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New Approaches to the Characterization of Obsidian from the Mediterranean Island Sources: Interpreting Chronological Change in Neolithic Sardinia and Corsica

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ABSTRACT

Geochemical fingerprinting of obsidian sources was first applied in the Mediterranean region nearly four decades ago. Since then, a number of analytical methods (e.g. INAA, XRF, SEM/Microprobe, ICP-MS) have proven successful in distinguishing the Mediterranean island sources of Giali, Lipari, Melos, Palmarola, Pantelleria, and Sardinia. Moreover, recent geoarchaeological surveys of the central Mediterranean sources have resulted in the more precise location and documentation of each obsidian flow or outcrop, and multiple chemical groups have been identified on at least three of the islands. The ability to specifically attribute artifacts to one of at least five obsidian flows in the Monte Arci region of Sardinia, for example, has enabled the study of specific patterns of source exploitation and the trade mechanisms which resulted in the distribution of obsidian hundreds of kilometers away during the Neolithic period (ca. 6000-3000 BC).

Results are presented here from the chemical analysis of 186 artifacts from several sites in Sardinia and Corsica as part of the largest and most comprehensive study of obsidian sources and trade in the Mediterranean. Analyses of large numbers of artifacts demonstrate the differential use of island subsources, which may be attributed to factors such as access (e.g. topography, distance from coast), size and frequency of nodules, and mechanical and visual properties. The patterns of source exploitation revealed by this study specifically support a down-the-line model of obsidian trade during the neolithic period. In addition, the spatial and chronological patterns of obsidian distribution may be used to address such issues as the colonization of the islands; the introduction of neolithic economies; and the increasing social complexity of neolithic and bronze age societies in the central Mediterranean.

INTRODUCTION

Obsidian sources in the western Mediterranean exist only on the islands of Lipari, Palmarola, Pantelleria, and Sardinia, while obsidian artifacts are found at Neolithic archaeological sites throughout Italy, in southern France, along the Adriatic coast of Yugoslavia, and in Sicily, Malta, and North Africa (Figure 1). Archaeologists use the concept of "trade" to explain the presence of non-local artifacts, and attempt to reconstruct the behaviors responsible for obsidian procurement, transport, production, use and disposal, and the social and political circumstances in which these activities transpired [1]. The determination of the geological provenance of an obsidian artifact establishes both end points of the *chaîne opératoire* (operational sequence), while study of distribution patterns and integration with typological, technological, and use-wear analyses may identify specific intermediate activities (Figure 2). In conjunction with studies of ceramics, flint, and ground stone tools, our understanding of raw material use and long-distance trade may be applied to interpretations of early island settlement,

Figure 1. Central Mediterranean obsidian sources and Neolithic archaeological sites with ten or more analyzed obsidian artifacts.

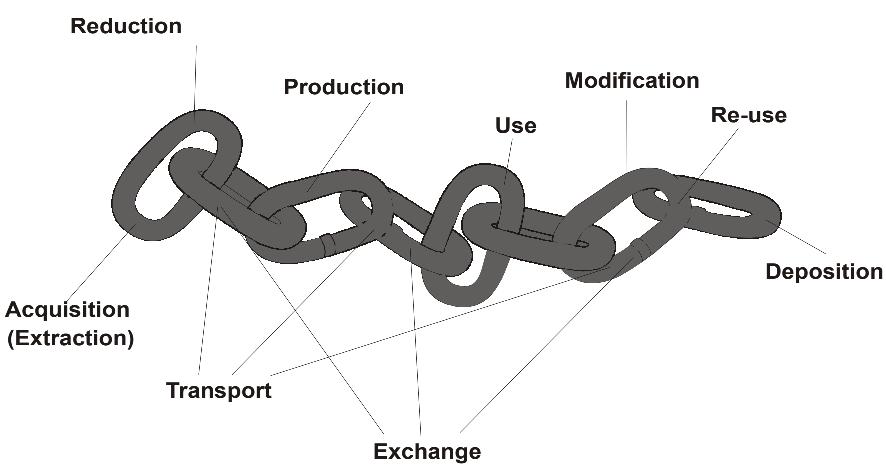

Figure 2. The chain of events that may be represented by obsidian artifacts found at archaeological sites.

the establishment of an agricultural way of life, division of labor and craft specialization, and the emergence of increasingly complex societies.

Obsidian provenance studies in the Mediterranean and Near East have a long history [2-4], but until recently the field investigation, detailed documentation, characterization analysis and publication of all of the obsidian sources was incomplete [5-6]. Significantly, the obsidian from each island has been treated by most archaeologists as deriving from a single source when in fact it occurs as multiple primary outcrops and secondary deposits. Furthermore, until a decade ago, very few provenience studies resulted in the analysis of ten or more obsidian artifacts from dated contexts at a single archaeological site [7-11], preventing the comparison of source exploitation patterns in a statistically meaningful way [12].

Early analyses of artifacts made of Sardinian obsidian suggested that multiple, chemically differentiable sources or flows exist on at least that island [3], and field and laboratory research by several teams has now resulted in the location and characterization of as many as nine chemically distinct obsidian source localities in the Monte Arci region, of which at least five were exploited in antiquity [6, 13-17]. Five chemical source groups have also been identified for Pantelleria [18]; obsidian occurs in two separate localities on Palmarola [19]; and multiple outcrops exist on Lipari as well [20]. A comprehensive geoarchaeological and geochemical investigation of these three islands has recently been undertaken by this author, and will result in a comprehensive detailed database for all central Mediterranean obsidian sources. This is critically necessary to support the emphasis of recent obsidian studies on using non- or minimally destructive techniques to analyze large numbers of artifacts or even entire assemblages from good archaeological contexts, and to attribute them to specific flows and outcrops [5, 21]. By doing so, it is possible to demonstrate real temporal and spatial patterns in source exploitation, and to postulate explanations for different patterns in terms of accessibility, quantity, quality, and appearance of the raw material, as well as social, political and/or technological variables which may control the timing and frequency of access, lithic reduction techniques, transportation routes and mechanisms, and ultimately the function of obsidian artifacts in particular regions and time periods.

The obsidian sources on all four islands are described here in some detail, and as a case study illustrating the value of this high resolution approach to obsidian sourcing, data are presented from the analysis of 186 artifacts from Neolithic sites in Sardinia and Corsica. These results are then discussed in their geoarchaeological context, and preliminary interpretations offered to explain the observed patterns and variations in source exploitation.

OBSIDIAN SOURCES

<u>Pantelleria</u>

Pantelleria, a small pear-shaped island of about 8 x 13 km, lies about 120 km south of Sicily and about 90 km east of Cap Bon, Tunisia. To reach Pantelleria requires significantly greater open-water travel than any other Mediterranean obsidian source, but this apparently was not an obstacle as Pantellerian obsidian is abundantly found at archaeological sites in Sicily beginning in the Early Neolithic period [10, 22]. Pantelleria is exceptional among the Mediterranean island obsidian sources in that its volcanic activity is not related to tectonic plate boundaries or island arc volcanism, and it is the type locality for peralkaline rocks, in particular its Na- and Fe-rich greenish opaque obsidian known as Pantellerite [23]. Pantellerian obsidian is thus often readily differentiable from the other central Mediterranean sources on a visual basis. Some recent geostratigraphic investigations have resolved some of the island's formational history [24-26], but have left many questions concerning obsidian sources and their exploitation unanswered. Most scholars have treated Balata dei Turchi as the only, or at least principal, source of obsidian on Pantelleria even though fission-track dates on archaeological artifacts have a range of nearly 100,000 years, suggesting the use of multiple source flows.

More recently, Francaviglia [18] used XRF to identify five chemical source groups on Pantelleria based on the combined statistical analysis of geological and archaeological samples, although only his Balata dei Turchi groups were defined by geological specimens. It is certain that obsidian from at least two source localities on Pantelleria did make its way to Sicily at sites such as Grotta dell'Uzzo [10], and to the small island of Ustica [27]. An intensive survey of the Pantellerian sources in 2000-2001 was successful in locating three vertically distinct obsidian flows at both Balata dei Turchi and at Salta La Vecchia, apparently representing different eruptive cycles. *In situ* material was also recovered near Lago di Venere, but no primary obsidian of workable quality was identified near Gelkhamar, postulated by Francaviglia to be the fifth source on Pantelleria. Two extensive workshop areas were also located near Balata dei Turchi. Dating and chemical analyses now in progress should resolve any questions about which sources on Pantelleria were exploited in antiquity.

Lipari

Lipari is the largest of the Aeolian Islands at ca. 38 km^2 and is located just 30 km north of the northeastern part of Sicily. Although obsidian from Lipari has been found widely distributed at archaeological sites throughout Italy and as far away as southern France and Algeria, a detailed systematic geochemical study of all the prehistoric geological sources themselves has never been completed, in part because much of the island has been covered by more recently produced pumice deposits and obsidian flows. Buchner [28] was the first to notice that some prehistoric archaeological sites were covered by the Forgia Vecchia and Rocche Rosse flows, which were therefore too recent to have been used during the Neolithic. Later field studies by Pichler [20] and others placed the Gabellotto flow between 4800 and 13,000 BP based on radiocarbon dating of its stratigraphic context. Fission-track dates on 66 artifacts of Lipari obsidian from archaeological sites in Italy [29] include only one determination older than 12,500 BP, seemingly supporting the hypothesis that the Gabellotto obsidian may have been the primary source used in antiquity. Only four fission-track dates (all from 20-30,000 BP) have been published, however, for geological samples of obsidian from the Acquacalda and Monte della Guardia sources on Lipari, leaving open the possibility that other sources of similar age to Gabellotto may have been available for prehistoric exploitation.

Detailed examination of prehistoric artifact assemblages has revealed at least two visual types of Lipari obsidian, one black and highly transparent, the other gray-banded, often with many spherulites present, suggesting that different obsidian outcrops might have different chemical fingerprints that would be useful for interpretation of prehistoric exploitation practices. In 2000-2001, a survey of all of the accessible prehistoric (and historic) obsidian outcrops on Lipari was conducted, and over 1000 samples were obtained from primary geological deposits, from within pumice layers, and along the coastline where erosion has most likely released obsidian nodules from both historic and prehistoric flows. Dating of these samples will identify those flows and find spots which were available for prehistoric exploitation, and chemical analyses now in progress may enable us to distinguish among some of them.

Palmarola

Palmarola is the westernmost of the Pontine Islands, located about 35 km west of Naples in the Gulf of Gaeta. The island, less than 3 km^2 in area, was first formed approximately 5 million years ago, with the intrusion of soda-rhyolitic lavas coming about 1.7 million years ago [19]. Several investigators have reported abundant secondary deposits of obsidian at Punta Vardella near the southeastern tip of the island [15, 28], although workable obsidian has also been reported from Monte Tramontana at the northern end of Palmarola. The chemical composition of obsidian from Monte Tramontana is similar to that of a limited number of tested artifacts from Italian archaeological sites, although fission track dates on artifacts suggests a range in their age of formation [15, 19, 29]. Apparently no samples from Punta Vardella have been dated or chemically analyzed.

During a detailed survey of the island in 2000-2001, several hundred samples of workable obsidian were obtained, primarily from secondary deposits both at Punta Vardella and in the port area near San Silverio at the southwest end of Monte Tramontana. A small amount of highly transparent obsidian was found at Punta Vardella, but most of the material found in both localities is grey to black and nearly opaque (and difficult to visually distinguish from opaque Sardinian obsidian). Only devitrified obsidian of unworkable quality was found *in situ* anywhere else on the island. Chronometric dating and chemical analyses now in progress will ultimately reveal whether any distinctions can be made between the two visual types of obsidian found at Punta Vardella, or in comparison with that found near San Silverio.

Monte Arci, Sardinia

Unlike all other Mediterranean island sources of obsidian, Sardinia is a large landmass at approximately 25,000 km^2, and is easily reachable from the mainland by first crossing the Tuscan Archipelago to Corsica. Sardinia is also unique in that it was settled prior to the exploitation of its obsidian sources, by people who developed a distinctive local culture [30]. In a comprehensive survey of the Monte Arci zone, Puxeddu [31] found 246 archaeological sites with obsidian in an area of *c*. 200 km^2, including several workshops for the production of tools. The Monte Arci volcanic complex, first described by della Marmora [32] and later by Washington [33], includes acidic lavas which frequently appear as massive, strongly vesiculated flows, often grading into a perlitic facies where obsidians are likely to occur. The acidic lavas are covered by more recent dacitic and basaltic flows. The available K-Ar and fission-track dates on geological obsidian samples all have uncorrected ages of about 3.2 million years.

Both translucent and opaque obsidian had long been recognized in archaeological assemblages, and at least three chemical groups (SA, SB, SC) were identified in early provenance studies on archaeological material, although only one geological source had been analyzed [3]. Several independent studies since have contributed to the characterization of the multiple Monte Arci obsidian outcrops. Unfortunately, results of the first study are available only in a brief conference paper [13], no details about the obsidian deposits themselves were published in the second study [14], and the third is an unpublished dissertation [15]. None of these studies included samples from all source localities.

My own survey of the Monte Arci zone, beginning in 1987, located an *in situ* obsidian source on the northeast side of Monte Arci for the first time, as well as multiple localities with *in situ* obsidian on the northwestern slopes of Monte Arci, in addition to the well-known deposits at Conca Cannas [12]. Very glassy, black but highly translucent obsidian was found *in situ* in the southwestern part of Monte Arci near Conca Cannas and Su Paris de Monte Bingias, in nodules up to 40 cm in length. Along the western flanks of Monte Arci, less glassy and black but usually opaque obsidian was found *in situ* at high elevations on Punta Su Zippiri, Punta Nigola Pani, and Monte Sparau North, and in the form of bombs up to 30 cm in length on the slopes of Cuccuru Porcufurau. Very glassy obsidian, variable in transparency and sometimes with phenocrysts up to 2 mm in diameter, was found to occur in large blocks (occasionally up to 1 meter in length) near Cucru Is Abis, Seddai, Conca S'Ollastu, and Bruncu Perda Crobina. Finally, on the northeastern side of Monte Arci, black, opaque, and less glassy obsidian, frequently with well-defined external gray bands, was found *in situ* along the ridge from Punta Pizzighinu to Perdas Urias in blocks up to 20 cm long; in one area here was found a concentration of pieces with red streaks. Larger, natural blocks of obsidian may also be found in relative abundance as secondary deposits at lower elevations, from Santa Pinta to Mitza Sa Tassa.

SOURCE ANALYSIS

The seminal contribution by Cann and Renfrew was the first to demonstrate that obsidian from each Mediterranean island could be distinguished based on its chemical composition using techniques such as optical emission spectroscopy [2]. Subsequent work has not only demonstrated the efficacy of other techniques, especially instrumental neutron activation analysis (INAA) and X-ray fluorescence (XRF), but also that each island has a different major element chemistry as well as trace element fingerprint, and even that individual flows on a single island may be uniquely characterized [3, 14]. In fact, simple bivariate plots of major elements can distinguish the Mediterranean island sources of Antiparos, Giali, Melos (2 sources), Pantelleria (4-5 sources), Lipari, Palmarola and Sardinia (at least 4 sources) [6].

My own research has been designed to use a multi-method exploratory approach to chemically characterize systematically collected geological obsidian samples from Sardinia, and more recently, Lipari, Palmarola and Pantelleria, in order to study exploitation patterns at high resolution. For Sardinia, the variability in visual characteristics observed for different areas of Monte Arci suggested that it should be possible to match the previously identified archaeological source groups to specific geographic localities. For the full chemical characterization of geological samples, a combination of inductively coupled plasma mass spectrometry (ICP-MS) [34-35], neutron activation analysis, and X-ray fluorescence spectroscopy is employed. One hundred and seventy-four geological specimens from 20 collection localities in Sardinia were analyzed semi-quantitatively for 38 major and trace elements using a Fisons PQ 2 Plus quadrupole ICP mass spectrometer, and 125 samples were analyzed for 11 major and minor elements using a Cameca MBX electron microprobe equipped with wavelength dispersive spectrometers [16]. A subset of 60 samples was then quantitatively analyzed for 27 elements by INAA at the Missouri University Research Reactor. The same set of 60 samples was also analyzed for 15 elements by XRF using a Spectrace 5000 spectrometer at the Northwest Research Obsidian Studies Laboratory. While these analyses demonstrated that as many as nine Sardinian sources may be identified, only four (SA, SB1, SB2, and SC) are of archaeological significance, since the Ceca sources are only represented by obsidian of unworkable size, the two SC source groups co-occur in the same area and are visually and physically indistinguishable, and the three SB1 source subgroups are only rarely represented among artifacts [6, 16]. INAA, XRF and laser-ablation ICP-MS analyses are now underway to fully characterize the multiple source localities on the other central Mediterranean source islands, and preliminary results indicate the existence of four to six chemical source groups on Pantelleria, and two on Palmarola. For those source localities on Lipari tested as of this writing, only a single chemical source group appears to exist.

Over 700 obsidian artifacts have already been analyzed using the electron microprobe since it requires that only a tiny sample be removed from artifacts, and large numbers of artifacts may be quantitatively analyzed at very low per-sample costs [36]. As many as 15-20 samples may be mounted and polished on a single one-inch epoxy disk, which may be reanalyzed as necessary, by microprobe or by other methods including laser ablation ICP-MS. The SEM with energy dispersive spectrometers also has been used for obsidian studies in the Mediterranean and elsewhere [37-38], but Ti, Mg, Mn and P are often below the minimum detection limits of EDS systems and these elements are often necessary for discriminating among the Mediterranean island sources and subsources. For the microprobe analyses, at least two points per sample were excited by a wide (40 μm) 15 keV electron beam so as to avoid inadvertently heterogeneous points, and the X-radiation was measured by WDS with counting times of 10-80 s per element [16]. Results were standardized to a total of 99% allowing 1% for trace elements and structural water. In addition to the use of bivariate plots of the major elements, robust multivariate statistical analysis was used to attribute each artifact to a specific source. Discriminant functions determined for the geological data were applied to each unknown (archaeological) sample using the jackknifing option in the software program BMDP 7M. More than 95% of the artifacts were attributed to an individual subsource with greater than 95% probability.

ARCHAEOLOGICAL SAMPLE SELECTION

In the central Mediterranean, obsidian use effectively began in the Early Neolithic, although a single artifact each has been reported from two Mesolithic sites: Arma dello Stefanin in northern Italy, and Perriere Sottano in Sicily. The earliest Neolithic in the central Mediterranean is characterized not only by obsidian trade but also the widespread use of ceramics with decorations impressed using the *cardium edule* shell, and dates to approximately 5700-5300; at this time Sardinia and Corsica became widely settled as domesticated animals and plants were introduced from the mainland [48]. In Sardinia, the latter part of the Early Neolithic is characterized by the eponymous Filiestru culture (5300-4700 BC), while Bonu Ighinu (4700-4000 BC) is contemporary with the Middle Neolithic in Corsica, and the Ozieri culture (4000-3200 BC) is the equivalent of the Late Neolithic. For the archaeological component of the study presented here, samples were selected from several sites occupied for at least two cultural periods in order to investigate the possibility of chronological change in obsidian exploitation patterns. In addition, sites were selected to represent different distances from the Monte Arci obsidian sources, as well as locations along a potential trade route from Monte Arci to northern Sardinia to Corsica to Tuscany.

One hundred and eighty-six obsidian artifacts were selected for analysis from six Neolithic archaeological sites: Cuccuru S'Arriu-Cabras [39], Grotta Sa Corona-Monte Maiore [40-41], and

Grotta Filiestru-Mara [42] in Sardinia; Strette [43-44] and Pietracorbara [45] in Corsica; and the small islet of La Scola near the island of Pianosa in the Tuscan archipelago [46-47]. The sites of Sa Corona, Filiestru, Strette and Pietracorbara include occupations from at least two different cultural phases of the Neolithic, and four phases are represented at Filiestru. For the Filiestru site, artifacts were also selected from multiple contexts within the same chronological phase. The ability to statistically manipulate the results for the large number of artifacts analyzed here emphasizes the limitations imposed on earlier studies based on much smaller numbers of artifacts. Similarly, the attribution of artifacts to specific source localities enables a discussion of selection strategies and mechanisms not possible when the sources are not well known or when obsidian is traced only to a generic island source.

RESULTS AND DISCUSSION

The results of the microprobe analyses for the Early Neolithic samples from Filiestru, Strette, Pietracorbara and La Scola have been published separately [49]; the rest are provided in Table I, along with both a visual assessment of source and the determination based on the chemical data. Visual assignment of source may be successful at a very high rate, with inaccuracies overcome by the large number of samples which may be examined inexpensively and nondestructively [21]. Figure 3 is one example of a bivariate plot of major element composition which may be used to attribute artifacts to specific geological source localities in Sardinia; all source attributions presented here are also based on multivariate analysis of all elemental data. The frequency at which each obsidian source is represented in each chronological site component is illustrated in Figure 4.

Obsidian usage in the Early Neolithic components of these sites has been preliminarily discussed elsewhere [5, 49], and is supplemented now by the results available for Su Carroppu in Sardinia [8]; Curacchiaghiu [3] and Lumaca in Corsica and Cala Giovanna on Pianosa island [50]; Casa Querciolaia and Paduletto di Castagneto in Tuscany [51]; Arene Candide in Liguria [52]; and a few sites in southern France [53]. Throughout the Neolithic, archaeological sites south of Tuscany are generally dominated by obsidian from Lipari and Palmarola, although few sites are represented by significant numbers of analyses. Pantellerian obsidian has only rarely been identified north of Sicily.

The results clearly show that type SB1 obsidian was rarely utilized at all, while type SA was generally less important than types SB2 and SC obsidian. This in itself was a surprising result since type SA obsidian is quite abundant, easily accessed, and of excellent glassy quality. Type SA obsidian is relatively more common, however, at archaeological sites in central and southern Sardinia [5, 8, 13]. Type SB2 obsidian was apparently more widely used in the Early Neolithic, with a strong drop-off in frequency over the course of the Neolithic at Filiestru [5] and Strette, and between the Filiestru and Bonu Ighinu periods at Sa Corona. While type SB2 obsidian is often even glassier than type SA, one likely explanation for the decline in its importance is its occurrence generally as small disbursed outcrops and bombs with the best and most accessible material already exploited by the later Neolithic. Type SB obsidian perhaps was obtained at a low-scale during the course of other activities such as sheep-herding. Over the course of the Neolithic, type SC obsidian becomes more important at Filiestru, Strette and Pietracorbara, despite its being the least glassy of the three main Sardinian obsidian types, and its location at higher elevations on the east side of Monte Arci. The most likely explanation is that its greater

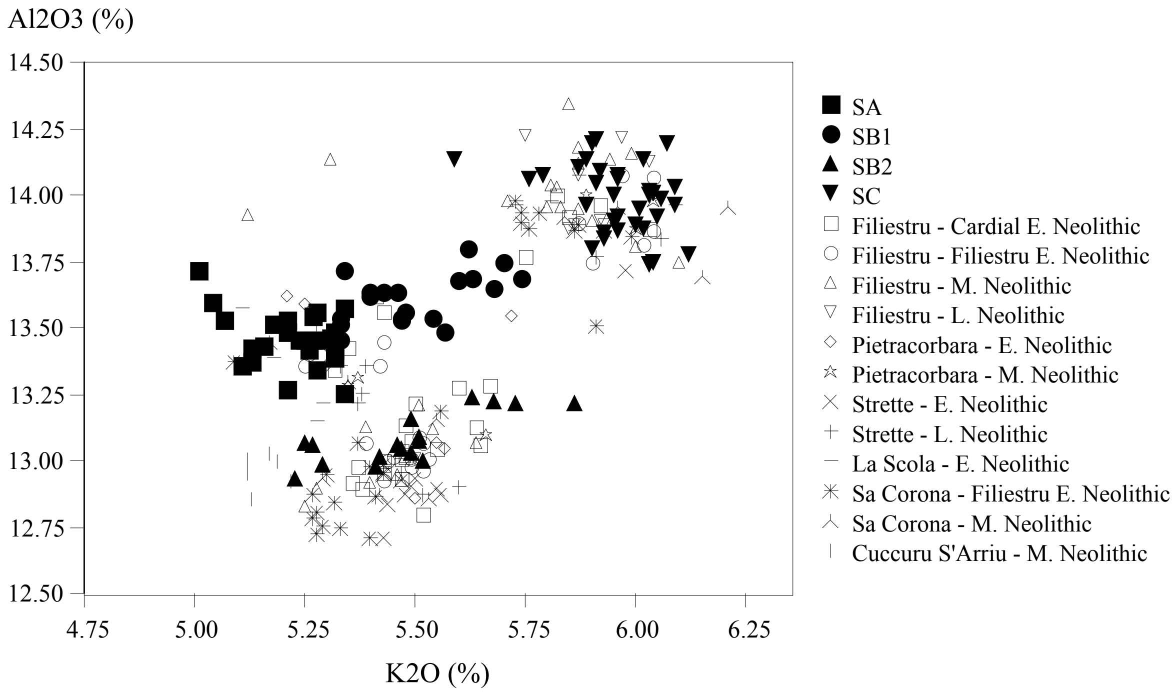

Figure 3. Bivariate plot of K_2O vs. Al_2O_3 concentrations in geological samples of Sardinian obsidian and from Neolithic artifacts. All analyses by electron microprobe.

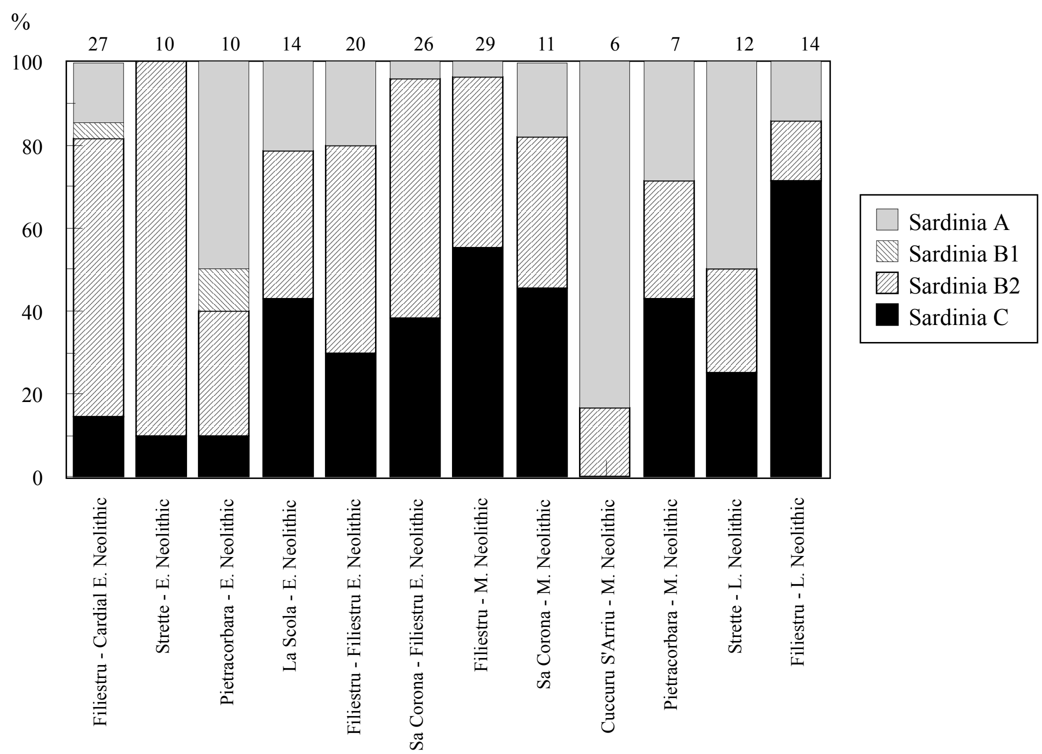

Figure 4. Obsidian source frequency at several Neolithic sites in Sardinia and Corsica. The number of analyzed artifacts for each site is given at the top of the bar.

durability became increasingly sought after during the Neolithic period [54], while the more concentrated nature of its secondary deposits made it more amenable to larger-scale exploitation than type SB obsidian. A lithic workshop area extending over several hectares at Mitza Sa Tassa is currently under investigation and is being turned into a geominerary park by the Sardinian government.

At Filiestru Cave, a total of 90 analyzed obsidian artifacts come from four different Cardial Early Neolithic units (B10, B11 t.2 and t.3, D7 stratigraphic column), two different Filiestru (later Early Neolithic) contexts (B9, D6 t.2), three different Bonu Ighinu Middle Neolithic units (B8 t.4, D5 t.5 and strat. col.), and a single Ozieri Late Neolithic level (D4 t.2). Differences between components of the same culture period were only observed for the Filiestru period, with type SB2 accounting for 90% of the 10 samples from D6 t.2 but only 10% of the 10 samples from B9. One way to account for a cluster of artifacts from the same source is if they were produced on-site from the same core, which could be tested by a typological/technological study of these pieces. The analyzed artifacts from Grotta Filiestru represent about 13% of the total obsidian assemblage. Nearly 600 additional obsidian artifacts were visually sourced, with the same pattern observed for each cultural period except for Bonu Ighinu where type SA obsidian appears to account for about 25% of the assemblage, compared to less than 5% type SA in the chemically analyzed sample [5]. This study of the Grotta Filiestru material exemplifies the value of analyzing significant numbers of artifacts to reveal changing patterns of source exploitation, and of using caution in sample selection strategies and in making interpretations based on statistically small numbers of samples.

CONCLUSION

In the Mediterranean region, obsidian artifacts may be traced not only to their island source, but to specific source localities on each island. In many cases, this may be accomplished using major element composition, as well as trace element fingerprints, allowing for the successful use of several different analytical techniques. The quantitative analyses of nearly 200 obsidian artifacts from six Neolithic sites in Sardinia, Corsica, and the Tuscan archipelago provides a high resolution picture of obsidian source exploitation and how it changed over the course of four cultural periods. A similar pattern of source representation is observed for a number of Early Neolithic sites in Sardinia, Corsica, Tuscany, and Liguria, supporting the hypothesis of a down-the-line trade mechanism [1, 49], while changes over the course of the Neolithic at individual sites is hypothesized to be a result of the physical properties, quantity, and accessibility of obsidian in each source zone, as well as the sociocultural system in which obsidian use is embedded. This case study focusing on obsidian originating from Sardinia exemplifies the approach currently being extended to obsidian sources on Lipari, Palmarola and Pantelleria, where multiple chemical and visual subgroups have also been identified. Further analyses of artifact assemblages, when integrated with typological, technological, and use-wear studies, will result in a more complete understanding of human behavior in the Neolithic central Mediterranean.

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Table I. Electron microprobe data for obsidian artifacts.

Cat.	**Visual**	**Chem.**	**SiO_2**	**Al_2O_3**	**TiO_2**	**Fe_2O_3**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**MnO**	**P_2O_5**	**BaO**	**Total**
178	SB2	SA	75.57	12.86	0.09	1.08	0.11	0.56	3.43	5.13	ns	ns	0.02	98.85
179	SA	SA	75.60	13.03	0.09	1.01	0.13	0.57	3.25	5.17	ns	ns	0.02	98.85
180	SA	SA	75.46	13.00	0.09	1.05	0.12	0.58	3.33	5.19	ns	ns	0.03	98.85
181	SA	SA	75.44	13.01	0.11	1.13	0.12	0.57	3.34	5.12	ns	ns	0.02	98.85
182	SA	SA	75.63	12.96	0.10	1.07	0.13	0.56	3.23	5.12	ns	ns	0.02	98.85
184	SA	SA	75.45	12.93	0.09	1.11	0.11	0.56	3.35	5.22	ns	ns	0.03	98.85
1090	SA	SA	74.67	13.45	0.10	1.23	0.08	0.62	3.49	5.17	0.08	0.08	0.03	99.00
1091	SC	SC	72.73	13.96	0.29	1.39	0.11	0.79	3.22	6.21	0.13	0.04	0.12	99.00
1092	SC	SC	72.44	13.92	0.29	1.65	0.22	0.88	3.32	5.84	0.14	0.03	0.11	99.00
1093	SB2	SB2	74.87	13.16	0.15	0.98	0.08	0.61	3.42	5.55	0.08	0.04	0.05	99.00
1094	SC	SC	72.57	13.87	0.31	1.58	0.30	0.92	3.31	5.93	0.16	0.04	0.09	99.00
1095	SB2	SB2	75.05	12.94	0.12	1.34	0.13	0.55	3.44	5.29	0.07	0.03	0.03	99.00
1096	SA	SA	74.85	13.30	0.07	1.25	0.08	0.58	3.39	5.35	0.07	0.05	0.01	99.00
1097	SB2	SB2	75.47	12.88	0.13	1.09	0.10	0.57	3.24	5.42	0.07	0.04	0.00	99.00
1098	SB2	SB2	75.30	12.86	0.12	1.16	0.09	0.54	3.27	5.53	0.06	0.04	0.03	99.00
1099	SC	SC	72.96	13.70	0.27	1.67	0.18	0.75	3.15	6.15	0.14	0.04	0.10	99.00
1100	SC	SC	73.25	13.96	0.28	0.61	0.23	0.91	3.30	5.96	0.14	0.04	0.09	99.00
1101	SC	SC	72.64	13.94	0.26	1.76	0.27	0.88	3.31	5.74	0.12	0.01	0.07	99.00
1102	SC	SC	72.56	13.88	0.29	1.73	0.27	0.89	3.33	5.76	0.14	0.02	0.12	99.00
1103	SC	SC	72.63	13.89	0.30	1.66	0.24	0.89	3.28	5.87	0.14	0.03	0.07	99.00
1104	SC	SC	72.68	13.85	0.29	1.56	0.26	0.85	3.21	5.99	0.14	0.04	0.13	99.00
1105	SC	SC	72.90	13.90	0.29	1.34	0.13	0.96	3.44	5.74	0.15	0.04	0.13	99.00
1106	SB	SB2	75.44	12.71	0.11	1.25	0.08	0.54	3.33	5.40	0.09	0.03	0.02	99.00
1107	SB	SB2	74.86	13.19	0.15	1.01	0.09	0.62	3.41	5.56	0.08	0.02	0.01	99.00
1108	SB2/SA	SB2	75.16	12.98	0.14	1.11	0.12	0.58	3.38	5.40	0.09	0.03	0.02	99.00
1109	SB2	SB2	75.50	12.85	0.13	1.04	0.11	0.56	3.38	5.32	0.07	0.03	0.02	99.00
1110	SB2/SA	SB2	75.09	12.73	0.12	1.12	0.09	0.57	3.40	5.28	0.08	0.03	0.01	99.00
1111	SA/SB2	SB2	75.37	12.88	0.12	1.15	0.09	0.57	3.40	5.27	0.07	0.04	0.04	99.00
1112	SA/SB2	SB2	75.48	12.81	0.12	1.17	0.10	0.56	3.36	5.28	0.08	0.03	0.02	99.00
1113	SB2	SB2	75.33	12.99	0.12	0.99	0.08	0.56	3.35	5.43	0.08	0.03	0.02	99.00
1114	SB2	SB2	75.28	12.95	0.12	1.17	0.11	0.57	3.35	5.30	0.08	0.02	0.05	99.00
1115	SB2	SB2	75.10	12.79	0.13	1.24	0.10	0.57	3.39	5.27	0.07	0.04	0.04	99.00
1116	SB2	SB2	75.48	12.75	0.12	1.16	0.10	0.56	3.34	5.33	0.07	0.03	0.00	99.00

Cat.	Visual	Chem.	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	BaO	Total
1117	SC	SC	73.64	13.38	0.24	1.27	0.25	0.87	3.39	5.09	0.14	0.03	0.12	99.00
1118	SC	SC	72.54	13.94	0.29	1.55	0.27	0.89	3.34	5.78	0.13	0.02	0.15	99.00
1119	SC	SC	72.83	13.87	0.29	1.41	0.17	0.90	3.36	5.86	0.13	0.03	0.13	99.00
1120	SC	SC	73.52	13.51	0.24	1.44	0.18	0.73	3.20	5.91	0.14	0.03	0.10	99.00
1121	SA	SB2	75.72	12.76	0.11	0.98	0.09	0.55	3.39	5.29	0.06	0.04	0.01	99.00
1122	SC	SC	72.61	13.98	0.28	1.69	0.28	0.86	3.30	5.73	0.14	0.04	0.10	99.00
1123	SB2	SB2	75.13	12.96	0.11	1.18	0.11	0.55	3.44	5.43	0.06	0.02	0.02	99.00
1124	SB2	SB2	74.92	12.87	0.12	1.15	0.08	0.55	3.38	5.41	0.06	0.04	0.04	99.00
1125	SB2	SA	74.62	13.47	0.09	1.18	0.07	0.57	3.54	5.31	0.08	0.05	0.01	99.00
1126	SA	SB2	75.21	13.07	0.10	1.01	0.08	0.57	3.46	5.37	0.07	0.04	0.03	99.00
1150	SA	SB2	75.37	12.90	0.12	1.18	0.09	0.56	3.34	5.28	0.08	0.04	0.04	99.00
1151	SA	SB2	75.23	12.93	0.13	1.16	0.09	0.54	3.34	5.47	0.06	0.02	0.03	99.00
1152	SC	SC	72.73	14.03	0.30	1.46	0.20	0.89	3.29	5.82	0.13	0.03	0.10	99.00
1153	SB2	SB2	75.52	12.83	0.12	1.13	0.08	0.55	3.36	5.25	0.06	0.03	0.03	99.00
1154	SC	SC	72.42	13.96	0.26	1.64	0.24	0.90	3.22	5.80	0.16	0.04	0.10	99.00
1155	SC	SC	72.74	13.96	0.30	1.46	0.15	0.90	3.29	5.83	0.14	0.03	0.08	99.00
1156	SC	SC	71.92	14.04	0.34	2.01	0.28	0.96	3.34	5.81	0.14	0.04	0.11	99.00
1157	SC	SC	71.98	14.14	0.34	1.93	0.36	1.08	3.59	5.31	0.14	0.04	0.11	99.00
1158	SC	SB2	75.20	12.95	0.11	1.14	0.10	0.56	3.34	5.46	0.06	0.05	0.03	99.00
1160	SA	SB2	75.29	12.93	0.12	1.08	0.08	0.55	3.38	5.43	0.08	0.03	0.02	99.00
1161	SA	SA	74.57	13.36	0.09	1.43	0.07	0.60	3.47	5.25	0.09	0.06	0.00	99.00
1162	SC	SC	72.82	13.75	0.26	1.67	0.25	0.83	3.24	5.90	0.14	0.04	0.10	99.00
1163	SC	SC	72.81	13.82	0.25	1.50	0.18	0.81	3.24	6.02	0.15	0.03	0.06	99.00
1164	SA	SA	74.74	13.36	0.09	1.24	0.05	0.57	3.37	5.42	0.08	0.07	0.00	99.00
1165	SA	SA	74.45	13.41	0.08	1.27	0.06	0.59	3.43	5.26	0.08	0.06	0.02	99.00
1166	SC	SC	73.22	13.87	0.23	1.29	0.11	0.79	3.23	6.04	0.12	0.03	0.06	99.00
1167	SA	SA	74.62	13.45	0.09	1.23	0.08	0.59	3.36	5.43	0.10	0.06	0.01	99.00
1168	SC	SC	72.21	14.08	0.30	1.68	0.19	0.93	3.35	5.97	0.15	0.02	0.12	99.00
1169	SC	SC	72.23	14.07	0.31	1.63	0.23	0.91	3.29	6.04	0.14	0.03	0.13	99.00
1187	SC	SC	72.39	14.13	0.30	1.58	0.25	0.90	3.37	6.03	0.13	0.04	0.12	99.00
1188	SC	SC	72.05	14.22	0.30	1.68	0.24	0.91	3.33	5.97	0.14	0.04	0.11	99.00
1189	SC	SC	72.40	14.08	0.28	1.61	0.22	0.92	3.33	5.87	0.14	0.03	0.12	99.00
1190	SA	SB2	75.05	13.01	0.11	1.11	0.11	0.56	3.41	5.50	0.08	0.04	0.01	99.00
1191	SC	SC	71.13	14.23	0.40	2.16	0.42	1.12	3.37	5.75	0.15	0.05	0.10	99.00
1192	SC	SC	72.78	13.89	0.27	1.54	0.21	0.88	3.21	5.93	0.13	0.05	0.11	99.00
1193	SC	SC	72.34	13.89	0.31	1.81	0.30	0.90	3.33	5.86	ns	ns	0.12	98.85
1194	SA	SC	72.64	13.88	0.30	1.55	0.27	0.90	3.29	5.85	0.16	0.03	0.13	99.00
1195	SA/SB2	SC	72.55	13.91	0.27	1.65	0.26	0.88	3.25	5.92	0.12	0.03	0.15	99.00
1196	SC	SC	71.51	13.78	0.26	1.70	0.25	0.84	0.71	9.69	0.14	0.04	0.11	99.00
1197	SC	SC	72.39	13.98	0.28	1.56	0.22	0.87	3.26	5.71	0.15	0.03	0.12	99.00
1198	SC	SC	72.63	13.93	0.33	1.63	0.23	1.02	3.84	5.12	0.17	0.02	0.09	99.00
1199	SA	SA	74.55	13.46	0.08	1.25	0.07	0.57	3.49	5.33	0.08	0.07	0.02	99.00
1200	SA	SB2	74.68	13.21	0.14	1.18	0.13	0.60	3.43	5.51	0.08	0.02	0.01	99.00
1201	SC	SC	72.51	14.14	0.32	1.41	0.24	0.93	3.43	5.94	0.14	0.02	0.12	99.00
1202	SC	SC	72.41	14.16	0.27	1.58	0.24	0.84	3.42	5.99	0.12	0.02	0.14	99.00
1203	SA	SB2	75.08	12.92	0.13	1.18	0.11	0.57	3.45	5.40	ns	ns	0.01	98.85
1204	SC	SC	71.74	14.35	0.37	1.48	0.24	1.07	3.40	5.85	0.15	0.02	0.11	99.00
1205	SC	SC	72.46	13.91	0.27	1.81	0.25	0.85	3.30	5.90	0.14	0.04	0.09	99.00
1206	SC	SC	72.33	14.12	0.28	1.63	0.25	0.89	3.34	5.87	0.14	0.04	0.10	99.00
1207	SC	SC	72.94	13.81	0.24	1.61	0.16	0.77	3.21	6.00	0.12	0.03	0.10	99.00
1208	SA	SB2	74.95	13.13	0.11	1.13	0.10	0.60	3.45	5.39	0.08	0.03	0.05	99.00
1209	SA	SB2	75.01	13.02	0.13	1.22	0.10	0.57	3.36	5.48	0.07	0.03	0.00	99.00
1210	SA	SB2	75.00	13.04	0.11	1.13	0.11	0.60	3.42	5.45	0.07	0.03	0.03	99.00
1211	SC	SC	72.03	14.18	0.34	1.60	0.25	1.03	3.41	5.87	0.14	0.03	0.12	99.00

Cat.	Visual	Chem.	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	BaO	Total
1212	SA/SB2	SB2	74.04	12.91	0.14	1.21	0.13	0.59	1.38	8.54	0.07	0.02	0.01	99.00
1213	SC	SC	73.33	13.75	0.23	1.12	0.10	0.77	3.22	6.10	0.13	0.01	0.12	99.00
1214	SA	SB2	74.99	13.07	0.13	1.08	0.09	0.58	3.29	5.64	0.08	0.03	0.03	99.00
1215	SA	SB2	74.77	13.12	0.14	1.15	0.13	0.59	3.40	5.54	0.08	0.04	0.03	99.00
1216	SC	SC	72.84	13.95	0.24	1.46	0.19	0.90	3.30	5.87	0.14	0.05	0.09	99.00
1217	SA	SB2	75.10	13.01	0.11	1.18	0.09	0.55	3.36	5.49	0.06	0.02	0.03	99.00
1218	SA	SB2	75.01	13.02	0.13	1.18	0.10	0.56	3.41	5.45	0.08	0.05	0.01	99.00
1219	SA	SB2	75.12	13.07	0.12	1.08	0.06	0.55	3.35	5.52	0.08	0.03	0.02	99.00
1220	SA	SB2	75.15	13.07	0.13	1.13	0.11	0.56	3.35	5.39	0.06	0.03	0.02	99.00
1221	SA	SB2	75.01	13.01	0.13	1.17	0.06	0.57	3.40	5.53	0.07	0.04	0.01	99.00
1222	SA	SB2	75.16	13.00	0.12	1.13	0.10	0.56	3.37	5.44	0.08	0.03	0.01	99.00
1223	SA	SB2	75.08	12.97	0.12	1.15	0.09	0.58	3.36	5.52	0.08	0.04	0.02	99.00
1224	SB2	SB2	75.28	12.98	0.12	1.00	0.09	0.58	3.31	5.49	0.08	0.04	0.03	99.00
1225	?	SC	72.56	13.90	0.31	1.72	0.23	0.91	3.24	5.87	0.14	0.03	0.09	99.00
1226	SA	SB2	74.85	13.09	0.15	1.22	0.13	0.59	3.34	5.51	0.07	0.04	0.01	99.00
1301	SA	SA	74.68	13.29	0.10	1.23	0.09	0.59	3.51	5.35	ns	ns	0.02	98.85
1302	SA	SA	74.63	13.32	0.09	1.27	0.09	0.59	3.49	5.37	ns	ns	0.00	98.85
1303	SA	SB2	74.56	13.10	0.15	1.18	0.13	0.61	3.41	5.66	ns	ns	0.06	98.85
1304	SC	SC	72.36	14.00	0.27	1.70	0.26	0.89	3.40	5.89	ns	ns	0.08	98.85
1305	SC	SC	72.25	13.88	0.29	1.83	0.29	0.90	3.30	6.00	ns	ns	0.11	98.85
1306	SC	SC	72.82	13.98	0.31	1.11	0.11	0.92	3.44	6.04	ns	ns	0.14	98.85
1307	SB2/SA	SB2	74.59	12.86	0.13	1.01	0.11	0.55	1.98	7.63	ns	ns	0.00	98.85
1318	SA	SA	74.83	13.26	0.09	1.24	0.08	0.56	3.41	5.38	ns	ns	0.00	98.85
1319	SB2	SB2	75.08	12.96	0.13	1.11	0.11	0.57	3.43	5.47	ns	ns	0.00	98.85
1320	SA	SA	74.59	13.36	0.09	1.20	0.08	0.57	3.54	5.39	ns	ns	0.04	98.85
1321	SA/SB2	SB2	75.10	12.91	0.11	1.12	0.11	0.57	3.33	5.60	ns	ns	0.01	98.85
1322	SA	SA	74.90	13.22	0.10	1.26	0.08	0.55	3.34	5.37	ns	ns	0.03	98.85
1323	SA	SA	74.36	13.46	0.09	1.45	0.07	0.63	3.58	5.23	ns	ns	0.00	98.85
1324	SA	SA	74.49	13.49	0.09	1.30	0.08	0.61	3.49	5.28	ns	ns	0.01	98.85
1325	SC?	SC	72.21	13.77	0.29	2.01	0.36	0.91	3.31	5.91	ns	ns	0.10	98.85
1326	SB2	SB2	75.14	12.88	0.11	1.15	0.10	0.59	3.32	5.52	ns	ns	0.03	98.85
1327	SC	SC	72.82	13.84	0.25	1.54	0.22	0.71	3.27	6.06	ns	ns	0.12	98.85
1328	SC	SC	73.01	13.97	0.28	1.15	0.12	0.84	3.27	6.09	ns	ns	0.13	98.85
1329	SA	SA	74.67	13.36	0.09	1.24	0.08	0.59	3.46	5.33	ns	ns	0.03	98.85

Cuccuru s'Arriu (Cabras): M. Neolithic (178-184)
Sa Corona (Monte Maiore): M. Neolithic (1090-1100); Filiestru E. Neolithic (1101-1126)
Grotta Filiestru (Mara): Filiestru E. Neolithic, B9 (1160-1169); D6 t.2 (1217-1226); M. Neolithic, B8 t.4 (1150-1158); D5 strat. col. (1197-1206); D5 t.5 (1207-1216); L. Neolithic, D4 t.2 (1187-1196)
Pietracorbara: Middle Neolithic, level V (1301-1307)
Strette: Late Neolithic, level XII (1318-1329)
ns = not sought