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# Non-Destructive pXRF on Prehistoric Obsidian Artifacts from the Central Mediterranean

**Robert H. Tykot**

Department of Anthropology, University of South Florida, Tampa, FL 33620, USA; rtykot@usf.edu;
Tel.: +1-813-974-7279

**Featured Application: The use of non-destructive, portable XRF instruments has expanded tremendously the elemental analyses of archaeological materials. This has revolutionized the data now available for our understanding of obsidian trade, maritime capabilities, and socioeconomic systems in the prehistoric central Mediterranean.**

**Abstract:** Volcanic obsidian was widely used in ancient times for stone tools, with its highly glassy nature making it sharper than other lithics for cutting purposes. In Europe and the Mediterranean, there are just several island sources, and a few in one inland region, all having been used since the beginning of the Neolithic period, ca. 6000 BCE. Maritime transport was necessary for access to the Italian and Greek island sources, with the distribution of artifacts over distances up to 1000 km. While elemental analyses were used for identifying specific sources starting in the 1960s, the development of non-destructive and especially portable X-ray fluorescence spectrometers has revolutionized the number of artifacts tested since 2010, allowing statistically significant numbers for potential comparisons based on variables including time period, open-water distance, visual and physical properties, and cultural contexts. One overall accomplishment is the documentation of long-distance travel routes in the Tyrrhenian and Adriatic Seas of the central Mediterranean, based on the distribution proportions and quantity of obsidian artifacts from different geological sources, apparently following a down-the-line prehistoric exchange system. The spread of Palmarola obsidian is much greater than previously thought, while in Malta, Pantelleria obsidian was specifically selected for burial accompaniments on Gozo.

**Keywords:** obsidian; sourcing; trade and exchange; pXRF; trace elements; Italy; central Mediterranean; Neolithic; prehistory

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## 1. Introduction

Volcanic obsidian was widely used in ancient times for stone tools, with its highly glassy nature making it sharper than other lithics for cutting purposes. In Europe and the Mediterranean, there are just several island sources in Italy and Greece, and a few in the inland Carpathian region, all having been used by the beginning of the Neolithic period, ca. 6000 BCE. Maritime transport was necessary for access to the island sources, while other materials would have been moved in opposite directions. Obsidian was likely a small part of this exchange system. The location and geological studies for each of the sources goes back to the early 20th century, while the ability to chemically identify specific sources began in the 1960s. The development of non-destructive and especially portable X-ray fluorescence spectrometers has revolutionized the number of artifacts tested since 2010, providing new interpretations of obsidian selection and use, which changed over time.

## 2. History of Obsidian

The modern word "obsidian" comes from the name of a Roman explorer, Obsius, who saw extensive geological quantities in Ethiopia [1], although obsidian sources on Italian islands, including Lipari and Sardinia and on the Greek island of Melos, had been used for thousands of years and were already well known from their wide usage.

Obsidian is an igneous glassy rock, formed during volcanic eruptions during the past 20 million years, which fractures conchoidally. It is typically an extrusive rock formed along the edges of viscous lava flows, in a volcanic dome, or when it cools while airborne. Some sources are intrusive, formed at the edges of dikes or sills. Obsidian may be found in many parts of the world, but only in certain geological regions where the magma composition was rhyolitic (or in some cases basaltic). Overall, the production of insufficient sizes to make stone tools (at least a few centimeters), the presence of gas vesicles trapped during formation (e.g., pumice), or the breakdown over time of unstable glass with phenocryst or spherulite crystalline formations limit the number of sources used in antiquity to certain mountainous terrestrial areas and volcanically formed islands (Figure 1).

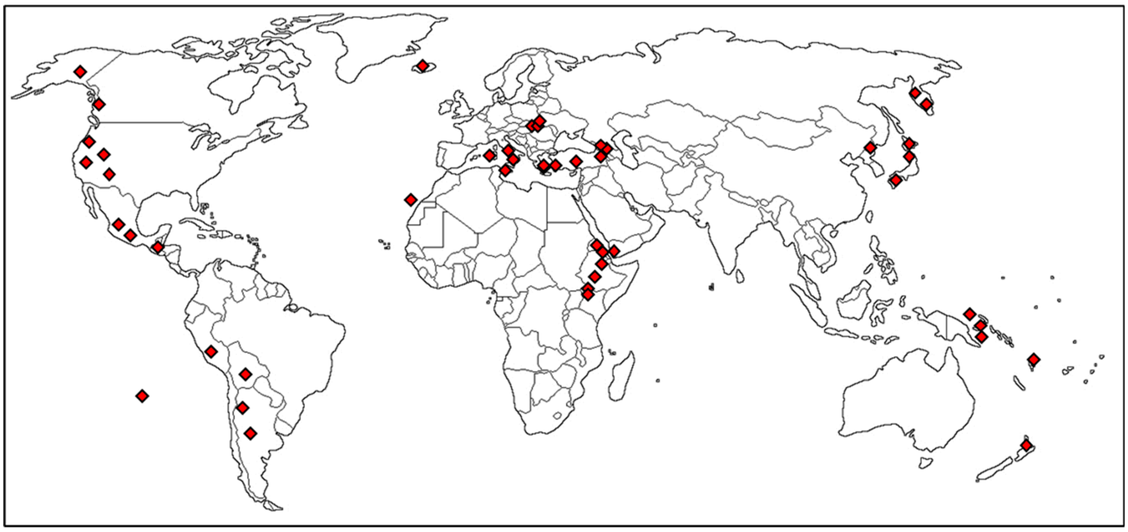

**Figure 1.** Map showing many of the obsidian source locations used in antiquity.

Obsidian was widely used for cutting and scraping tools during the Old and New Stone Ages, starting in the Lower Paleolithic by early *Homo* (ca. 1.75 million years ago) and continuing until recently in some parts of the world [2]. Due to its higher level of sharpness, compared to chert (flint), quartzite, and other stone tool material, it was intentionally acquired, flaked to produce broken edges, transported, and traded over distances of 1000 km or more within the central Mediterranean [3]. The preparation of cores was generally done near the geological source, with blades and other tools produced by trained lithic workers at many of the distant archaeological sites (Figure 2). Findings of obsidian artifacts at mainland sites in Greece and Italy, from island geological sources in the Mediterranean, infers the development of maritime travel by the late Upper Paleolithic [4] of at least simple crafts, to more complex vessels by the Early Bronze Age (3rd millennium BCE); the earliest remains found in the Mediterranean of open-water boats (or drawings) are only more recent. Obsidian is still used today for surgical procedures (including eye and heart), due to its greater sharpness and faster healing process, compared to stainless steel scalpels (just search online for a commercial scalpel vendor). Obsidian was also used for polished mirror surfaces, and for jewelry in certain cultures even today.

**Figure 2.** Example of Neolithic obsidian blade tools from Sicily. Scale in centimeters. Most stone tools would have been mounted on wood or bone handles (rarely preserved).

In addition to the size of natural obsidian blocks, and the quantity produced in a geological source area, the visual characteristics of obsidian were important, especially when there was a variety in color, luster, transparency, and the presence of phenocrysts. Most obsidian is in the black-to-gray color range, but there are some sources with brown, tan, red, orange, yellow, or blue, often mixed with black, caused by some inclusions in the magma or by trace elements. The orientation of any patterns may be indicative of the geological formation process (e.g., lava flow).

The ability to identify the geological origin of obsidian artifacts found at archaeological sites allows the reconstruction of cultural interaction and trade patterns, including the likely movement of other materials (e.g., pottery, domesticated animals, clothing, food products) as well.

## 3. Analytical Methods

The chemical analysis of obsidian to look at trace elements began in the early 1960s with the use of optical emission spectrometry, with simple X-Y graphs, such as barium vs. zirconium, distinguishing many sources in the Mediterranean and Near East [5]. By the mid-1970s, additional methods, including X-ray fluorescence (XRF) spectrometry and instrumental neutron activation analysis (INAA), were able to produce even more distinctive results by using many trace elements with excellent precision [6,7]. In addition, fission-track dating was also used, discriminating the limited numbers of obsidian sources by differences in their formation ages [8]. During the 1980s, major and minor elements were also shown to be successful in distinguishing obsidian sources, using atomic absorption spectroscopy (AAS) [9] and scanning electron microscopy with an energy-dispersive spectrometer (SEM-EDS) [10]. The homogeneity in the composition of molten lava, and the rapid formation of glassy obsidian, have led to significant differences between sources in composition for many major and trace elements. This allows a choice of simple X-Y graphs of a few elements to distinguish source groups.

Despite the development of these many methods of successful analyses by the 1980s, little detailed research had been done on the geological obsidian sources from an archaeological perspective, particularly that discriminating between multiple subsources of usable obsidian within each island. The total number of central Mediterranean obsidian artifacts that had been analyzed in the 1960s and 1970s was less than 200, and by the end of the 1980s, this had reached only about 500 total (see table IX, pp. 66–68 in [11]). Many of those artifacts tested had come from museum collections dating back to the late 19th and early 20th centuries, not having archaeological contexts or chronology. Even by 1995, the total analyzed was fewer than 900, with only 26 sites having 10 or more artifact analyses and allowing statistical comparisons (Table 1). Nevertheless, a lot had been learned about obsidian trade by that time [12].

**Table 1.** Analyses of obsidian artifacts in the central Mediterranean.

| *Years* | *≥10 Per Site* | *≥25 Per Site* | *Analyses* | *% Total* |
|---|---|---|---|---|
| 1964–1994 | 26 | 7 | 884 | 5% |
| 1995–2010 | 97 | 33 | 3217 | 19% |
| 2011–2021 | 158 | 108 | 12,895 | 76% |
| Total | 281 | 148 | 16,996 | 100% |

In the 1990s, however, the introduction of inductively coupled plasma (ICP), optical emission spectrometry (OES), and mass spectrometry (MS), often with laser ablation (LA), allowed the minimally destructive analysis of artifacts and increased the numbers tested [11,13–15]. XRF also developed further, with some instruments allowing minimally destructive (or even non-destructive) analyses. The use of mounted microsamples of 1–2 mm wide solid pieces of obsidian, with as many as 16 samples on a single 1-inch disk, was developed for electron probe microanalysis (EPMA) for this reason [11,13]. Similar analyses were conducted using a scanning electron microscope (SEM-EDS) on obsidian artifacts [16]. Overall, the use of automated analyses also reduced costs, which are always a limiting factor for archaeological studies. By 2010, more than 3000 obsidian artifacts in the central Mediterranean had been analyzed [13].

Starting in this millennium, the creation of desktop, non-destructive XRF analysis instruments [17–19], and especially portable XRF spectrometers, has revolutionized the analysis of obsidian in many parts of the world [20–26]. The homogeneity of obsidian and its high resistance to weathering are part of the success of non-destructive surface analyses. The pXRF may simply be placed adjacent to the cleaned object in the field, running on batteries and using a built-in computer, or within museums or other facilities (Figure 3). The main reasons for initial commercial production of pXRFs was for businesses and agencies with applications such as field testing of soils near factories; however, its utility for analyzing art and archaeology objects represented an academic market, too. After about 2005, commercially produced hand-held portable XRF (pXRF) instruments were available from several companies. Their small size makes them transportable in a backpack and as carry-on luggage on planes.

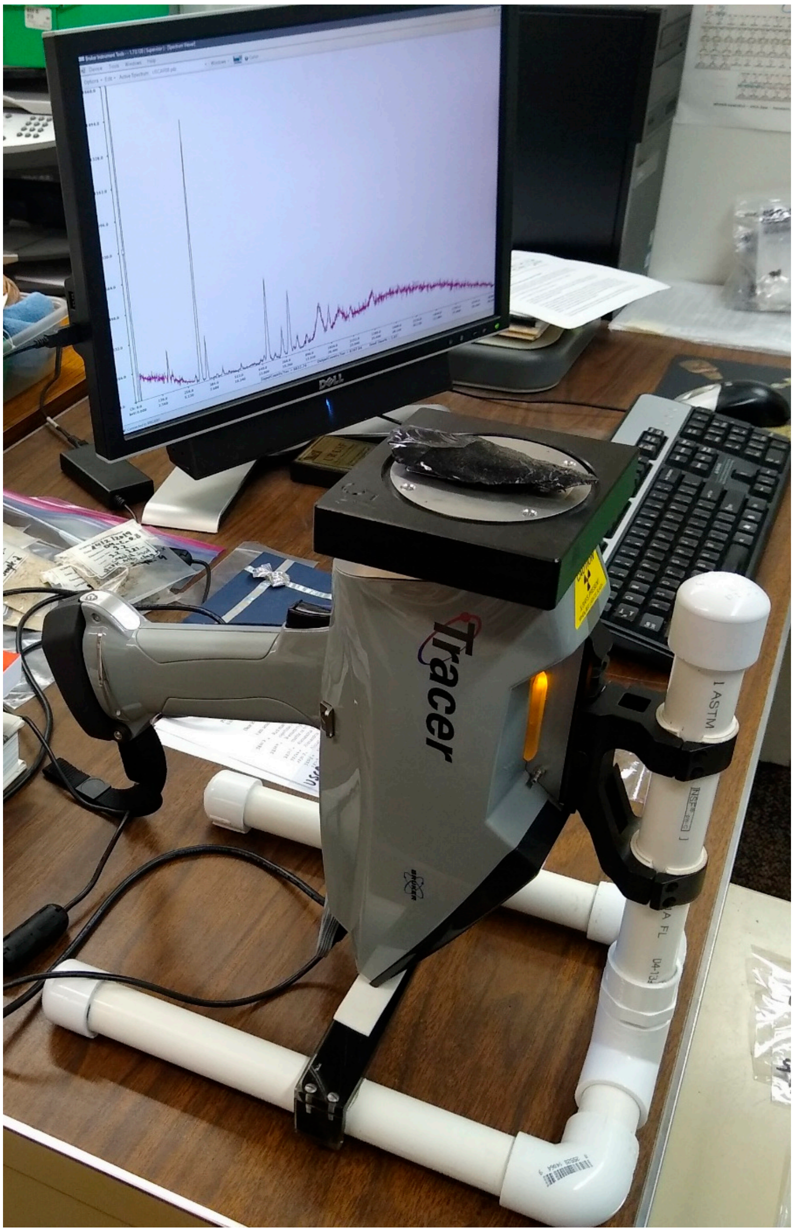


**Figure 3.** Most recent pXRF instrument (Bruker Tracer V*g*) used in these studies. Mounted upright using a home-made plastic stand.

In traditional XRF instruments, samples are placed within a vacuum chamber so that secondary X-rays are not absorbed prior to reaching the detector. However, a vacuum is not necessary for quantitative measurements of elements above potassium, so that obsidian objects need not be contained in a vacuum chamber for measurement of K-shell electron replacements of elements from Ca to La. For hand-held XRF instruments, 50 kV is the highest energy setting for primary X-rays, thus limiting K-line energy measurements of only a few elements in periodic table row 6. For pXRF analyses, elements specifically used for obsidian source identification include major elements Ca, Ti, Mn, Fe, and trace elements, including Rb, Sr, Y, Zr, and Nb (Figure 4). The use of a filter (12 mil Al, 1 mil Ti, 6 mil Cu) reduces the background for these elements, with detection limits for trace elements in single digit ppm [27,28].

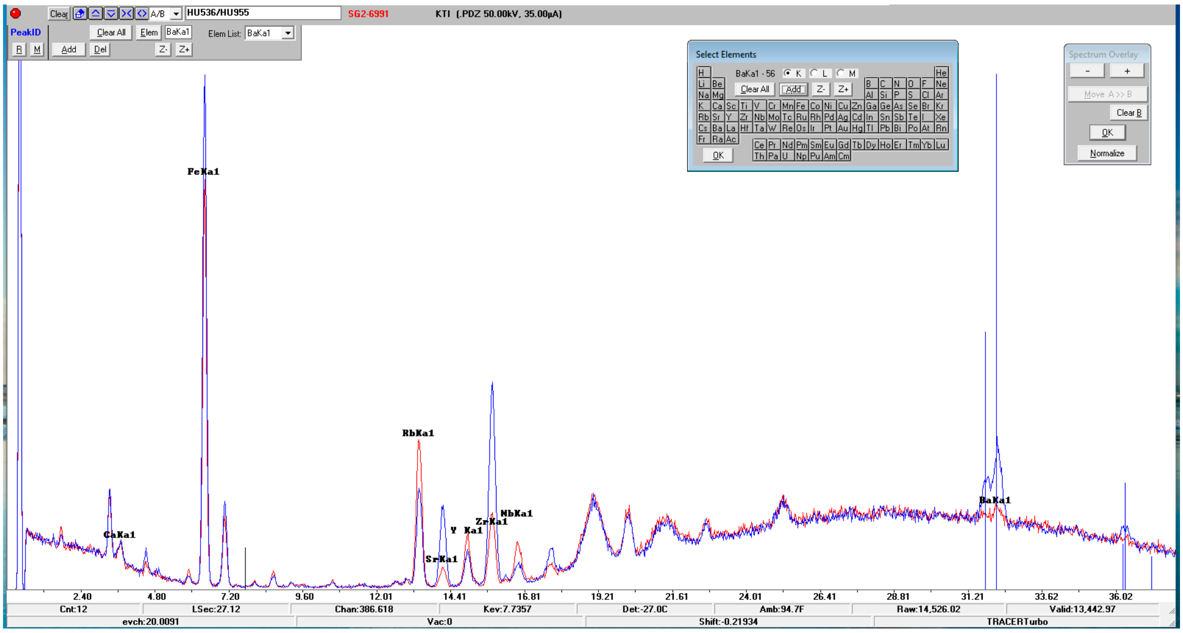


**Figure 4.** K-line energy peaks for two obsidian samples. In blue is from Monte Arci (Sardinia) SC; note the high strontium, zirconium, and barium peaks when compared to SA (in red). The blue lines represent the multiple peaks for barium.

As with all XRF instruments, the specific energy peaks for different elements, especially the L-lines for elements in period table rows 6 and 7 (e.g., Cs, Ba, La, Ce, Nd, Th, U) overlap with the K-lines for lower Z elements, thus limiting precision for those trace elements with similar energy levels to major elements (e.g., Fe and below) when significantly present. Other elements, such as those used for compositional analysis of metals and other materials (Ti, Cr, Fe, Co, Ni, Cu, Zn, As, Pd, Ag, Cd, Sn, Sb, Pt, Au, Hg, and Pb), may also be detected, and other filters used to minimize background effects [29].

In most cases, the highly precise measurements of the K-lines of just a few of these trace elements is sufficient to distinguish obsidian sources in any part of the world, while multi-variate statistics of 5–7 trace elements may be used for identifying pottery production groups [27]. The beam size of the X-rays is typically about 5–8 mm in diameter, with some having options for smaller beams reaching the sample. The length of time necessary for analysis has decreased with newer pXRF models, which use silicon drift (SDD) rather than silicon PIN (Si-PIN) detectors; with the first Bruker Tracer model used in 2007–2012 (III-V+), each spot for trace element analysis was run for 180 s; for 2013–2016 (III-SD), 60–90 s; and for 2017 to the present (V*i*, V*g*), just 30 s. Running for longer times does not go beyond limitations of the detector and increase the precision or sensitivity limits. For homogenous obsidian, one analysis per artifact was sufficient and only in a few cases were reruns needed to confirm the results and source assignment. In some of those cases, the samples were of irregular shape, or were small bladelets just a few mm in width and fewer in thickness, with lower than usual total counts. Incorrect source assignment is avoided in such cases by using trace element ratios.

Museums and government agencies in many countries are open to international collaboration and access to their archaeological collections, with analytical research facilitated when done without necessary permissions for destructive sampling, and movement (of intact artifacts or samples) to laboratories, even within the same country. The portability, easy operation, and low maintenance for hand-held XRFs also enabled many archaeologists to conduct analyses themselves, without depending on a geoscientist or laboratory staff to prepare and run their samples. The homogeneity of obsidian, the relatively flat areas on stone tools that may be tested, and little if any surface weathering make it a perfect material for non-destructive X-ray fluorescence analysis.

For a number of years, however, there were concerns raised about the integrity of analyses being conducted and, in particular, the production of data with actual concentration values [23,30]. How do we deal without calibrated quantitative results for major elements silicon (typically 65–75% for $SiO_2$ in obsidian), aluminum, sodium, potassium, and magnesium? How do we deal with matrix effects on secondary X-rays? What standard reference materials may be used for inter-laboratory comparisons? These issues were mostly for archaeology users who needed to compare their analytical data for artifacts with those of other scholars' analyses of geological source samples in their geographic region. Obsidian calibration software was developed and shared, however, by 2008 for the Bruker pXRF instruments, based on 40 geological obsidian samples analyzed by INAA, LA-ICP-MS, and XRF [22,31]. Separately, pXRF users who analyzed sufficient geological samples of known origin could also make a direct comparison of the uncalibrated raw data with that from the archaeological samples that they analyzed with the same instrument. Nevertheless, the use of calibrated data is expected for publications in many journals. For archaeological obsidian artifact studies, nearly all research is conducted by scholars with geological samples from their region of interest.

## 4. Obsidian Sourcing in Europe and the Mediterranean

There are four obsidian sources in the Central Mediterranean, from volcanic formations on the Italian islands of Sardinia [11,13,32–35], Palmarola [36], Lipari [37,38], and Pantelleria [3,39–42] (Figure 5). People with agriculture lived on both Sardinia and Lipari from the start of the Early Neolithic (ca. 6000 BCE), with the use of obsidian for stone tools starting at the same time. No one settled on the tiny island of Palmarola, while it appears that Pantelleria was not occupied until about 3000 BCE [43]. There is also Melos in the Aegean with two subsources [44], and one Carpathian source that was used, in southeastern Slovakia [45,46]. Geological surveys and analytical research were conducted on each, assessing the quantity and quality of obsidian from multiple outcrops and the ability to distinguish between these sources. For the four Italian islands, analyses were conducted by the author, using INAA, LA-ICP-MS, and EDS-XRF, defining multiple subsources for each island, which is important for the study of archaeological artifacts and our interpretation of prehistoric access and collection of obsidian [2,3,35,47].

Non-destructive analyses by pXRF of obsidian artifacts are also able to distinguish Monte Arci (Sardinia) subsources (Sardinia A, Sardinia B1, Sardinia B2, Sardinia C), as well as for Lipari (Gabellotto, Canneto Dentro, Monte Guardia) and Pantelleria (Lago di Venere 1 and 2, Balata dei Turchi) (Figures 6–9). At least with the elements currently measured and calibrated, we cannot distinguish the three Balata dei Turchi subgroups, nor the three subsources on Palmarola. Given the circumstances in which obsidian would have been obtained on these two islands during the Neolithic period, in particular by visitors rather than residents, these distinctions are not considered important.


**Figure 5.** Map showing obsidian sources in Europe and the Mediterranean.

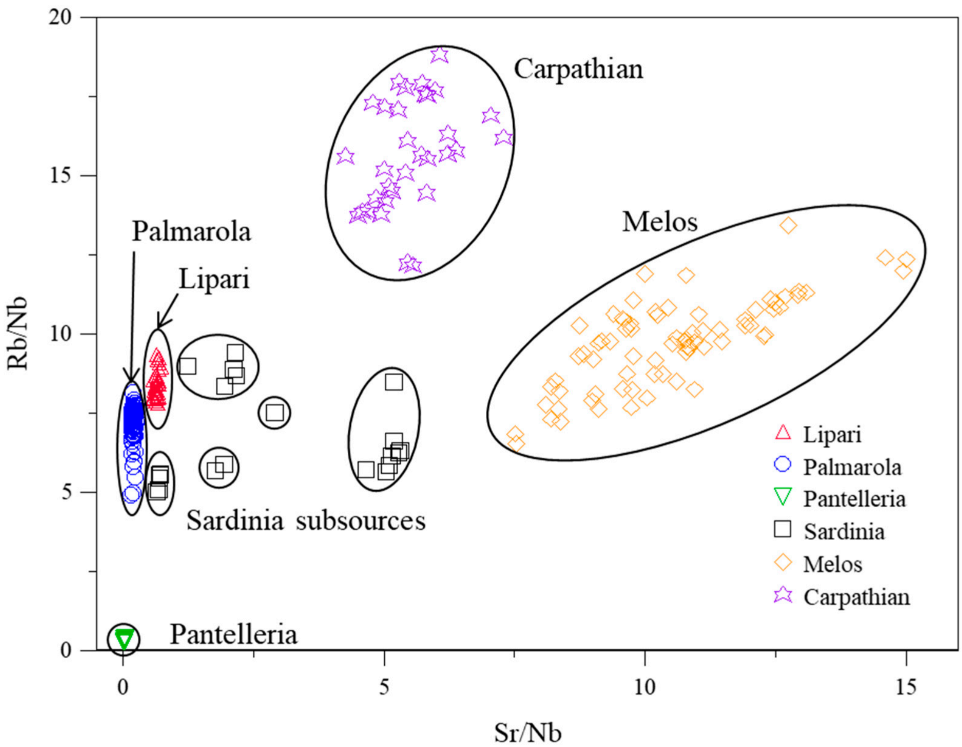


**Figure 6.** Distinguishing European obsidian sources with selected trace elements. Not all geological samples tested are shown.

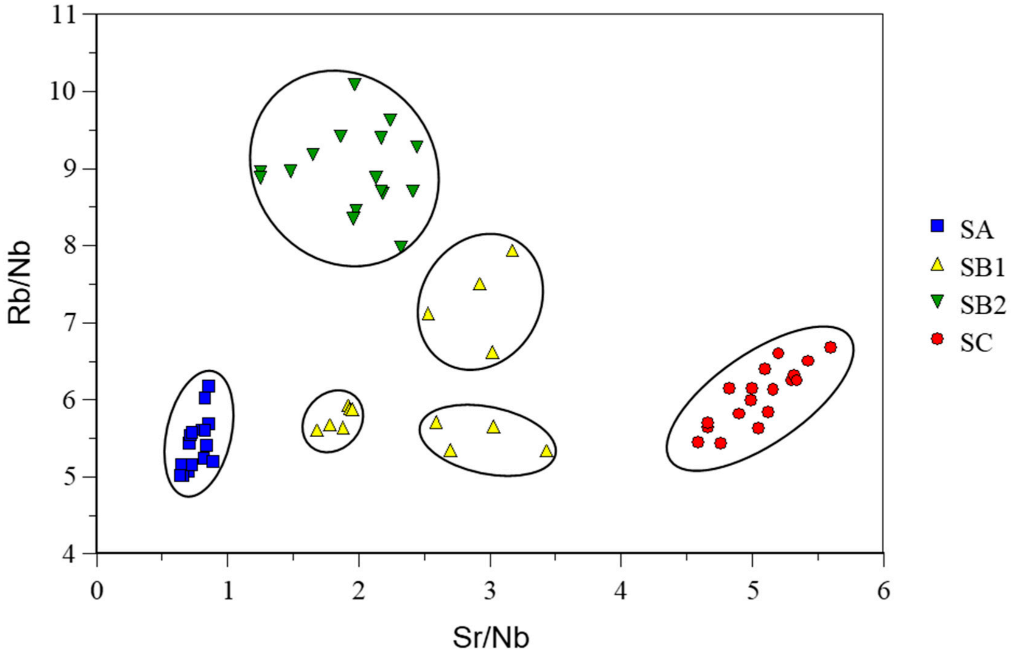


**Figure 7.** Separation of multiple subsources for Monte Arci (Sardinia) using a selection of geological samples collected by the author.

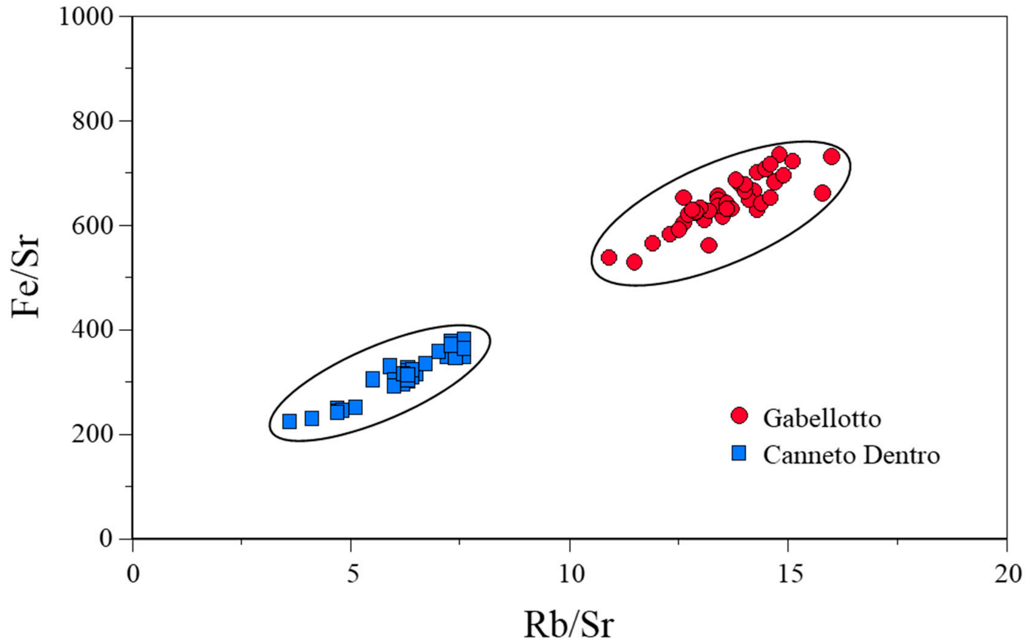


**Figure 8.** Two prehistoric Lipari obsidian groups used for tools, using geological samples collected by the author.

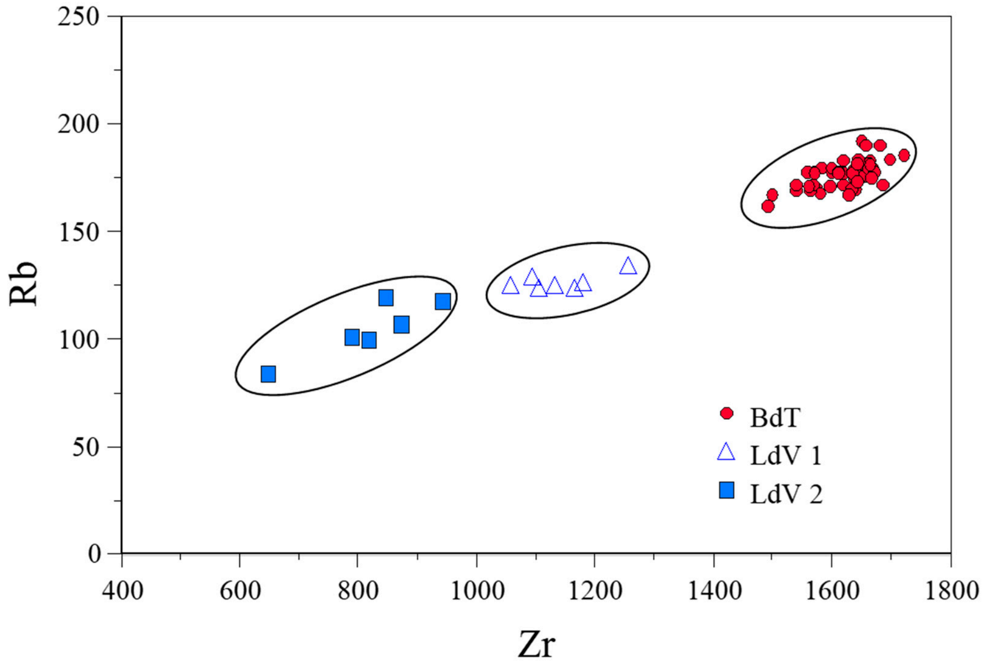


**Figure 9.** Pantelleria is separated by Balata dei Turchi (BdT), and both Lago di Venere (LdV) 1 and 2.

## 5. Applications of pXRF on Obsidian Artifacts from Central Mediterranean Sites

With a non-destructive pXRF, the author expanded his research on obsidian, from a focus on Sardinia and Corsica [13,33,42,48–50] to throughout Italy as well as to Malta and Croatia [3,51–54]. In the past ten years, more than 12,000 artifacts have been analyzed, with $\geq$ 25 from each of the > 100 archaeological sites (Figure 10).

### *5.1. Sardinian Obsidian in Continental Italy*

The transportation and trade of obsidian from Monte Arci in Sardinia to Corsica and beyond was realized in the early study by Hallam et al. [7], which identified it at several sites in Southern France and Northern Italy. Since then, Monte Arci obsidian has been identified at many sites in Northern Italy, which also is a great distance from the other central Mediterranean sources, with changes over time in proportion to Lipari obsidian [55,56]. In addition, social network analysis supports hypotheses of different obsidian pathways, including open-water north-bound from Corsica to Southern France [57]. With the very large number of non-destructive analyses conducted in this millennium, we now see that Sardinian obsidian also reached central Italy as a significant percentage of assemblages and made its way to southernmost Italy and even Sicily in very small numbers, supporting an interpretation of a down-the-line type exchange during the Neolithic [3]. A total of just 23 artifacts of Sardinian obsidian (out of nearly 1300 obsidian artifacts analyzed) were identified at sites south of Rome, indicating that travel routes were not directly across the Tyrrhenian, but from Sardinia to Corsica, then through the Tuscan archipelago and southward, on or along the Italian peninsula (Figure 11). Undoubtedly, other materials were exchanged and traveled in opposite directions, including domesticated animals (sheep, goat, cattle, pig), produce (from wheat, barley, other plants), clothing, tools, wood, etc. [58].

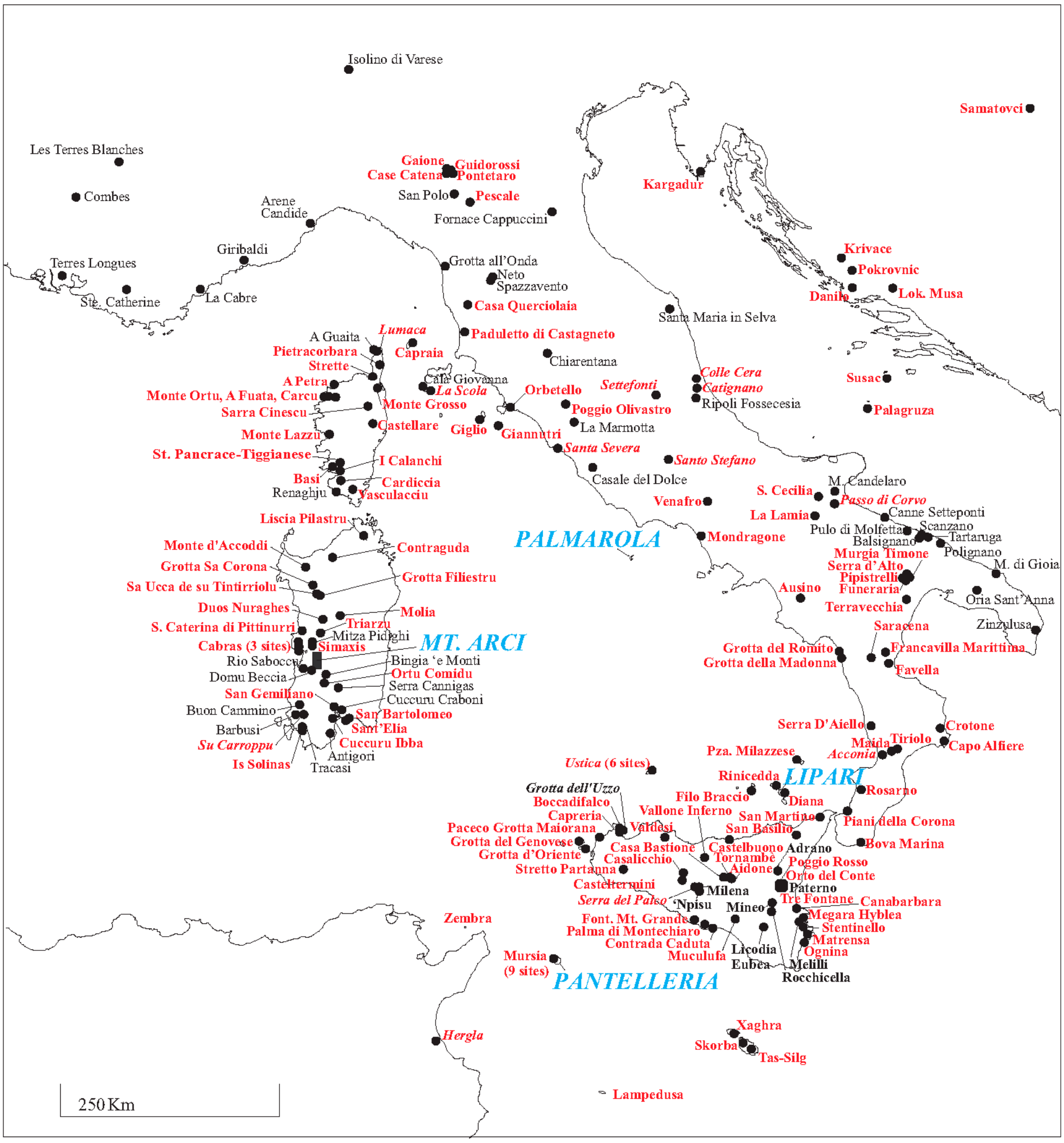


**Figure 10.** Map of central Mediterranean showing archaeological sites with ≥10 source analyses of obsidian artifacts. Sites in red analyzed by the author.

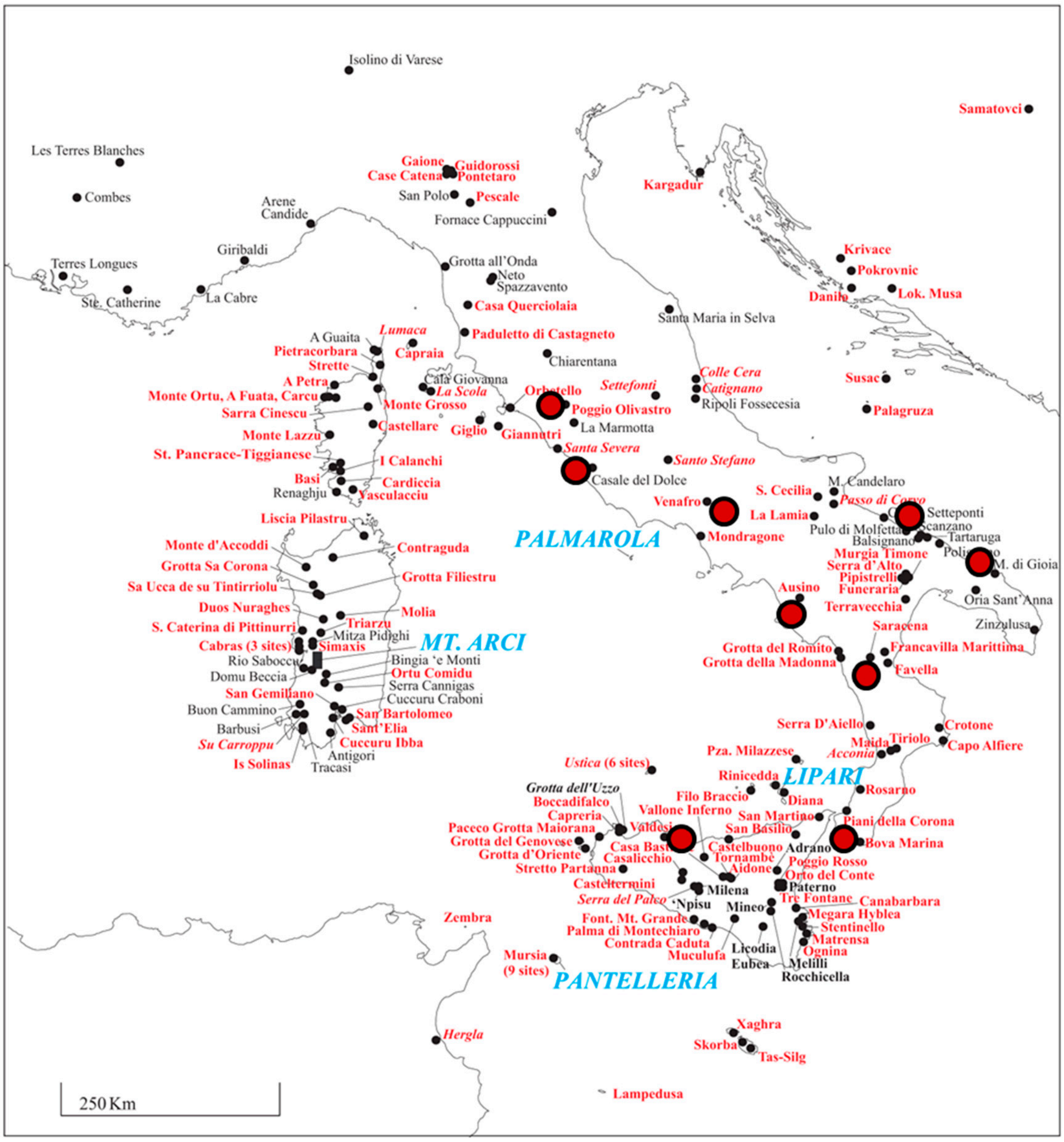


**Figure 11.** Map with sites in southern Italy with Sardinia obsidian artifacts. From north to south, in red circles: Poggio Olivastro 20/100 (20%); Casale del Dolce 1/35 (3%); Venafro 1/132 (<1%); Pulo di Molfetta 1/37 (2.7%); M. Di Gioia 12/12 (100%); Ausino 3/21 (14%); Saracena 4/842 (<1%); Bova Marina 1/200 (<1%); Valdesi 1/41 (2.5%).

### *5.2. Obsidian Artifacts from Sites around the Adriatic and in Croatia*

Prior to its political breakup, no obsidian artifacts found in Yugoslavia had been analyzed. Since then, however, a significant amount of archaeological research was conducted in Croatia, with obsidian found at many prehistoric sites along the Dalmatian coast, on islands in the Adriatic Sea, and as far north as Istria. At first, the results of analyses by pXRF, which showed that most were from Lipari, with very little reaching there over land from the Carpathian sources, were not expected [53,59]. In addition, the presence of some from Palmarola, on the island of Sušac and on the mainland at Lok. Musa, was surprising considering our previous thoughts of it having limited distribution [47] (Figure 12). Obsidian from Palmarola, however, was identified at three Neolithic sites along the Italian coast as well as at sites in the Tavoliere and near the Gargano Peninsula from where travel by island hopping over the Adriatic likely occurred [47,53,60]. Entirely unexpected was the identification of four obsidian artifacts on the island of Palagruža coming from Melos

(Sta Nychia subsource) since no others have been securely identified in prehistoric contexts west of Albania [59,61]. The Palagruža site, however, dates to the Copper Age, when increasing social and economic complexity began in the Aegean.


**Figure 12.** Map with directions to archaeological sites with Palmarola obsidian artifact attributions, including across the Adriatic.

### *5.3. The Small Island of Ustica, Northwest of Sicily*

Ustica is a small island, about 8 $km^2$, located > 50 km north of Capo Gallo (coast north of Palermo in western Sicily). Despite its isolated location, there is archaeological evidence of its occupation also beginning in the Neolithic time period, indicating the rather long-distance open-water travel capabilities at that time. The use of obsidian artifacts, coming from both Pantelleria and Lipari, was first shown with analyses of artifacts from excavations of a Bronze Age site [62], and more recently at several different sites with more than 1100 obsidian artifacts found and analyzed [51,63–65] (Figure 13). In comparison to travel of much more modest distances from northern Corsica through the Tuscan archipelago to mainland Italy, and across the central Adriatic to Croatia, Ustica was not a stop along the way to other places but instead the only reason for travel in its direction.

As noted already, there is no direct or indirect evidence of the boats, rafts, or other open-water vessels that were used in the 6th millennium BCE to reach islands in the Mediterranean (or in the following 4000 years), but it strongly appears that such travel was regular and able to transport not only a few people but also domesticated animals and other items of their material culture. Obsidian from Lipari, in the Aeolian Islands, may have been transported over 25 km to northeastern Sicily, then along the shorelines to Palermo and from there to Ustica, but the proportions of Lipari to Pantelleria obsidian (average of 90% Lipari, 10% Pantelleria), when compared to what was found at the site of Grotta dell'Uzzo in northwest Sicily, suggest more direct open-water travel of >100 km from the westernmost Aeolian island of Alicudi to Ustica [65]. This is supported by the open-water distance from Pantelleria to southwest Sicily (~100 km), followed by travel along the western coast and then > 50 from Capo Gallo to Ustica. The small but seemingly consistent percentage of obsidian from Pantelleria reflects not only the much greater distance of travel, but also its visual and physical properties and their demand when compared with Lipari obsidian.

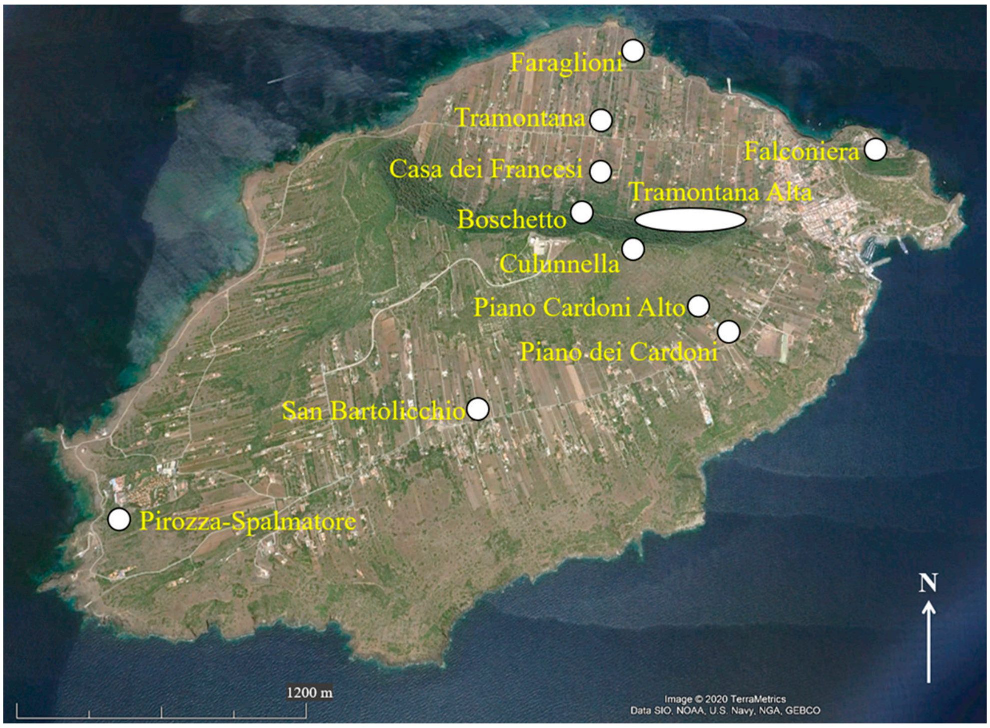


**Figure 13.** Archaeological sites on Ustica (north of Palermo, Sicily). The ellipse for Tramontana Alta is the sloped pathway along which surface artifacts were collected.

### *5.4. Obsidian at Sites in Malta*

The Maltese Islands are about the same distance south of Sicily as Pantelleria, while they were occupied from the Neolithic, and, like elsewhere, were using obsidian from both Lipari and Pantelleria [3,66]. Three different sites were excavated: Skorba, occupied throughout the Neolithic, and Tas-Silj, which is Bronze Age, both on Malta; and the Brochtorff Circle at Xaghra, on the smaller island of Gozo, which is Copper Age (Figure 14).

Skorba has a combination of residential and ritual structures, with seven phases spanning from ca. 5500–2500 BCE (Ghar Dalam, Grey Skorba, Red Skorba, Zebbug, Ggantija, Saflieni, and Tarxien) and each with obsidian present [67]. Following the excavation, visual distinctions of the nearly 300 obsidian artifacts found were initially used to assign nearly 80% to Lipari (black-grey) and 20% to Pantelleria (dark green), and a selection of 25 were analyzed by INAA to confirm this [7]. More recent analyses by pXRF confirmed the visual assignments while also indicating that those from Pantelleria mostly came from Balata dei Turchi with a small number from Lago di Venere, and that all of the Lipari obsidian came specifically from Gabellotto. The proportion of Lipari to Pantelleria for each time period was consistent, and quite similar to that for the sites on Ustica.

Much more recent excavations at the Brochtoff Circle at Xaghra revealed a large number of underground, individual chamber tombs dating to the 3rd millennium BCE [68]. More than 100 obsidian artifacts were analyzed by pXRF, with the results being very different than at the site of Skorba, overall. Only 28% were from Lipari and 72% from Pantelleria, while at Skorba, none of the small number (8) of obsidian artifacts from the contemporary Tarxien phase came from Pantelleria. Again, all of the Lipari obsidian was from the Gabellotto subsource, while the Pantelleria artifacts came from multiple subsources on Pantelleria, mostly Balata dei Turchi. Since the many tomb chambers, representing about 700 individuals, were not of the same time period but spanned many families over at least a few hundred years, the high selection of Pantelleria obsidian was not a single incident, but an extended cultural burial practice.

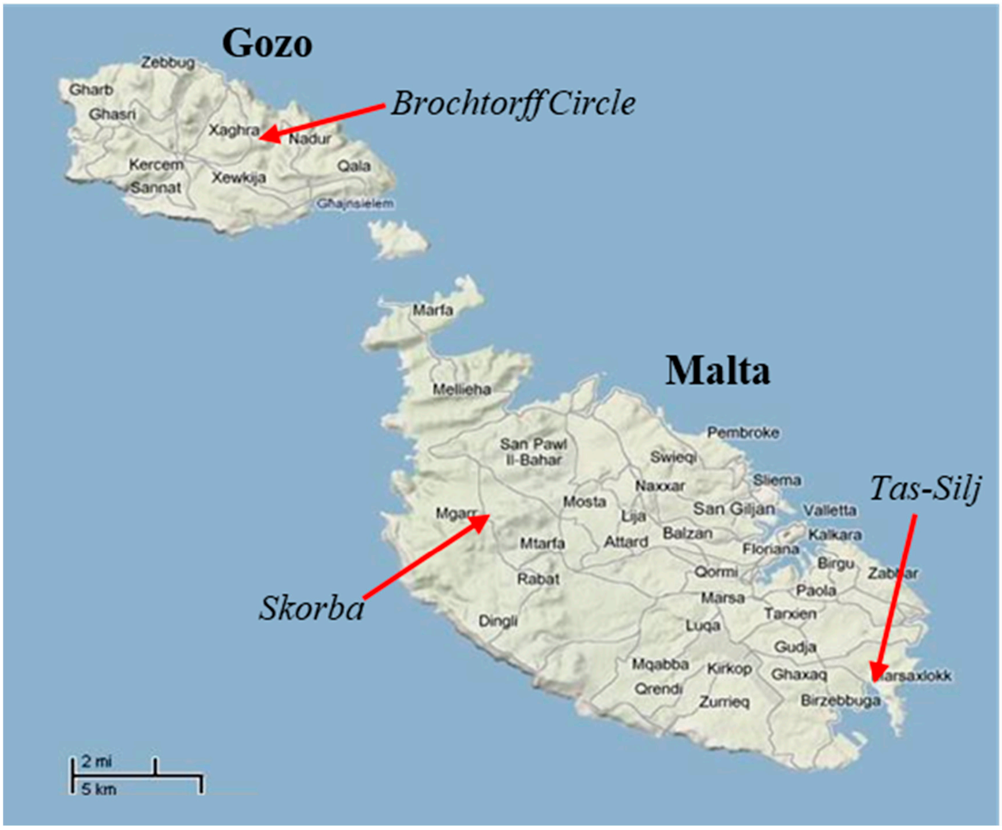


**Figure 14.** Malta island sites with obsidian artifacts.

## 6. Discussion and Conclusions

These four examples of obsidian studies in the central Mediterranean illustrate the importance of analyzing large numbers of artifacts, allowing statistically significant numbers for comparisons based on variables, including time period, open-water distance, visual and physical properties, and cultural contexts. One overall accomplishment is the documentation of long-distance travel routes, based on the distribution proportions and quantity of obsidian artifacts from the different geological sources (Figure 15). This involved minimizing open-water travel when possible, while demonstrating multiple steps and the likely multiple transactions during the Neolithic, prior to the development of both complex societies and technological advancements in the Bronze Age, leading also to the decreased long-distance distribution of obsidian. In general, there was a major long-distance distribution to the north and northwest, which began with the spread of agriculture and domesticated animals in the Early Neolithic and continued through the end of the Late Neolithic (ca. 6000–3000 BCE) [2,3,37].

Over the last decade, more than 75% of the elemental analyses of obsidian were accomplished with the development of non-destructive XRF instruments, especially those that are hand-held and easily portable, which have enabled low-cost and rapid analyses of archaeological artifacts within museums and storage facilities. This has changed the status of our research on obsidian, as described in the recent past [14]. Many other methods have shown to be quite successful in distinguishing geological sources, and there are still experimental studies continuing with a variety of analytical methods, including Cl and Na proportions, geological formation age, and magnetic properties. Most important, however, is still the need for further studies of excavated obsidian artifacts, for different time periods and geographic locations, and integration with studies of lithic typology, the technology used for the production of stone tools, microscope-based use-wear patterns, and other parts of the *chaîne opératoire*.


**Figure 15.** Obsidian distribution directions in the central Mediterranean.

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**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Elemental data for individual artifacts is published or in course of publication. Requests may be sent to the author.

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**Conflicts of Interest:** The author declares no conflict of interest.

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