

## **Sourcing of Sardinian Obsidian Collections in the Museo Preistorico-Etnografico “Luigi Pigorini” Using Non-Destructive Portable XRF**

Robert H. Tykot<sup>1</sup>

### **Riassunto**

*Si presentano in questa sede i risultati delle analisi non distruttive, effettuate impiegando uno spettrometro portatile in Fluorescenza di raggi X, su circa 180 manufatti preistorici in ossidiana provenienti da 15 siti archeologici nell'Oristanese e nel Cagliaritano in Sardegna, conservati a Roma presso il Museo Preistorico-Etnografico “Luigi Pigorini”. Congiuntamente alla determinazione fisico-visuale di questi strumenti si esamina l'uso dell'ossidiana nei diversi periodi di tempo e si propongono interpretazioni per modelli cronologici e geografici che possano essere riferiti alla qualità, alla quantità, all'accessibilità e ai fattori socio-economici implicati nell'acquisizione, nella produzione e nell'uso dell'ossidiana preistorica in Sardegna.*

### **Abstract**

*Results are presented here for the analysis, using a non-destructive portable X-ray fluorescence spectrometer, of nearly 180 prehistoric obsidian artifacts from 15 archaeological sites in the Oristano and Cagliari areas of Sardinia, stored in the Museo Preistorico-Etnografico “Luigi Pigorini” in Rome. Combined with physical/visual assessment of these stone tools, obsidian usage for different time periods is examined, and interpretations proposed for chronological and geographic patterns that may be related to the quality, quantity, access, and socioeconomic factors involved in the acquisition, production, trade, and use of obsidian in prehistoric Sardinia.*

### **Introduction**

Obsidian, the black volcanic glass found in the Monte Arci region of the Province of Oristano, has been recognized at archaeological sites in Sardinia for well over a century (Spano 1870; 1873; Lovisato 1875;

---

<sup>1</sup> Department of Anthropology, University of South Florida, Tampa, FL 33620, USA. [rt yokot@cas.usf.edu](mailto:rt yokot@cas.usf.edu)

Mantovani 1875; Nissardi 1886; see also Tykot 1992: 57-58 for more detailed accounting of early citations of Sardinian obsidian). Della Marmora (1839-40) provided the first substantial geological information on the obsidian beds of Monte Arci, with his observations largely confirmed by Washington (1913) nearly a century ago. But the seminal contribution on Sardinian obsidian sources was that of Puxeddu (1958), who surveyed and identified several hundred sites with worked obsidian and describes 4 source areas in the Monte Arci region.

Since then, instrumental methods of chemical analysis have allowed for the differentiation of multiple subsources on Monte Arci (Cann and Renfrew 1964; Hallam et al. 1976; Mackey and Warren 1983; Francaviglia 1986; Herold 1986; Tykot 1997). Most significantly, analyses of large numbers of obsidian artifacts have revealed regional and chronological patterns and changes in the usage of the Monte Arci subsources (Tykot 1996; 2002a; 2002b; Tykot and Ammerman 1997). While it is possible to distinguish as many as seven subsources of usable obsidian, it appears sufficient for archaeological interpretations to assign artifacts to four: SA (Conca Cannas area); SB1 and SB2 (east and south, respectively, of Santa Maria Zuarbara); and SC (Perdas Urias/Sennixeddu) (Tykot 2002c; 2004).

It is also possible to discriminate visually, to a certain extent, between some of the Monte Arci obsidian subsources. The combination of color, transparency, lustre, and the presence of external or internal banding and/or phenocrysts was used to visually identify the geological source of archaeological artifacts. In general, types SA (transparent) and SC (opaque) are readily distinguished from one another, while type SB2, which ranges from transparent to almost opaque, is often confused with type SA. Type SB1, which apparently was not widely used, is not visually distinguishable from type SC (Tykot 1992; 1997; 2004).

In this study, more than 450 prehistoric obsidian artifacts from 15 archaeological sites in the Oristano and Cagliari areas of Sardinia, stored in the Museo Preistorico-Etnografico "Luigi Pigorini" in Rome, were visually sourced, followed by elemental analysis of 178 randomly selected samples using a non-destructive portable X-ray fluorescence spectrometer which has already been demonstrated to be successful in distinguishing Monte Arci subsources (Tykot et al. 2008).

### **1. Sardinian Obsidian in the Pigorini Museum**

The Museo Preistorico-Etnografico "Luigi Pigorini" in Rome has in its collections a significant body of Sardinian material, including obsidian artifacts, acquired from 20 sites during the late 1800s (Lo Schiavo 1980;

Prina 1968-69). In particular, in the 1880s Orsoni (1879) provided an entire collection of material from the caves of San Bartolomeo and Sant' Elia and from the site of Monte Urpino in Cagliari, and somewhat later Zanardelli (1899) sent thousands of surface finds from the Cabras and Oristano areas (Figure 1).

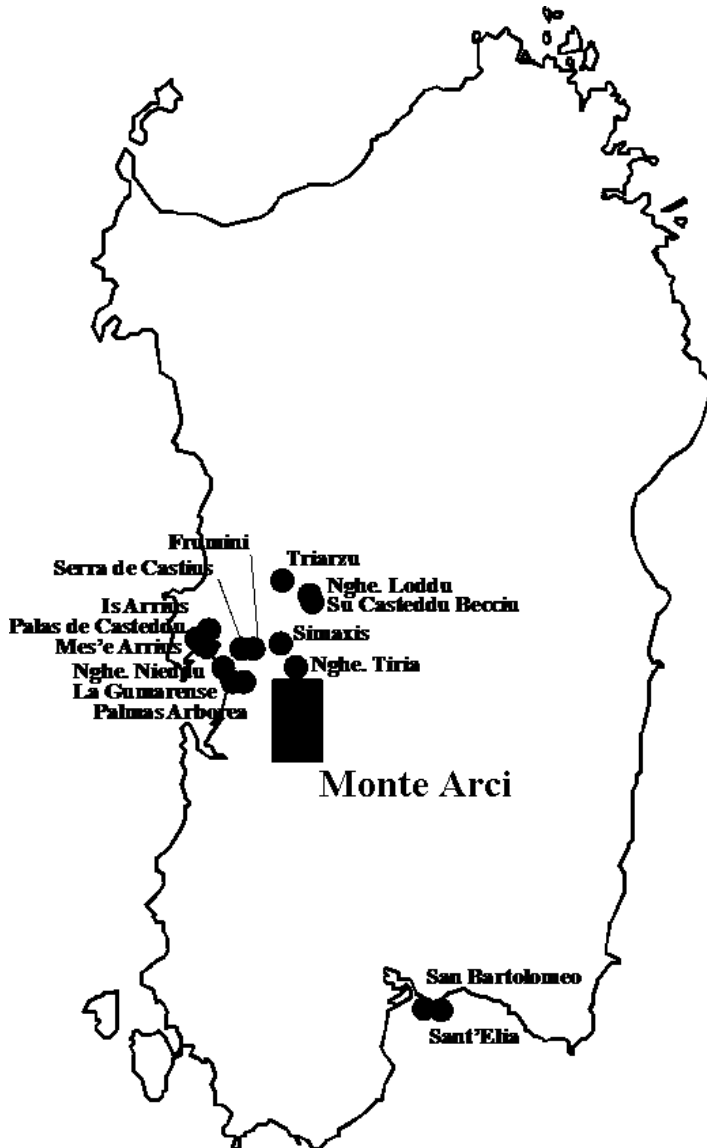


Fig. 1: The fifteen sites in Sardinia with obsidian collections in the Pigorini Museum.

My examination of these collections was initially designed to quantify their contents and to select samples for provenance analysis (Figure 2). All flake samples examined were randomly selected from each assemblage. Given the superficial archaeological context of the artifacts in the Zanardelli collections, and the questionable stratigraphic integrity of the San Bartolomeo material (Atzeni 1962; Lo Schiavo 1980), only visual provenance analyses were initially performed (in the mid-1990s), with the chemical analyses done recently on a subset of samples.

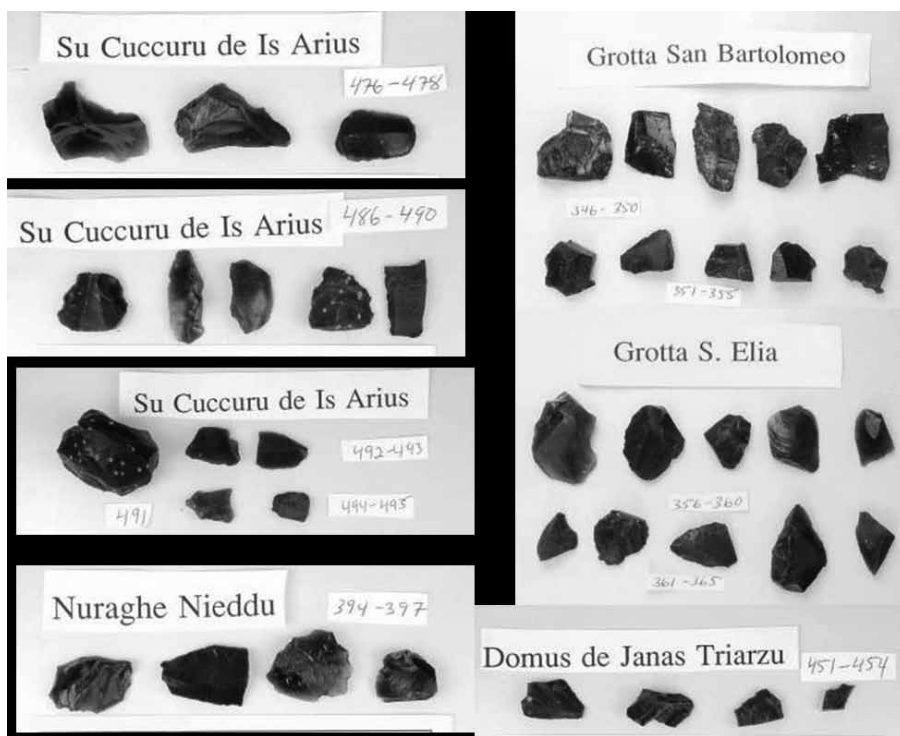


Fig 2: Photographs of some of the obsidian artifacts from Sardinia tested in this study illustrate some of the visual differences between Monte Arci subsources.

Information, including a visual assessment, follows, for 15 of the 20 Sardinian sites with obsidian represented in the Pigorini collections. The last five collections listed were not examined because of the small number of obsidian artifacts in them.

1. Su Cuccuru de Is Arrius (Cabras). 1787 flakes (3 SA, 4 SB2, 11 SC), 16 blades (10 SA, 1 SB2, 5 SC), 8 arrowheads (4 SA, 4 SC), 1 discoid (SA), 4 small cores. Total weight 7741 g. Bonu Ighinu (Middle Neolithic).
2. Mes'e Arrius (Cabras). 57 flakes plus 2 points (20 SA; 39 SC). Total weight 185 g. Late Neolithic.
3. Palas de Casteddu (Cabras). 500 flakes (250 very small) (5 SA; 1 SA/SB2; 4 SC), 5 points, 1 core. Total weight 1709 g. Late Neolithic.
4. Grotta San Bartolomeo (Cagliari). Strato I sepolcrale: 19 flakes (9 SA; 10 SC), total weight 84 g. Strato II sepolcrale: 20 flakes (8 SA; 12 SC), total weight 66 g. Strato III sepolcrale: 16 flakes (4 SA; 1 SA?; 11 SC). Strato IV-V sepolcrale: 76 flakes (16 SA; 6 SB2; 54 SC), total weight 380 g. Strato di abitazione: 23 blades (22 SA; 1 SC). Late Neolithic.
5. Simaxis. 405 flakes (4 SA; 6 SC), 1 discoid, 1 core. Neolithic.
6. Grotta Sant'Elia (Cagliari). Strato II sepolcrale: 21 flakes (7 SA; 14 SC). Total weight 76 g. Neolithic?
7. Stazione La Gumarense (Santa Giusta). 88 flakes (4 SA; 5 SC), 2 discoids. Total weight 448 g. Late Neolithic-Chalcolithic.
8. Domus de janas di Triarzu (Paulilatino). 18 flakes (2 SA; 8 SC). Total weight 24 g. Neolithic-EBA.
9. Cantoniera Frumini (Sili). 156 flakes (4 SA; 6 SC). Total weight 840 g. Chalcolithic.
10. Palmas Arborea (Oristano). 6 flakes (3 SA; 1 SC). Total weight 20 g. Chalcolithic.
11. Serra de Castius (Sili). 35 flakes (4 SA; 1 SB2; 5 SC). Total weight 196 g. Chalcolithic.
12. Su Casteddu Becciu (Fordongianus). 46 flakes (2 SA; 1 SB2; 5 SC). Total weight 184 g. Chalcolithic-EBA?
13. Nuraghe Tiria (Villaurbana). 87 flakes (5 SA; 2 SB2; 3 SC). Total weight 182 g. Nuragic.
14. Nuraghe Loddu (Fordongianus). 25 flakes (9 SC). Total weight 72 g. Nuragic.
15. Nuraghe Nieddu (Oristano). 370 flakes (4 SA; 6 SC), 1 discoid, 4 blades (one 8 cm in length), 1 core. Total weight 1344 g. Nuragic.
16. Domus de janas Su Ladere de Iosso (Paulilatino). 3 flakes. Not examined. Neolithic-EBA?
17. Nuraghe Zendero (Paulilatino). 17 flakes. Nuragic. Not examined.
18. Nuraghe Truberi (Fordongianus). 3 flakes. Nuragic. Not examined.
19. Nuraghe Aunes (Ghilarza). 20 flakes. Nuragic. Not examined.
20. Nuraghe Cuao (Bonarcado). 2 flakes. Nuragic. Not examined.

## 2. Analysis by X-Ray Fluorescence Spectrometry

In this study, a Bruker Tracer III-V portable X-ray fluorescence spectrometer was used to analyze the Pigorini Museum collections. This instrument, which is entirely non-destructive, was previously tested on geological samples to demonstrate that it could differentiate all of the Mediterranean sources and subsources. A specific “obsidian” filter (12

Table 1: Visual and pXRF obsidian source assignments for Sardinia sites in the Pigorini Museum collections. The artifacts tested by pXRF were randomly selected from each site collection’s overall obsidian assemblage

Site	Cultural Period	Visual				pXRF				
		SA	SB	SC	total	SA	SB1	SB2	SC	total
Su Cuccuru de Is Arrius (Cabras)	Middle Neolithic	60	13	61	134			10	10	20
Mes'e Arrius (Cabras)	Late Neolithic	20		39	59	2		2	6	10
Palas de Casteddu (Cabras)	Late Neolithic	5	1	4	10	2		5	3	10
Grotta San Bartolomeo (Cagliari)	Late Neolithic	60	6	88	154	10		2	28	40
Simaxis	Neolithic	4		6	10		5	3	2	10
Grotta Sant'Elia (Cagliari)	Neolithic?	7		14	21	3			7	10
Stazione La Gumarene (Santa Giusta)	Late Neolithic-Chalcolithic	4		5	9		2	4	3	9
Domus de janas di Triarzu (Paulilatino)	Neolithic-EBA	2		8	10	1		1	8	10
Cantoniera Frumini (Sili)	Chalcolithic	4		6	10	3	2	2	3	10
Palmas Arborea (Oristano)	Chalcolithic	3		1	4	1		2	1	4
Serra de Castius (Sili)	Chalcolithic	4	1	5	10	1		5	4	10
Su Casteddu Becciu (Fordongianus)	Chalcolithic-EBA?	2	1	5	8			4	4	8
Nuraghe Tiria (Villaurbana)	Nuragic	5	2	3	10		1	9		10
Nuraghe Loddu (Fordongianus)	Nuragic			9	9				8	8
Nuraghe Nieddu (Oristano)	Nuragic	4		6	10	1		3	5	9
	<i>Total</i>	184	24	260	468	24	10	52	92	178
	<i>Percentage</i>	39.3	5.1	55.6		13.5	5.6	29.2	51.7	

mil Al + 1 mil Ti + 6 mil Cu) was used to enhance results for certain elements known to be useful for sourcing obsidian, while the analysis settings chosen were 40.00 kV, 10.00  $\mu$ A, and 300 seconds. The results were calibrated against known obsidian samples used in multiple laboratories, including the Missouri University Research Reactor and the Smithsonian Institution (Table 1).

Geological samples from all of the Monte Arci subsources were also tested with the exact same instrument.

As has been shown by other XRF analyses, simple X-Y plots of elements such as Sr (strontium) and Zr (zirconium) may clearly distinguish the Monte Arci subsources (Figure 3). When compared with the quick, visual assessments done on the same collections, it is clear that overall percentages may be very similar, but that results for specific artifacts and

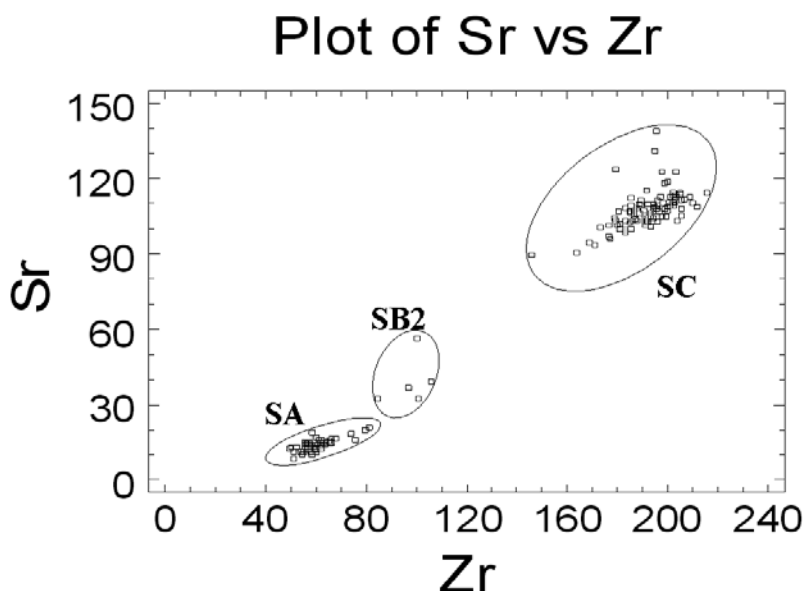


Fig. 3: Discrimination of Monte Arci subsources and assignment of artifacts using pXRF elemental data.

sites may be quite erroneous, thus emphasizing the importance of using scientific analyses at least on statistically significant numbers of samples, and in any study where results for specific artifacts are important.

### 3. Discussion

The absence of good archaeological context for most of the obsidian in the Pigorini collections demands that we be extremely cautious in our interpretation of this material. It is clear, however, that types SA and SC obsidian dominate all of these collections; type SB2, with few exceptions, appears to be present only at the prenuragic sites, despite the proximity of many of the sites to the Monte Arci zone and in particular to the SB sources on its western flanks (Figure 4). This is however consistent with analytical data from a multitude of sites in Sardinia, Corsica, the Tuscan Archipelago, and northern Italy, which show little use of type SB by the Late Neolithic (Tykot 1996; 2002a; 2002b).

Given the proximity of the Oristano area sites to Monte Arci, obsidian may have been acquired directly from its source, whereas sites elsewhere in Sardinia (and in Corsica and mainland Italy) probably obtained obsidian indirectly through various exchange mechanisms (see also Lugliè 2004). The similarity in usage patterns of the Monte Arci subsources, in Oristano

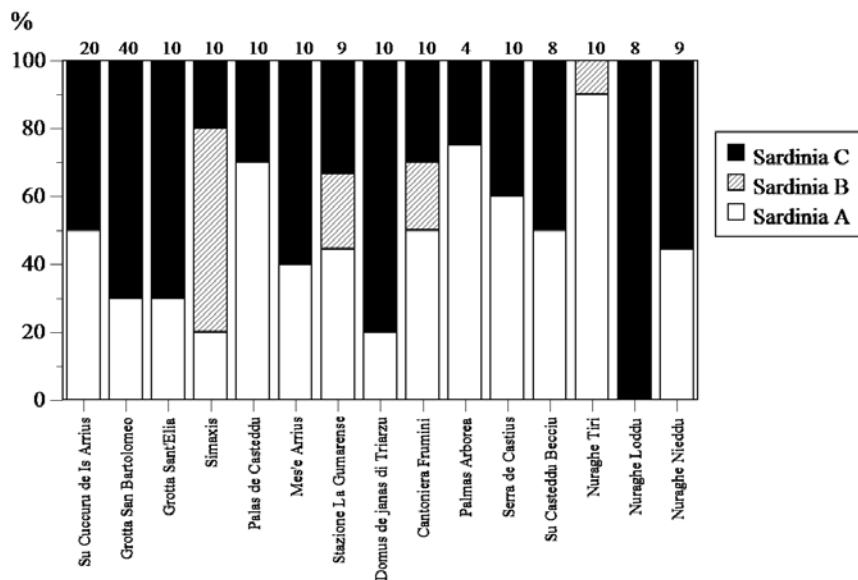


Fig. 4: Monte Arci (Sardinia) subsurface distribution for the fifteen sites tested by pXRF. The number of artifacts tested for each site is provided at the top.

province as well as in northern Sardinia and elsewhere, does provide support for a down-the-line exchange mechanism. Neolithic Oristanese communities in the 'supply zone' may have been the initial link in a far-reaching chain of exchange activities.

The small percentage of SB2 obsidian present at Grotta San Bartolomeo and Grotta Sant'Elia in southern Sardinia is not surprising, since the SA source is closer to these Cagliariaritano sites, and since both probably date to the Late Neolithic at the earliest. Other recent studies have also shown that the SB subsources were only occasional contributors to obsidian assemblages in southern Sardinia (Tykot et al. 2008).

The importance of SC obsidian at sites in the Oristano region suggests that the combined economic and social 'value' of this type roughly equaled that of SA, since the procurement cost for SC (from the eastern side of Monte Arci, at higher elevation and primarily in dispersed secondary deposits) was probably somewhat greater than for SA (on the western side, at low elevation, in an easily accessible concentrated deposit). Some SC obsidian is however available on the southern end of Monte Arci, in secondary deposits (Lugliè et al. 2006). Type SA has been considered to be of finer quality (glassier and sharper, but more brittle) than type SC, but the roughly equal use of the two types in the Oristano area suggests that the local craftspeople either did not make a distinction on that basis, or preferred to have both varieties for different tasks.



The results presented here do suggest variation between sites, but one must consider the modest number of artifacts tested by pXRF for many of these sites, as well as the specific time periods involved. For Simaxis, the quantity of type SB2 obsidian is greater than all other sites tested, while the percentage of SA obsidian is greater for many of the Oristano area sites, especially the Chalcolithic and Bronze Age sites, than what has been found for Late Neolithic sites in Sardinia, Corsica, and northern Italy. This situation only emphasizes the difficulty of explaining prehistoric behaviors which may have varied considerably both chronologically and geographically. Exchange in obsidian, while highly visible in the archaeological record, may not have been such a fundamental activity –economic or social– in the past. Rather, other lithic materials, ceramics, basketry, textiles, salt and other items may have been exchanged in conjunction with obsidian. In Sardinia, the quantity of obsidian utilized at sites outside the Monte Arci region may have justified the acquisition of obsidian as a dedicated, economically-important process, even if that were described as embedded procurement in the midst of prospecting or transhumant activities. In northern Italy and southern France, where obsidian was only occasionally more than a few percent of the lithic assemblage, it is more reasonable to envision acquisition of obsidian as a minor part of exchange processes, activities which may have been infrequent, and which were regulated by socially significant and dynamic local factors including prestige display, community and ethnic alliances. Such non-economic factors resulted in the declining presence of obsidian at sites outside of Sardinia and Corsica by the end of the Neolithic period, while within Sardinia obsidian continued to be used thru Nuragic and even later times.

Clearly, when making interpretations about usage of obsidian subsources one must consider the specific geographic and chronological context within the site that samples are being selected from, and the typology represented (e.g. multiple pieces possibly from the same core, vs. totally independent artifacts). There potentially are intra-site differences as well, as shown for the Late Neolithic site of Contraguda (Tykot et al. in press; Lai et al. 2006); this may also be the case for Su Cuccuru de Is Arrius (artifacts tested from two areas), and for San Bartolomeo (artifacts tested from four layers), but more typological work needs to be done on the specific samples tested for those two sites (Figure 5).

#### **4. Conclusion**

The analysis of obsidian artifacts from the Museo Preistorico-Etnografico “Luigi Pigorini” collections serves to amplify the data available

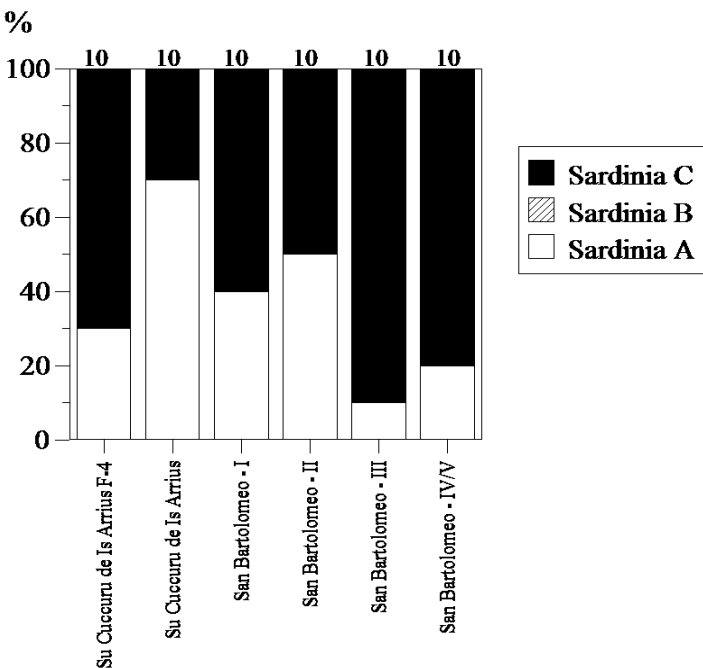


Fig. 5: Intra-site contexts at Su Cuccuru de Is Arrius, and Grotta di San Bartolomeo may represent selection and use of obsidian from particular Monte Arci subsources.

for understanding the socioeconomic aspects of obsidian usage in Sardinia, especially for post-Neolithic time periods, as well as for better understanding particularistic geographic and chronological patterns of usage of Monte Arci obsidian. Even for Sardinia, where the overall distribution of obsidian from Monte Arci is fairly well-established compared to most other regions with obsidian, much more work still needs to be done, specifically the integration of typological, technological, and use-wear studies with sourcing analyses, on large numbers of artifacts from excavations with good contextual and chronological information. This requires collaborative efforts among specialists in these various subdisciplines.

**Acknowledgments**

I thank Dott. Giovanni Scichilone, Superintendent of the Pigorini Museum at that time, for granting permission to conduct this study, and Dott.ssa Grazia Bulgarelli and Dott. Rico Pellegrini for their help in locating and examining the individual collections.

## References

- ATZENI, E.  
1962 The cave of San Bartolomeo, Sardinia, *Antiquity* 36: 184-189.
- CANN, J.R. and RENFREW, C.  
1964 The characterization of obsidian and its application to the Mediterranean region, *Proceedings of the Prehistoric Society* 30: 111-133.
- DE LA MARMORA, A.F.  
1839-40 Voyage en Sardaigne, ou description statistique, physique et politique de cette île, avec des recherches sur ses productions naturelles et ses antiquités. Turin: J. Bocca.
- FRANCAVIGLIA, V.  
1986 Characterization of Mediterranean obsidian sources by classical petrochemical methods, *Preistoria Alpina* 20 (1984): 311-332.
- HALLAM, B.R., WARREN, S.E. and RENFREW, C.  
1976 Obsidian in the western Mediterranean: characterisation by neutron activation analysis and optical emission spectroscopy, *Proceedings of the Prehistoric Society* 42: 85-110.
- HEROLD, G.  
1986 Mineralogische, Chemische und Physikalische Untersuchungen an den Obsidianen Sardiniens und Palmarolas. *Grundlagen zur Rekonstruktion Prähistorischer Handelswege im Mittelmeerraum*. PhD dissertation, Universität (TH) Fridericiana Karlsruhe.
- LAI, L., TYKOT, R.H. e TOZZI, C.  
2006 Nuovi risultati sulla provenienza dell'ossidiana del sito neolitico recente di Contraguda (Sardegna), in *Materie prime e scambi nella preistoria italiana*, Atti del XXXIX Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria (Firenze, 25-27 Novembre 2004): 598-602. Firenze.
- LO SCHIAVO, F.  
1980 Storia e consistenza della collezione paleontologica sarda nel Museo Pigorini di Roma, in *Studi di Archeologia Dedicati a Pietro Barocelli*: 1-14. Torino: Soprintendenza Archeologica del Piemonte.
- LOVISATO, D.  
1875 Una pagina di Preistoria Sarda, *Atti della R. Accademia dei Lincei* 4: 82.
- LUGLIÈ, C.  
2004 Modalità di acquisizione dell'ossidiana del Monte Arci nel Neolitico, in: P.M. Castelli, B. Cauli, F. Di Gregorio, C. Lugliè, G. Tanda e C. Usai, eds., *L'ossidiana del Monte Arci nel Mediterraneo: Recupero dei Valori di un Territorio*, Atti del Convegno Internazionale (Oristano-Pau, 29 Novembre - 1 Dicembre 2002): 47-60. Ghilarza: Tipografia Ghilarzese.

- LUGLIÈ, C., LE BOURDONNEC, F.-X., POUPEAU, G., BOHN, M. MELONI, S., ODDONE, M. and TANDA, G.  
 2006 A map of the Monte Arci (Sardinia Island, Western Mediterranean) obsidian primary to secondary sources. Implications for Neolithic provenance studies, *C. R. Palevol.* 5: 995–1003.
- MACKAY, M. and WARREN, S.E.  
 1983 The identification of obsidian sources in the Monte Arci region of Sardinia, in A. Aspinall and S.E. Warren, eds., *Proceedings of the 22nd Symposium on Archaeometry*, University of Bradford, Bradford, U.K. March 30th - April 3rd 1982: 420-431. Bradford: University of Bradford.
- MANTOVANI, P.  
 1875 Una stazione dell'età della pietra in Sardegna, *Bullettino di Paletnologia Italiana* 1: 81-90.
- MICHELS, J., ATZENI, E., TSONG, I.S.T. and SMITH, G.A.  
 1984 Obsidian Hydration Dating in Sardinia, in M.S. Balmuth and R.J. Rowland, Jr., eds., *Studies in Sardinian Archaeology*: 83-113. Ann Arbor: University of Michigan Press.
- NISSARDI, F.  
 1886 *Notizie degli Scavi*: 467.
- ORSONI, F.  
 1879 Ricerche paletnologiche nei dintorni di Cagliari, *Bullettino di Paletnologia Italiana* 5: 44-46.
- PRINA, M.  
 1968-69 *Materiali paletnologici di derivazione sarda conservati nel Museo Pigorini in Roma: classificazione e studio*. Tesi di laurea, Università di Cagliari.
- PUXEDDU, C.  
 1958 Giacimenti di ossidiana del Monte Arci in Sardegna e sua irradiazione, *Studi Sardi* 14-15: 10-66.
- SPANO, G.  
 1870 *Scoperte Archeologiche dell'Isola nell'Anno 1870*.  
 1873 *Scoperte Archeologiche*. Vol. II.
- TYKOT, R.H.  
 1992 The sources and distribution of Sardinian obsidian, in R.H. Tykot and T.K. Andrews, eds., *Sardinia in the Mediterranean: A Footprint in the Sea. Studies in Sardinian Archaeology Presented to Miriam S. Balmuth*: 57-70. Sheffield: Sheffield Academic Press.  
 1996 Obsidian procurement and distribution in the central and western Mediterranean, *Journal of Mediterranean Archaeology* 9: 39-82.  
 1997 Characterization of the Monte Arci (Sardinia) obsidian sources, *Journal of Archaeological Science* 24: 467-479.  
 2002 New approaches to the characterization and interpretation of obsidian from the Mediterranean island sources, in P.B. Vandiver, M. Goodway, J.R. Druzik and J.L. Mass, eds., *Materials Issues in Art*

- and *Archaeology VI*. Materials Research Society Proceedings 712: 143-157. Warrendale, PA.
- 2002b Geochemical analysis of obsidian and the reconstruction of trade mechanisms in the Early Neolithic period of the western Mediterranean, in K. Jakes, ed., *Archaeological Chemistry. Materials, Methods, and Meaning*. ACS Symposium Series 831: 169-184. Washington, DC: American Chemical Society.
- 2002c Chemical fingerprinting and source-tracing of obsidian: the central Mediterranean trade in black gold, *Accounts of Chemical Research* 35: 618-627.
- 2004 L'esatta provenienza dell'ossidiana e i modelli di diffusione nel Mediterraneo centrale durante il Neolitico, in P. Castelli, B. Cauli, F. Di Gregorio, C. Lugliè, G. Tanda and C. Usai, eds., *L'ossidiana del Monte Arci nel Mediterraneo: recupero dei valori di un territorio*: 118-132. Ghilarza: Tipografia Ghilarzese.
- TYKOT, R.H. and AMMERMAN, A.J.  
1997 New directions in central Mediterranean obsidian studies, *Antiquity* 71: 1000-1006.
- TYKOT, R.H., GLASCOCK, M.D., SPEAKMAN, R.J. and ATZENI, E.  
2008 Obsidian subsources utilized at sites in southern Sardinia (Italy), in P.B. Vandiver, B. McCarthy, R.H. Tykot, J.L. Ruvalcaba-Sil and F. Casadio, eds., *Materials Issues in Art and Archaeology VIII*. Materials Research Society Symposium Proceedings 1047: 175-183.
- TYKOT, R.H., LAI, L. and TOZZI, C. in press.  
Intra-site obsidian subsource patterns at Contraguda, Sardinia (Italy). *Proceedings of the 37th International Symposium on Archaeometry* (Siena, Italy, May 12-16, 2008).
- WASHINGTON, H.  
1913 Some lavas of Monte Arci, Sardinia, *American Journal of Science* 36: 577-590.
- ZANARDELLI, T.  
1899 Le stazioni preistoriche e lacumaresi nel Campidano di Oristano, *Bulletino di Paletnologia Italiana* 25: 8-177.