10.1

Obsidian in Prehistory

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1 Introduction

According to the Natural History of Pliny the Elder [1], obsidian was a kind of glass found in Ethiopia by a Roman explorer named Obsius, a “stone very dark in color and sometimes translucent” but which “has a cloudier appearance than glass, so that when it is used for mirrors attached to walls it reflects shadows rather than images. Gems are frequently made of it.” At Pliny’s time, however, obsidian had already been long sought after as indicated, for instance, by its use for the pupils of Tutankhamun’s eyes in the funerary mask of the young pharaoh.

Obsidian is in fact a rather rare type of volcanic rock of little importance in the modern world, even to geologists (Chapter 7.2). It thus is infrequently listed in the indexes of geology reference volumes, even those specifically devoted to igneous rocks and their classification. Today, obsidian is used for some eye and heart surgical operations due to the slow healing rates of glass, and as a gemstone for jewelry and decorative objects where it may come from very far away: on the Italian island of Pantelleria, the geological-type location for Pantellerite, the irony is that a gift shop sells many items from Pachuca (Mexico)!

Of much greater significance is that obsidian was highly valued by prehistoric people in the form of lithic (flaked) materials that are among the most common artifacts in the archaeological record. They were the product of several distinct actions: acquisition of the raw material, preparation of a core for flaking, primary trimming, secondary trimming and shaping, use, maintenance or modification, and disposal. When flaked, obsidian produces extremely sharp cutting edges and is often superior to chert, flint, jasper, and other lithic materials for cutting materials such as animal flesh and nonwoody plants.

Obsidian use for stone tools dates back to nearly two million years ago at early hominin sites in Ethiopia where standardized tools were produced in the Lower Pleistocene Acheulean. Significant quantities of obsidian have been found at later archaeological sites hundreds of kilometers away from their geological source, even when alternate lithic materials were available at lesser distances. These findings indicate that obsidian was selected for use because of its particular physical and visual properties and that the exploitation of such a valuable rock was by the way probably the cause of the initial human settlement of islands such as Lipari or Pantelleria.

Obsidian is playing a particularly special role in archaeology for several reasons: (i) it can be easily identified as a nonlocal material; (ii) it is relatively easy to determine the specific source of archaeological specimens through chemical analysis; (iii) its hydration, which develops over time, can be used to date directly the production of tools; (iv) its broad spatial distribution provides a means for investigating the interaction of different social or cultural groups, and to speculate on the parallel movement of materials that are not as well preserved in the archaeological record; and (v) it gives us the opportunity to examine the chronological developments and the dynamic nature of its usage by prehistoric peoples, and the economic and social conditions under which this usage occurred.

Starting in the early 1960s, elemental analysis of obsidian artifacts has been successful in identifying their geological source [2]. Since then numerous such studies have been performed around the world, using many different methods of analysis, so that the principles behind obsidian analysis and sourcing are well established [3]. On the other hand, development of nondestructive and portable instruments has overcome the restrictions imposed on obsidian analyses by many museums and governmental agencies, greatly enhancing the number of artifacts analyzed [4, 5].
To review these various features, this chapter will first summarize the geological context of obsidian formation and the reasons for their compositional differences. The main uses of this material, its resulting wear, and the manner artifacts can be dated will then be described briefly. More importance will be given to chemical compositions, which may be used to identify the geological origin of obsidian artifacts. The complex pattern of these sources will be illustrated for Europe and particularly for the western Mediterranean. Some examples of the conclusions drawn from these studies for prehistoric trade and ancient socioeconomic systems will be presented.

2 Geological Formation, Properties, and Sources

Obsidian is a naturally occurring glass with silica contents of 65–80 mol % and relatively high alkali contents (8–10 mol % of Na₂O + K₂O). There are two varieties, termed calc-alkaline obsidian (with high SiO₂ and relatively high CaO contents), and peralkaline (if the alkali total exceeds the Al₂O₃ content, also lower SiO₂ and CaO), deriving both from parent rhyolitic magmas (Chapter 7.2). Especially, the more typical obsidian with 75–80 mol % SiO₂ are so strongly polymerized and viscous that they cannot always complete their ascent up to the Earth’s surface (Chapter 7.2). When they do so, instead of crystallizing as granite at shallow depths, their high viscosity then makes vitrification possible even for large blocks upon rather slow cooling.

That each obsidian source has its own chemical fingerprint in terms of minor and trace elements is the result of complex geological phenomena. First, SiO₂-poor buoyant magmas form at depths of at least 100 km by partial melting of mantle rocks whose elemental composition can vary from one place to another. Then, during their ascent to the surface, magmas undergo a long process termed magma differentiation through which they give rise to residual melts progressively enriched in SiO₂, alkali oxides, and some trace elements as a result of partial crystallization of dense, SiO₂-poor minerals such as olivines [(Mg,Fe)₂SiO₄] and pyroxenes [(Ca,Mg,Fe)₂SiO₄]. In addition, chemical and physical interactions with a variety of surrounding fluids and rocks take place during the slow ascent of the magma so that in the end, even obsidian from successive flows of the same volcano can have different chemical fingerprints.

But geological obsidian is not as homogeneous as modern human-made glass because it frequently includes crystals and bubbles. In the form of tiny particles, magnetite (Fe₃O₄) is, for instance, often the first crystal to form. Whether as isolated spherulites or as thick beds within the obsidian, crystals reduce the stone’s ability to be flaked into a tool, as does exposure to groundwater that causes over long periods of time the formation of a white, hydrated amorphous phase called perlite.

In regions with the appropriate geological and geochemical characteristics, nearly all sources of usable obsidian are thus less than 20 million years in age. They are found in many places along the mountain chains of western North America and the Andes of South America; in southeast Europe, Anatolia, and the Middle East; on several Mediterranean islands; in East Africa; in northeast Asia and Japan; and on islands of Southeast Asia, Oceania, and the Pacific (Figure 1). Whether the obsidian is in primary or secondary geological contexts, these sources vary considerably in the magnitude and extent of the obsidian flow and in the size and quality of the obsidian blocks that are accessible (Figure 2).

Elemental composition, crystallinity, and the redox state of transition elements affect the color and transparency of obsidian, which are important visual characteristics and factors in their selection for use. Most are gray-to-black, while some are green, brown, and tan. A few examples of red, blue, yellow, and orange are also known. Obsidian is commonly dark because of the presence of nanometric crystals of iron oxides whose varying stoichiometries yield a variety of gray/black or mahogany hues. Like that of thick window glass, the green hue of peralkaline obsidian is due to the presence of ferrous Fe²⁺ at high concentrations (cf. Chapter 6.2). But since there is movement of the Earth’s crust and cooling of the lava takes place under uncontrolled temperature and redox conditions, the microstructure of obsidian, and thus its color and transparency, can vary within a single volcanic complex.
3 Obsidian Use in Prehistory

As a glass, obsidian is very sharp and brittle, with a Mohs hardness of 5.0–5.5. This gives it both advantages (e.g. utility for cutting) and disadvantages (e.g. easy breakage) when compared with other stone material. First and foremost, it was used for stone tools, but also in some cases for jewelry or other decorative uses. Compared with other stones (flint/chert, quartzite, rhyolite, etc.), obsidian had significant cutting advantages, thanks to its glassy sharpness, especially for meat, hides, and other organic materials. Along with its visual distinctions, these characteristics often led to obsidian’s selection over other available raw materials and to its resulting transport over great distances.

Obsidian from mainland sources was utilized very early on, with procurement ranges of at least 100 km for Lower Paleolithic people in east Africa and Eurasia. Including those in Japan, island sources appear to have been first used in the Upper Paleolithic (ca. 40–10 kya). Obsidian sources in the Americas were utilized starting with its Pre-Clovis inhabitants (>13 kya). In the Mediterranean, all of the island obsidian sources were regularly in use from the Neolithic period.

**Figure 1** World map of obsidian sources utilized in ancient times. In the western Americas and eastern Asia, obsidians form in the geological context of compressive subduction zones by differentiation of andesite magmas. In other regions, they form from basaltic magmas in the extensive contexts of plate separation.
Figure 2 Balata dei Turchi (southern side of Pantelleria, Italy) primary obsidian flows (three arrows on left), with secondary deposits on slope in the lower right. Peralkaline obsidian, dark green, opaque.

Some geological sources are fairly recent, coming, for example, from the volcanic outcrops in Lipari formed about 8.5 kya ago [6], which were thus unavailable to the earlier residents of Sicily and peninsular Italy.

The discovery of obsidian artifacts has always been of importance to archaeologists, especially when there was no nearby geological source, as it indicates some kind of long-distance mobility or contact. The quantity or percentage of lithic artifacts made of obsidian, along with its visual, physical, and chemical properties may be highly informative about ancient societies and how/why they obtained the raw material, produced finished objects, how and why they were used, and in what contexts they were left behind. In addition, other materials likely were transported in parallel to the obsidian.
4 Obsidian Studies

4.1 Typo-Technology

Typological and technological studies of lithic finds are necessary for full socioeconomic interpretations of obsidian (and other stone tool) production and use. Starting with natural obsidian blocks, direct or indirect percussion may have been used for production of cores, often not far from the geological source, with the side effect of leaving behind large flakes and shatter (Figure 3). The cores may have been of specific types, for example, polyhedral blade cores, distributed over great distances to secondary production locations. The presence of smaller debitage and spent cores indicates such local production of tools. Certain tools were also retouched to enhance cutting properties. The production of stone tools requires some experience, as well as the intention to make specific types such as blades, scrapers, and arrowheads, which would have been mounted on wooden or bone handles.
Figure 3 Obsidian blocks (up to 40 cm in length), cores (up to 15 cm), blade (20 cm) and arrowheads (4–8 cm) from different parts of the Mediterranean.

4.2 Use-Wear Studies

Macroscopic and microscopic examination of wear patterns on obsidian may be done to determine their actual usage, adding significantly to their archaeological context and associated materials [7]. In general, these patterns differ depending on the hardness (soft, medium, and hard) and siliceousness (animal, vegetal, and inorganic) of the worked material. Use-wear fractures are recorded as being absent, or at a rate of occurrence with fractures classified as flakes (couchoidal fractures), snaps, or steps. The distribution of edge-wear fractures is recorded as random or regular, and light or heavy, and complements width and edge rounding by wear fracture. The most likely function of a tool is determined from the type of use-wear, its frequency, size, and distribution. Owing in part to variations in the physical properties of obsidian from different geological sources, along with the actual use methods employed, experimental studies have been conducted in different parts of the world. In particular, it has been shown that there are quantitative and qualitative differences in wear patterns between obsidian from different geological formations, which may have influenced selection when material from more than one source was accessible [8].

4.3 Dating Methods

Obsidian hydration has been used in many parts of the world as a method to determine the date at which a tool was made from the rate of diffusion of water onto a freshly exposed surface. With a methodological approach begun in the 1960s, the thickness of the hydration rim or band may be measured by high-powered microscopy of a thin section (ca. 30 μm thick) [9]. The problem is that the rate of rim growth is affected by temperature, humidity, and pressure, as well as by the specific geochemistry and physical properties of the obsidian. To produce accurate age estimates, the recommended calibration thus consists of depositing a “standard” of freshly flaked obsidian in the ground for one year at a depth similar to that of the archaeological stratum along with a measurement device to determine the effective hydration temperature (EHT). The implicit assumption made is of course that these underground conditions did not change markedly since the obsidian was buried.
Another dating approach relies on secondary-ion mass spectrometry for depth profiling the hydration rim by direct measurements of the H concentration. Equations for the diffusion process are still being developed, but this analytical method is nondestructive and has the additional advantages of incorporating the kinetics of the diffusion mechanism for water molecules and determining the saturation layer. Even more recently, infrared photoacoustic spectroscopy (IR-PAS) is being developed as an obsidian-dating method [10].

5 Provenance Analysis Methods

The characterization of obsidian begins with macroscopic observations and measurements of physical properties including color, transparency, density, and the presence of large crystals (phenocrysts). Whereas these features might have been important for obsidian users, they are often insufficient by themselves for reliably defining individual origins when multiple sources of obsidian exist in a particular region. One exception to this rule is the regional presence of a single peralkaline (green) obsidian source, for example, Pachuca in Central America and Pantelleria in the western Mediterranean. Another exception is found when there is a single source with large “snow flake” phenocrysts of cristobalite, for example, Giali in the Aegean. In some cases, microscopic analysis may differentiate sources from features such as crystal dimensions, frequency, and orientation patterns (streaks, linear, and random).

Whereas many methods of scientific analysis have been successful in distinguishing among sources in a particular region, the analysis of archaeological artifacts is often limited if the method is destructive or costly and if the artifacts must be taken outside a museum since museums and government agencies increasingly forbid destructive methods and limit analyses in external laboratories. Some countries do not allow artifacts to be sent beyond their borders, even if they do not have the analytical instrumentation needed.

The conservation and preservation of archaeological materials is actually of great long-term importance, in particular for obsidian put on display in museums, or involved in multiple studies including technology, typology, use-wear, and dating, as well as the large assemblages stored in warehouses. And even though the depth and quantity of obsidian artifact analyses has changed significantly since the first studies of the 1960s along with the development of many instrumental methods of analysis (Table 1), they vary considerably in different parts of the world because research funding for archaeology is generally limited relative to other disciplines.

A broad variety of analytical methods have nonetheless been successful in distinguishing geological obsidian sources from elemental or isotopic composition, geological dating, and magnetic properties. Within a single region, the volcanic events that produced obsidian may differ by hundreds of thousands or millions of years and be dated precisely by potassium-argon dating, which relies on the decay of $^{40}$K into $^{40}$Ar with a half-life of 1.25 x 10$^9$ years, or by the more sophisticated $^{40}$Ar–$^{39}$Ar technique. These methods, however, are not only expensive but also destructive so that they are rarely used on artifacts. Fission-track dating is another method that is based on the density of fossil damage tracks left within the atomic network of the artifact through atom bombardment by the alpha rays emitted when uranium isotopes decay radioactively. It has been used to some extent in determining formation ages, but the total number of artifacts tested is limited. Strontium isotopes ($^{87}/^{86}$) and magnetic properties (conferred by the permanent magnetization acquired by magnetite crystals upon cooling below their Curie temperature in the Earth’s magnetic field) also have been shown to be successful, but remain rarely used.
Table 1 List of analytical sourcing methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Measurements</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dating</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argon–Argon (Ar–Ar) or Potassium–Argon (K–Ar) dating</td>
<td>Yes</td>
<td>Date of formation</td>
<td></td>
</tr>
<tr>
<td>Fission-track (FT) dating</td>
<td>Yes</td>
<td>Date of formation</td>
<td></td>
</tr>
<tr>
<td><strong>Isotopes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal ionization mass spectrometry (TIMS)</td>
<td>Yes</td>
<td>Sr isotope ratios</td>
<td></td>
</tr>
<tr>
<td><strong>Magnetic properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Susceptibility and magnetometer instruments</td>
<td>No</td>
<td>Magnetic susceptibility, remanent magnetization</td>
<td>Need outcrop database</td>
</tr>
<tr>
<td><strong>Elemental</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atomic absorption spectroscopy (AAS)</td>
<td>Yes</td>
<td>Major/trace elements</td>
<td></td>
</tr>
<tr>
<td>Electron probe microanalysis (EPMA) (quadrupole)</td>
<td>Maybe&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Major/minor elements</td>
<td>Surface analysis</td>
</tr>
<tr>
<td>ICP mass spectrometry (ICP-MS)</td>
<td>Yes</td>
<td>Major/trace elements</td>
<td></td>
</tr>
<tr>
<td>With laser ablation (LA-ICP-MS)</td>
<td>Maybe&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Major/trace elements</td>
<td>Surface analysis</td>
</tr>
<tr>
<td>ICP atomic/optical emission spectroscopy (ICP-AES, ICP-OES)</td>
<td>Yes</td>
<td>Major/trace elements</td>
<td></td>
</tr>
<tr>
<td>Instrumental neutron activation analysis (INAA)</td>
<td>Yes</td>
<td>Trace elements</td>
<td>Few major elements</td>
</tr>
<tr>
<td>Optical emission spectroscopy (OES)</td>
<td>Yes</td>
<td>Major/trace elements</td>
<td>Few major elements</td>
</tr>
<tr>
<td>Proton-induced X-ray/Gamma ray emission (PIXE/PICME)</td>
<td>Maybe&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Major/trace elements</td>
<td>Surface analysis</td>
</tr>
<tr>
<td>Scanning electron microscopy (SEM-EDS)</td>
<td>Maybe&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Major/minor elements</td>
<td>Surface analysis</td>
</tr>
<tr>
<td>X-ray fluorescence (XRF) (energy dispersive)</td>
<td>Maybe&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Major/trace elements</td>
<td>Surface analysis</td>
</tr>
<tr>
<td>Portable (or handheld) X-ray fluorescence (pXRF)</td>
<td>No</td>
<td>Major/trace elements</td>
<td>Surface analysis</td>
</tr>
</tbody>
</table>

<sup>a</sup> A sample must be taken for solution, powder, or to fit within a chamber (depending on the size).

The compositional homogeneity of a given obsidian source, coupled with significant differences between different flows, has resulted in highly successful differentiation from certain elements, either major (i.e. with oxide abundances higher than 1 mol %) or in trace at lower contents. Referring to Chapter 5.1 for a review of these analytical methods, we, for instance, note that since the 1970s both X-ray fluorescence (XRF) and neutron activation analysis (INAA) have been widely used in obsidian studies. Inductively coupled plasma mass spectrometry (ICP-MS) methods were added in the 1990s (first archaeological use of ICP-MS presented by the author at a conference in 1991); and portable (including handheld) XRF in the 2000s (Figure 4).

Notwithstanding potential limitations regarding transport and destructivity, the analytical method selected for archaeological projects is often based on availability in local institutional facilities and on the cost involved. Nevertheless, obsidian sources can often be separated from simple X–Y or multivariate graphs of selected elements. For example, in both Mesoamerica and in the Aegean/Central Anatolia, scatter plots with just Sr, Rb, and Zr clearly separate the existing groups [11, 12].
Figure 4. An obsidian sample sitting on a portable XRF instrument for the desktop nondestructive analysis of trace elements. The four most intense fluorescence bands shown on the computer screen are those of Fe (K$_{\alpha1}$), Rb (K$_{\alpha}$), Y (K$_{\alpha}$), and Zr (K$_{\alpha}$).
6 The Issue of Obsidian Sources: The European Region

For Europe, obsidian sources are limited to the Carpathian Basin (Slovakia, Tokaj Mountains of northeastern Hungary, and southwestern Ukraine); the Italian islands of Lipari, Palmarola, Pantelleria, and Sardinia; and the Greek Aegean islands of Melos, Giali, and Antiparos. The nearest other sources are in central and eastern Anatolia and the Caucasus, and on Tenerife in the Canary Islands.

For the central Mediterranean obsidian sources, there is considerable variation in color, transparency, and other visual characteristics, which may allow assignment of artifacts to a specific island, depending on the location and time period. Whereas Pantelleria obsidian is the only green (peralkaline) source, chemical analysis is still necessary to distinguish among the multiple subsources utilized there whose products were transported then to Sicily, Malta, and Tunisia. Lipari obsidian exists in both a highly glassy and transparent form (scale 4–5 out of 5) and in a mostly opaque form (scale 0–1) with numerous plagioclase feldspar [(Ca$_{2-x}$Na$_1-x$)Al$_1+x$Si$_3-y$O$_8$] phenocrysts. In Sardinia, the situation is more complex because of the existence of several Monte Arci subsources with a variety of features [13]. The transparent SB2 (4–5 out of 5) is similar to type SA, and even to Lipari obsidian. SC sources are opaque and can be distinguished from type SA, which is transparent (4 out of 5), but not from SB1. Obsidian from Lipari and from these three Monte Arci subsources have been found at Neolithic sites in peninsular Italy, requiring scientific analysis for positive identification. In later periods (Copper and Bronze Ages), the SB1 and SB2 subsources appear not to have been used very much at all, so that a reasonable estimate of the percentage SA vs. SC may be made visually, albeit with some caution.

Elemental analysis, however, is highly successful in confidently distinguishing all Mediterranean sources and subsources (Figure 5) so that, starting in the 1990s, it has been widely used on large numbers of artifacts. Trace elements such as Nb, Rb, Sr, and Zr will separate all of the sources, as well as five subsources (different flows from the same volcanic complex) each for Sardinia [13] and Pantelleria [14], three each for Lipari [15] and Palmarola [16], and two for Melos [12]. The major elements Si, Al, K, Na, and Ca also can distinguish all of the Mediterranean sources, and some subsources (Figure 6).

The analysis of statistically significant numbers of obsidian artifacts and their assignment to the specific subsources utilized in former times is important in many cases, as these distributions relate to potential differences in the availability, quantity, quality, and features of the raw material. The relative importance of these sources may have changed over time at individual archaeological sites, whereas it also may vary between sites and even within sites based on the context (e.g. residential locations, ritual areas, and burials) [17]. Scientific analysis also is necessary to identify confidently “outliers,” for example, the finding of a few pieces of obsidian from Melos in the Adriatic, or from Sardinia in southern Italy, which have important significance in our understanding of long-distance contacts and trade not only of obsidian but likely other materials as well [18].

7 Obsidian Artifacts Studied in the Western Mediterranean

In the western Mediterranean, extensive studies have been done on obsidian sources and subsources, and on a large number of artifacts. This work includes a geological survey and characterization of the visual, physical, and chemical properties of the Monte Arci obsidian flows on Sardinia [13]. Elemental analysis of geological samples by INAA actually distinguished nine different subsources: SA, SB1a, SB1b, SB1c, SB2, SC1, SC2, and two others of unworkable size [19]. Conducting 200 analyses using ICP-MS in the early 1990s showed this method equally successful. However, given the tiny amount of SB1 obsidian having been used in the past, and the lack of visual/physical/geographic differences between SC1 and SC2, it was deemed unnecessary to distinguish these subgroups when addressing archaeological hypotheses of usage. Since the SA, SB1, SB2, and SC subsources could be distinguished in electron-microprobe analyses with wavelength-dispersive spectrometers, this minimally destructive and relatively low-cost method was used on 800 Neolithic and
Bronze Age period (ca. 6000–1000 BCE) obsidian artifacts. The averaged results obtained on the 30-μm spots analyzed showed that the three main subsources (SA, SB2, and SC) were widely used in the Early Neolithic period, and that by the Late Neolithic, SB2 was no longer in use while SC dominated most assemblages [17] (Figure 7). This pattern was confirmed by later studies at a large number of different sites in Sardinia and Corsica. Detailed geological survey was also conducted on the other Italian island obsidian sources (Lipari, Palmarola, and Pantelleria). Extensive chemical analyses of geological samples by INAA, LA-ICP-MS, and XRF revealed three subgroups each for Lipari [15] and Palmarola [16], while confirming five subgroups for Pantelleria. Laser ablation ICP-MS was chosen for the analysis of several hundred obsidian artifacts from Pantelleria, Corsica, and mainland Italy sites, due to it being minimally destructive on these small artifacts. The results expanded our understanding of the chronological change in Monte Arci subsource usage, along with Lipari and Palmarola obsidian in mainland Italy. Research on obsidian in the western Mediterranean continues in southern France, Corsica, and mainland Italy.

Figure 5 Trace element graph distinguishing Mediterranean obsidian sources.
Figure 6 Multiple flows (subsources) may be distinguished on the islands of (a) Sardinia (Monte Arci) and (b) Melos.
Since 2007, a portable handheld XRF spectrometer has been used instead, mostly conducting the analyses within museums or government storage facilities in Sardinia, Sicily, Malta, different parts of mainland Italy, and in Croatia (Figure 6). The portability, nondestructive nature, and relatively lower cost of this instrument has allowed the analysis of over 10,000 obsidian artifacts so far, identifying some surprising patterns of usage, as well as unexpected outliers [5, 18].

Figure 7 Bar chart showing source frequencies for Early Neolithic (a) and Late Neolithic (b) sites in the western Mediterranean.
One major surprise is the pattern of Lipari and Pantelleria obsidian use on the two main islands of Malta. At the mostly residential site of Skorba on Malta, 79% of the obsidian is from Lipari, and 21% from Pantelleria, whereas at the ritual and burial site of the Brochtorff Circle on Gozo, 72% are from Pantelleria and only 28% from Lipari. This major reversal is likely related to the specific purpose and usage of the obsidian at these two sites. Furthermore, the Pantelleria obsidian came from multiple subsources, while all of the Lipari obsidian was just from the Gabellootto subsourse. Some obsidian artifacts from the Canneto Dentro subsourse have been identified, however, at sites in Sicily [5].

8 Obsidian Trade and Socioeconomic Systems

The ability to identify specific geological outcrops from which obsidian was utilized in prehistoric times, and to conduct analyses on large numbers of artifacts, has allowed archaeologists to test hypotheses about trade, transport (terrestrial and maritime), and about the socioeconomic systems involved and their changes over time. In this millennium, studies have been flourishing as a means to address broader archaeological research questions devoted, for instance, to procurement methods and spatial distribution, contact between different cultural groups, obsidian as a marker of cultural identity, and inferences about the movement of people and other materials [20].

![Figure 8](Image) Sites with 10 or more artifacts tested (circles by the author, squares by others, triangles by both).
Notable changes have occurred over time, which include access to island sources during the Holocene, development of territorial control and specialist production in later times, and symbolic and ritual use in some complex ancient and historical societies. One study, on Epi-paleolithic and Early Neolithic obsidian at the site of Kortik in southeast Anatolia, shows heterogeneity on the local and regional scale in raw material selection from different sources and the technology used in this part of the Fertile Crescent [21], whereas another on the Bronze Age in the same region suggests that obsidian cores and preforms, rather than finished tools, were distributed to local specialists for production of blades [22]. Similar social network issues have been addressed for sites in prehistoric Peru, most likely related to the development of more complex exchange systems by the Nasca, where economic models based on the proximity of obsidian sources have considered elevation and river location changes over time [23]. As for Mesoamerica, changes over the Preclassic, Classic, and Post-Classic Maya period resulted in a highly commercialized economy that does not conform with presumptions often made about preindustrial systems [24]. Archaeological sites are still being discovered and excavated, not just in developing countries in Africa, the Near East, East Asia, and Latin America, but even in settled areas of Europe. One example is the Middle Neolithic site of Terres Longues, at Trets, near Marseilles and the Mediterranean coast, where more than 4500 obsidian artifacts were recently excavated. This accounts for 90% of all obsidian artifacts found so far in France, combining discoveries of obsidian at more than 60 other prehistoric sites [25]. The study of such a large assemblage reinforces the previous evidence that Sardinian type A obsidian dominated this region, while the much higher percentage of obsidian in the lithic assemblage at Terres Longues suggests it might have been a redistribution center.

9 Conclusions and Closing Perspectives

Obsidian has long been an important raw material because its glass-like physical properties made it distributed far away from its geological sources until the advent of metals caused its various advantages to fade away. Scientific analyses have been developed for identifying the origins of individual artifacts and studying their use. More and more studies are multidisciplinary, and integrate the scientific analyses with the archaeological contexts, chronology, lithic typology, and usage studies. But while extensive research has been done in some parts of the world, there remain many areas where the geological sources have not been fully identified and thoroughly studied, and/or large numbers of obsidian artifacts have not yet been analyzed. Doing so for significant-sized lithic assemblages can lead to a fundamental understanding of ancient technological, economic, and cultural practices and how they changed over time.

The International Association for Obsidian Studies (IAOS: http://members.peak.org/~obsidian) is a professional organization, and international obsidian conferences have been held in Greece, Japan, Italy, and Hungary. Public interest in obsidian has increased, with a major museum and center for obsidian studies established in Japan (www.meiji.ac.jp/cip/english/institute/obsidian.html) and one in Italy (www.museossidiana.it), along with many museum exhibits that include obsidian artifacts.

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Note

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