources in a given region of study. Since the early 1960s, instrumental methods of chemical analysis have been used in archaeological provenance studies, often focusing on the trace element "fingerprinting" of individual sources. Once again, obsidian has proved to be ideal for such studies (Cann and Renfrew 1964; Hallam et al. 1976; Renfrew and Aspinall 1990; Renfrew et al. 1965; Renfrew and Dixon 1976; Shackley 1997), although success with other lithic materials, ceramics, and even certain metals has been achieved (e.g. Gale and Stos-Gale 1992; Luedtke 1992; Moens and Ulens 1995; Neff 1992; Sieveking and Newcomer 1987; Williams-Thorpe and Thorpe 1992).

In recent years, instrumental improvements in sample handling, precision and accuracy, along with advances in data reduction, have resulted in a number of analytical methods having been successfully employed in provenance studies (Figure 5.2). Methods that measure elemental or isotopic composition have been widely used on obsidian, flint, and other lithic materials, while several other methods have been used in certain cases. The most common elemental methods of analysis include neutron activation analysis (NAA), x-ray fluorescence (XRF), and proton induced x-ray/gamma ray emission (PIXE/PIGME); optical emission spectroscopy (OES) and atomic absorption spectroscopy (AAS) have been largely superseded by inductively coupled plasma spectroscopy (ICP-S; often referred to as ICP). Quantitative x-ray analysis is also available with an electron microprobe equipped with wavelength dispersive spectrometers (WDS), and most scanning electron microscopes have semi-quantitative analysis capabilities using energy dispersive spectrometers (SEM-EDS). All of these methods

involve the measurement of characteristic wavelengths of electromagnetic radiation (in visible, x-ray, or gamma-ray portions of the electromagnetic spectrum) absorbed or emitted when a sample is “excited” (e.g. by bombardment with neutrons, x-rays, or electrons). A complex spectrum is produced in which peaks at

<p>Elemental Methods</p> <ul style="list-style-type: none"> Neutron activation analysis (NAA) X-ray fluorescence (XRF) Electron microprobe with wavelength dispersive spectrometers Scanning electron microscope with x-ray analyzer (SEM-EDS) Atomic absorption spectroscopy (AAS) Optical emission spectroscopy (OES) Proton induced x-ray/gamma ray emission (PIXE/PIGME) Inductively coupled plasma spectroscopy (ICP-S) <p>Isotopic Methods</p> <ul style="list-style-type: none"> Thermal ionization mass spectrometry (TIMS) Stable isotope ratio analysis (SIRA) ICP mass spectrometry (ICP-MS) Laser ablation ICP mass spectrometry (LA-ICP-MS) <p>Other Methods</p> <ul style="list-style-type: none"> Fission track dating Electron paramagnetic resonance (EPR) Cathodoluminescence (CL) Magnetic parameters Mössbauer spectroscopy

Figure 5.2. Analytical methods used in provenance studies.

certain wavelengths are characteristic of one or more elements, and the area under a peak (intensity) is proportional to the amount of that element present in the analyzed material. Problems of spectral overlap and matrix interferences, however, are quite common, so the specific elements that can be analyzed vary from technique to technique. While accuracy is addressed through the use of standards of known values, detection limits (precision) vary both between methods and within each method depending on the brand or configuration of the instrument. Detection limits for many elements are in the parts per million range (or less) for most of these techniques; the microprobe and SEM are limited to the analysis of major and minor elements.

Methods based on atomic or molecular mass spectra include thermal ionization mass spectrometry (TIMS), used for precise measurements of the isotope ratios of heavy elements (e.g. lead, strontium); light stable isotope ratio analysis (SIRA), for light elements (e.g. carbon, oxygen and nitrogen); and ICP mass spectrometry (ICP-MS), for a large range of elements but often at reduced preci-

sion relative to TIMS (Halliday et al. 1998; Tykot and Young 1996). The usefulness of isotopic methods for provenance studies is three-fold: (1) the precision of a mass isotope measurement is typically much greater than for elemental analysis methods because there are far fewer overlaps in mass spectra than in electromagnetic spectra, allowing smaller differences between sources to be identified and measured; (2) elemental composition may be different between a raw material (e.g. metal ore, clay) and a finished product (metal artifact, pottery vessel), whereas the relative abundance of the isotopes of most elements remains unchanged (not usually relevant to lithic provenance studies, unless weathering has altered an artifact's composition); and (3) elemental concentration can also be calculated from mass isotope measurements (as is most commonly done with ICP-MS). TIMS has been extensively used for lead isotope analyses of copper, lead and silver objects in the Mediterranean (Gale and Stos-Gale 1992), and for strontium and neodymium isotopes in other materials (e.g. ivory: van der Merwe et al. 1990), but rarely for lithic provenance studies (e.g. Gale 1981). Isotope ratio measurements using ICP-MS, however, are less time consuming and costly, and the precision of the newest magnetic sector instruments with multi-collectors rivals that of TIMS. Some preliminary studies of turquoise (Young, in Tykot and Young 1996) and marble (Castorina et al. 1997) using lead and strontium isotope ratios, respectively, show the promise of this evolving technique. The use of a laser ablation device with ICP-MS holds great potential for archaeological materials because only the tiniest scar is left on the artifact where the sample was removed, thus minimizing the destructive nature of sampling artifacts and preparing the sample for quantitative chemical analysis (Tykot and Young 1996). The reduced precision of LA-ICP-MS relative to solution ICP-MS is not likely to be a factor in archaeological provenance studies, especially of homogeneous materials like obsidian (e.g. Gratuze 1999).

Stable isotope analysis of carbon and oxygen is limited to limestone, marble, and other carbonate-containing lithic materials. Cathodoluminescence (Barbin et al. 1992) and electron paramagnetic resonance (Armiento et al. 1997) have also been used in marble provenance studies with some success. Fission track dating has been widely used for obsidian sourcing, and is very successful when significant differences exist in the age of formation of the different obsidian sources (Bigazzi and Bonadonna 1973; Bigazzi and Radi 1981; Bigazzi et al. 1971, 1976, 1990). In the Mediterranean and Near East, however, many more obsidian sources can be distinguished using elemental methods of analysis. Magnetic parameters (McDougall et al. 1983), Mössbauer spectroscopy (Longworth and Warren 1979), and backscattered electron petrography (Kayani and McDonnell 1996; 1997) have been applied with only limited success to obsidian sourcing.

In too many instances, instrumental methodology has been emphasized at the expense of addressing sourcing issues of archaeological significance. While it is necessary to demonstrate first that a particular technique can be applied to provenance studies, all too often these preliminary studies have failed to consider the limitations inherent in the analysis of many archaeological materials. The result has been that many techniques have been tried out, but few have been widely used to determine the source of significant numbers of artifacts. It is per-

haps in the nature of pilot studies not to explore all the possible avenues of investigation, since the goal is often to maintain a narrow range of focus in order to determine the efficacy of a method. Such efforts often betray the archaeologist's lack of familiarity with the intricacies of a specialized field. More thorough training in analytical techniques or stronger dialogue with specialists could minimize this problem.

Sample Selection and Other Considerations

Archaeological materials are often compositionally similar to naturally occurring materials—for lithic artifacts the composition is the same as that of the raw material—but analytical methods appropriate for geological specimens may not be suitable for archaeological artifacts (Figure 5.3). First and foremost we must consider the destructive nature of many analytical techniques. In many cases, a sample is physically removed from each artifact, either as a solid or as a powder. This may be done because the artifact is too large to analyze whole; it is impractical or impossible to transport the artifact(s) to the laboratory; or the technique itself requires samples to be powdered or put into solution. AAS and ICP, for example, usually require the sample to be put into solution; XRF and PIXE need a polished flat surface to produce fully quantitative results; and the determination of some elements by NAA will leave the sample too “hot” to be returned.

<p>Analysis Type bulk or surface? destructive or non-destructive? precision and accuracy availability and cost</p> <p>Samples minimum sample size required solid or powder form? pre- and post-analysis handling</p>

Figure 5.3. Considerations when choosing an analytical method.

For heterogeneous materials it is important to take enough sample so that it is reasonably representative of the whole artifact—100 milligrams seems to be a standard amount. Electron microprobe analyses of areas 40 microns or less in diameter have shown that for homogeneous materials like obsidian, it is sufficient to remove 1 mm² samples from an artifact. Similarly, for isotopic measurements of major components, e.g. carbon and oxygen in marble, as little as one milligram may be necessary. While these quantities are certainly small, their removal from an artifact may nevertheless have a significant impact on its integrity, especially for small artifacts such as lithic flakes and blades. For elaborate or morphologically distinctive artifacts it may be necessary to remove the sam-

ple by drilling from a less visible portion of the artifact, a time consuming activity at the least. For such artifacts, it is often impossible to remove a solid sample. LA-ICP-MS leaves only a tiny crater where sample has been removed by the laser, but the artifact must be transported to the instrument, and it must fit inside the laser ablation chamber which is typically only two or three inches in diameter.

For solid samples, it is also important to consider whether the technique produces results based on the bulk or surface composition of the sample, and the range of elements (or isotopes) that can be analyzed. For lithics, bulk and surface composition should be the same, but artifact surfaces may become weathered or otherwise altered by the burial environment. Care must be taken, therefore, when using surface analytical techniques such as XRF, PIXE, and LA-ICP-MS. While NAA gives the bulk composition of the sample, it is rarely used to provide data on the major element composition of lithic materials; XRF and PIXE provide data on major and many trace elements. Among the solution-based techniques, analyses also often focus on trace rather than major element composition.

Precision (the plus or minus, or replicability, of each analysis) and accuracy (nearness to actual values) vary not only for each technique, but also for each element (or isotope) under analysis. Overall analytical precision is limited by a combination of sample preparation techniques and instrumental conditions, while accuracy is typically corrected for through the use of standard reference materials, ideally similar in composition to the sample so as to avoid matrix effects. Elemental (or isotopic) composition cannot be considered characteristic of a particular source if the analytical precision of the measurement approaches the difference in value between two sources.

The actual process of taking compositional data and attributing an artifact to a particular source is not a trivial exercise. Sufficient samples of geological source material must be available to establish the variability within a single source (absolutely a minimum of 15 and preferably 25-30 for homogeneous sources). Elements that have limited ranges of variation within sources, and have little or no overlap with other sources must then be selected; many elements will not be useful in source discrimination. For obsidian, bivariate plots of certain trace elements appear to be sufficient for visual assignment of artifacts to individual island sources, at least in the Mediterranean (e.g. Hallam et al. 1976). In other regions, and/or to assign artifacts to specific subsources, multi-variate statistical analysis is usually necessary. The most powerful method is discriminant function analysis, in which sources are predefined based on the compositional data for geological specimens, and artifacts are assigned based on their posterior probability of belonging to one of these preexisting groups. As with all statistical techniques, one must verify the suitability of the data for a particular technique (e.g. requirements of normality).

Availability of instrumentation and the cost of analysis unfortunately are two practical aspects in the choice of technique for archaeological provenance studies. Funding, when more than nominal, is nevertheless finite, and per sample costs are likely to be less when instrumentation at an academic institution—

especially one's own—is employed. A trade-off therefore often results when these factors are considered along with the type of analysis, sample requirements, and particular elements analyzed. Fortunately, costs have been much reduced for many methods due to lower prices for the instrumentation itself combined with automation of the analysis. Lower costs and generally reduced sample size requirements now permit the analysis of larger numbers of artifacts. Such studies overcome the interpretive limitations imposed by small data sets, and allow detailed examination of geographic and temporal differences in lithic exploitation patterns. Comparison of the results from earlier and more recent studies of obsidian artifacts at several sites in the central Mediterranean illustrate the importance of analyzing statistically significant numbers of artifacts prior to drawing conclusions about the relative importance of individual sources. As sample size increases, a greater degree of variation appears in the data (Figure 5.4).

Earlier Study	Later Study
Arene Candide 2 samples 100% Sardinia	Arene Candide 26 samples 42% Palmarola, 58% Sardinia
Filiestru 4 samples 50% SA, 25% SB, 25% SC	Filiestru 86 samples 10% SA, 49% SB, 41% SC
Basi 4 samples 100% SC	Basi 133 samples 44% SA, 5% SB, 51% SC
Poggio Olivastro 4 samples 100% Lipari	Poggio Olivastro 202 samples 100% Sardinia

Figure 5.4. Lessons in the number and selection of obsidian samples from Neolithic sites in Italy.

Obsidian Sourcing in the Central Mediterranean: A Case Study

Obsidian is widely considered an ideal material for source tracing, and provenance studies of Mediterranean obsidian have been described as a success story (Williams-Thorpe 1995). As such, a review of obsidian research, specifically in the central Mediterranean, illustrates well the principles and prerequisites of provenance studies and their potential contribution to reconstructions of prehistoric trade.

While it was only in the early 1960s that chemical characterization studies of obsidian began, the principal Mediterranean sources of obsidian were already known (Figure 5.5). Prior to the application of instrumental methods of analysis,

an ordinary wet chemical analysis of major elements had produced the surprising (and erroneous) result that obsidian artifacts in Malta were of Melian origin (Cornaggia Castiglioni et al. 1962, 1963). The first successful provenance study of Mediterranean obsidians relied on trace element concentrations of barium, zirconium, niobium and yttrium, measured by optical emission spectroscopy (Cann and Renfrew 1964). These results demonstrated that it was possible to differentiate many of the sources in the Mediterranean region, but they did not distinguish between Lipari and Palmarola. Furthermore, all sources were represented by a very limited number of specimens.

More detailed examination of the Mediterranean sources, using neutron activation analysis, was completely successful in attributing artifacts not only to specific islands, but even in distinguishing among multiple flows on Sardinia and Melos (Hallam et al. 1976; Renfrew and Dixon 1976; Williams-Thorpe et al. 1979, 1984), and in the complex sources of central Europe (Williams-Thorpe

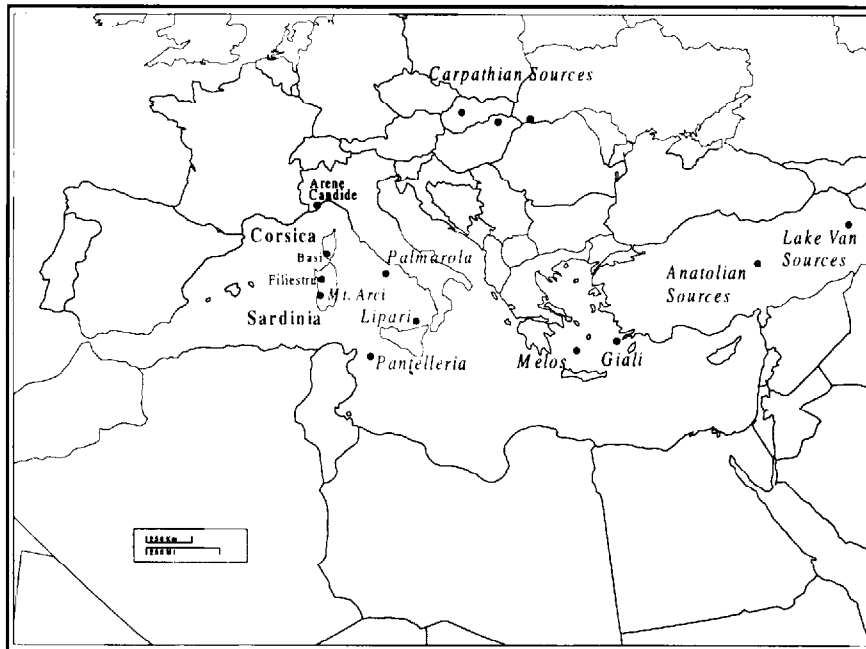


Figure 5.5. Mediterranean obsidian sources and selected sites mentioned in the text.

et al. 1984) and central and eastern Anatolia (Cauvin et al. 1998). The existence, however, of multiple Sardinian flows was based on compositional clusters of artifacts rather than of geological samples, so the actual location of several sources remained unknown. For Lipari, several flows have been identified—some of historic age—but only the Gabelotto flow has been studied in any detail (Francaviglia 1984). Multiple flows also exist on Pantelleria, but these too have only been preliminarily studied (Francaviglia 1988). Fission-track dating

also emerged as a useful provenance method since the ages of the different island sources were substantially different (Bigazzi et al. 1971; Bigazzi and Bonadonna 1973; Bigazzi et al. 1976). Provenance studies based on fission-track dating, however, were unable to distinguish among the multiple Sardinian sources, which were presumably close in age (e.g. Bigazzi and Radi 1981; Bigazzi et al. 1992). The interpretive significance of being able to distinguish between multiple flows was not really recognized until provenance studies of large numbers of artifacts began to reveal patterns in the exploitation of specific obsidian sources (see Tykot and Ammerman 1997).

During the 1970s and 1980s a number of other archaeometric techniques were tested for their usefulness in provenance studies. Initial attempts at using strontium isotopes (Gale 1981), Mössbauer spectroscopy (Longworth and Warren 1979), electron paramagnetic resonance (Aramu et al. 1983), and magnetic parameters (McDougall et al. 1983) have not been pursued further, and were generally unsuccessful in distinguishing among all sources.

It was only in the 1980s that serious attempts were made to locate and properly characterize all of the Sardinian obsidian sources. Besides the well-known source at Conca Cannas (SA), Mackey and Warren (1983) were able to locate additional Monte Arci sources *in situ* and resolve some of the questions surrounding the SB source previously identified only from archaeological samples. Unfortunately, their research was published only briefly and never continued. Herold (1986), also a geologist, conducted a thorough survey and analysis of the Sardinian sources but has never formally published his thesis. Herold was able to identify four chemical subgroups among numerous localities with small unworkable nodules, in addition to the four usable sources identified by Mackey and Warren (1983). Also working independently, Francaviglia (1984) identified two SC subgroups, but neither was found *in situ*. All three of these studies relied on x-ray fluorescence analyses of trace elements, supplemented by neutron activation in the cases of Mackey and Warren (1983) and Herold (1986). Francaviglia also demonstrated that all of the main Mediterranean obsidian sources (Sardinian A, B, C, Lipari, Pantelleria, Palmarola, Melos, Giali) could be chemically differentiated on the basis of major/minor elements alone. The use of major elements to discriminate between three principal Sardinian groups was also confirmed by Michels et al. (1984) using atomic absorption spectroscopy as part of an obsidian hydration dating project.

When this author began his own research on the Sardinian sources, there nevertheless remained a number of problems regarding the sources and usage of Sardinian obsidian. The SC source(s) had not been located *in situ*, and the number and location of SB sources was not entirely resolved. A detailed survey of obsidian outcrops in the Monte Arci area began in 1987 and has resulted in the *in situ* location of all usable sources and their chemical characterization by ICP-MS, XRF and electron microprobe (Figure 5.6; Tykot 1992, 1995, 1997, 1998, 2001). For the purposes of archaeological provenance studies, it is useful to distinguish chemically among four geographically-specific sources (SA, SB1, SB2, SC), which also have distinctive characteristics that might have been important

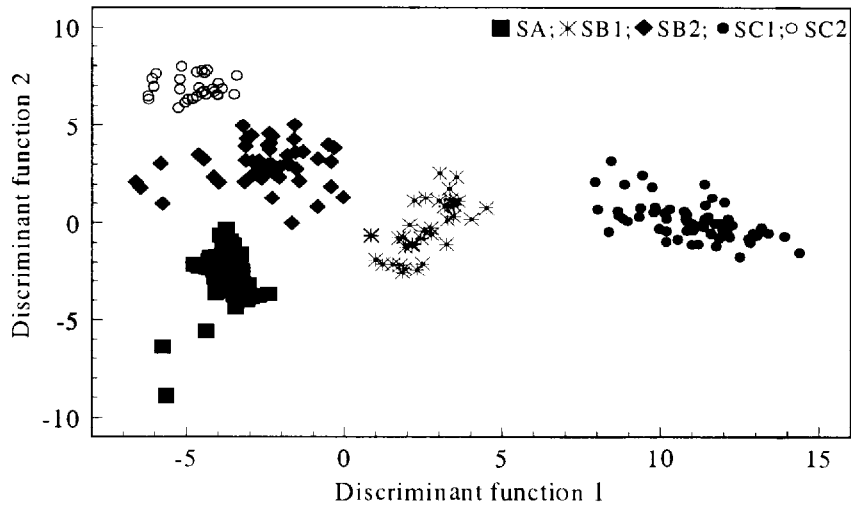


Figure 5.6. Discriminant analysis using eight elements measured by ICP-MS, for geological samples from Monte Arci, Sardinia. Five subsources are clearly distinguishable.

in their exploitation by prehistoric peoples (e.g., accessibility and density of source material; color, transparency, and luster; fracture properties). It is not possible to distinguish among these four sources using fission-track dating or SEM-EDS, although both appear to have sufficient precision to distinguish two Monte Arci subgroups (Acquafredda et al. 1999; Bigazzi and Radi 1998).

Until a decade ago, it was nearly impossible to assess the relative importance of different sources at a single site or within a single chronological period. While obsidian from about 100 western Mediterranean sites had been analyzed, most sites were represented by only a few samples, many from imprecise contexts. Only four sites had more than ten analyses, and only at Skorba in Malta could we look at chronological change in source utilization. This situation has begun to be addressed with larger numbers of artifacts analyzed at several sites in southern France (Crisci et al. 1994); at Gaione and Arene Candide in northern Italy (Ammerman et al. 1990; Ammerman and Polglase 1997); at many sites in Sardinia and Corsica (Tykot 1995, 1996, 2002a, 2002b); at Acconia and Bova Marina in southern Italy (Crummett and Warren 1985; Tykot and Robb, unpublished data); at Grotta dell'Uzzo in Sicily (Francaviglia and Piperno 1987); at Zembra in Tunisia (Tykot 1996), and several other sites in Tuscany, the Adriatic islands, and elsewhere (Tykot et al., unpublished data).

These analyses of significant numbers of artifacts at individual sites allow for hypothesis testing and interpretation that was not possible with limited numbers of analyses (Tykot 1996, 2002a, 2002b; Tykot and Ammerman 1997). For example, it has been hypothesized that in Sardinia during the Early Neolithic (ca. 6000-5000 B.C.), less-organized selection of source material would result in the presence of obsidian flakes from multiple sources, and in its relatively inefficient use; by the Late Neolithic (ca. 4000-3000 B.C.), procurement would have

been better organized, focusing on the higher quality SA obsidian, and featuring more efficient reduction technology in the production of cores and blades (Hurcombe and Phillips 1998). An apparent shift in source utilization which supports this technological hypothesis of obsidian selection is observed at Arene Candide in Liguria, where less-intensive, on-site production of tools from multiple obsidian sources (SA, SB, SC, PI) in the Early Neolithic is followed by nearly exclusive importation of blades of high-quality Lipari obsidian in the Late Neolithic (Ammerman and Polglase 1993, 1997).

This pattern, however, is not paralleled in Sardinia and Corsica. Type SA, SB2, or SC may be the most frequent at any one site in a given chronological period. At Grotta Filiestru, for example, the use of clear, glassy type SB2 obsidian from the western flanks of Monte Arci decreases over four Neolithic cultural periods, while the use of opaque, less-glassy type SC obsidian from the north-eastern part of Monte Arci increases; type SA is never more than 20% of the assemblage (Tykot 2002b)(Figure 5.7). In contrast, type SA accounts for an average of 40% of the assemblage at Basi in Corsica, SB2 is never important, and this pattern does not change for eight stratigraphic levels including the Early (Cardial) and Late (Basien) Neolithic, a span of approximately 2000 years. At the same time, more than 90% of the Sardinian obsidian found at sites in southern France is of type SA (Tykot 2002a).

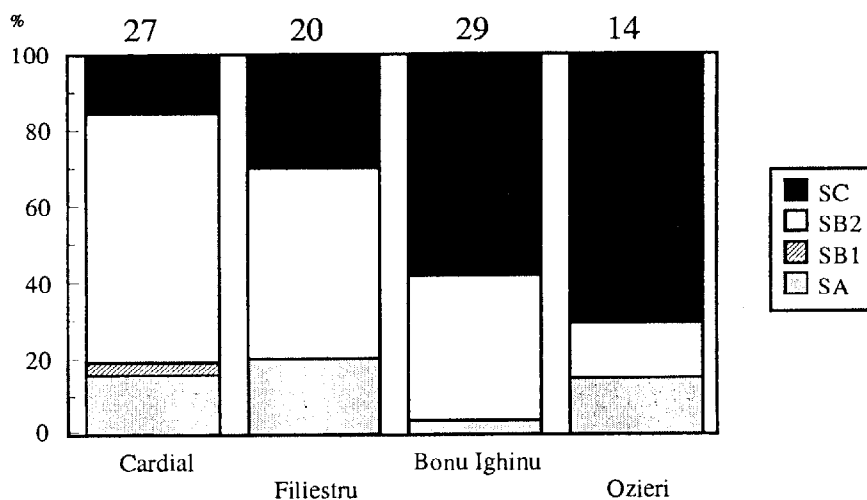


Figure 5.7. Changes in frequency of specific Sardinian obsidian sources at Filiestru Cave during the Neolithic period by phase.

These different obsidian use patterns—both geographic and chronological—imply that the cultural factors and exchange mechanisms involved in the *chaîne opératoire* of Mediterranean obsidian were complex. Obsidian may not have always been dispersed through simple down-the-line transactions from its respective source zones. It is also possible that maritime contacts between Sardinia

and the mainland were not necessarily routed across the shortest open-water crossings (from Sardinia to Corsica to Elba to Tuscany and then northward along the coast to Liguria and southern France). Differences in use-function, especially if considered in the context of more locally available alternative lithic resources, may correlate with obsidian selection and can be investigated through the integration of provenance determination and use-wear analysis (Hurcombe 1992a, 1992b).

Discussion and Conclusion

Many lessons can be learned from this example of obsidian provenance studies in the Mediterranean. First, complete characterization of all relevant geological sources should be conducted prior to the analysis of archaeological artifacts. In the western Mediterranean, analyses of artifacts continued for more than two decades before all of the sources were located *in situ*. While it is possible to go back and try to assign artifacts based on our current knowledge of the sources, many artifacts have not been analyzed for the particular elements or other characteristics necessary to distinguish among the sources. In other cases the compositional data that would allow reassignment were not published, and the artifacts themselves may have been entirely sacrificed for the analysis, or otherwise are now no longer available for reanalysis.

Second, elemental characterization and fission-track dating are the only methods that have been applied with any success and frequency to Mediterranean obsidian artifacts. A lot of effort has been expended testing a variety of alternative methods to see if they could distinguish among the Mediterranean sources. Other methods, however, have proven to be ineffective, inappropriate for obsidian sourcing because of sample requirements or expense, or just have not been pursued beyond an initial study. While the application of new techniques to archaeological materials should be encouraged, the involvement of both physical scientists and archaeologists at the beginning of the investigation would likely result in a more efficient use of time and resources. A systematic approach to sourcing is highly recommended (Glascok et al. 1998; Shackley 1998).

Third, artifacts from a large number of sites have been analyzed, but until recently the selection criteria were poorly conceived. Far too many obsidian artifacts come from unstratified or imprecisely dated contexts to have any real interpretive value, and with few exceptions too few from a single context have been analyzed to evaluate the relative frequency of the source(s) represented at a single site or in a single cultural phase. Greater effort should be expended on analyzing significant-sized assemblages from properly excavated contexts, and on using the results to address questions of archaeological interest (e.g. exchange mechanisms; transport routes; sociocultural interactions; island colonization; diffusion of technology; raw material selection and use-function). Parallel information could be derived from provenance studies of flint, greenstone and other lithic materials, as well as ceramics.

Fourth, methods must be chosen which are appropriate for archaeological artifacts, and for the particular questions being addressed. The information obtained should be maximized, while any impact on the artifacts should be minimized. Keeping costs down effectively results in the ability to analyze more artifacts and to obtain more reliable use patterns. Consultation or collaboration with geologists or archaeological scientists is recommended to determine which method(s) are most appropriate.

Lithic artifacts, as the most durable and visible traces of the past, will continue to be an important source of information about the societies that used them. Provenance studies, while providing direct information on the exploitation and use of raw materials from specific sources, will continue to contribute to an understanding of human behaviors at other points in the *chaîne opératoire*, especially when integrated with results from typological, technological, and use-wear studies.

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