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Obsidian consumption in Chalcolithic Sardinia: a view from Bingia 'e Monti

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ABSTRACT

This study represents a contribution towards an understanding of the nature of obsidian exploitation in Sardinia during the Chalcolithic (ca. 3200–2200 cal B.C.). A total of 154 obsidian artifacts from Bingia 'e Monti in south-central Sardinia was techno-typologically characterized. Of these, 146 were elementally analyzed employing energy-dispersive X-ray fluorescence (EDXRF) as a means of sourcing the raw materials. It is argued that the community's residents obtained obsidian directly from Sardinian source areas, then reduced the material on-site for the production of lunates and expedient flake tools. By contextualizing the study within a broader consideration of obsidian distribution and use within Sardinia, it is shown that obsidian exploitation at this time differs from earlier periods, arguably related to a reconfiguration of socio-economic interaction spheres and exchange networks.

1. Introduction

This paper explores obsidian consumption on the Italian island of Sardinia during the Chalcolithic (ca. 3200–2200 B.C.) through the analysis of 154 obsidian artifacts from Bingia 'e Monti in south-central Sardinia (Fig. 1). While the circulation of Sardinian obsidian in the Neolithic is well documented (Hallam et al., 1976; Le Bourdonnec et al., 2010; Lugliè et al., 2007, 2008; Tykot, 1996 *inter alia*), the use of these raw materials in the Chalcolithic has received far less attention in what appears to be an important transitional period characterized by the decline of long-distance Neolithic exchange networks.

While there are four obsidian sources in the West Mediterranean (Fig. 1), only obsidian from the four subsources of Monte Arci is known to have been exploited by people on the island itself. Despite the presence of Mesolithic populations on Sardinia (see Table 1 for a list of relevant time periods and dates), it is not until the beginning of the Neolithic that we see the first evidence of obsidian use by the islanders (see Lugliè et al., 2007, 2008; Tykot, 1996) and the long-distance procurement of Sardinian raw materials by populations on Corsica and mainland Italy (Ammerman and Polglase, 1993; Bigazzi and Radi, 1998; Léa, 2012; Tykot et al., 2003 *inter alia*). While the long-distance procurement of Sardinian obsidian continues into the Chalcolithic, used by communities on Corsica and mainland Italy (see Bigazzi and Radi, 1998; Hallam et al., 1976; Randle et al., 1993), there is a sharp fall-off in the number of sites at which obsidian has been reported. The declining use of Sardinian obsidian in the Chalcolithic mirrors the diminished exploitation of other West Mediterranean sources in the 3rd millennia B.C. in that obsidian consumption becomes a much more local phenomenon, largely restricted to populations within the immediate vicinity of the various sources.

Through the integration of raw material sourcing and techno-typological analysis, this broad-based artifact characterization study uses the analysis of the Bingia 'e Monti assemblage as a means of undertaking a more general consideration of obsidian consumption in Chalcolithic Sardinia. The resultant data allows it to be argued that the community's residents obtained obsidian directly from the source areas, then reduced the material on-site for the production of lunates and expedient flake tools. It is further posited that the nature of obsidian exploitation on Sardinia during the Chalcolithic differs from that of the Neolithic, a change in

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Fig. 1. Map showing the location of Bingia 'e Monti in relation to the various obsidian sources in the West Mediterranean.

tradition that is related to a larger reconfiguration of interaction spheres and exchange networks.

2. Site background

Bingia 'e Monti is located in south-central Sardinia (Fig. 1). The site was excavated in the years 1983–1985 and 1988–1990, originally led by Dr. Giorgio Murru and later by Dr. Enrico Atzeni and Dr. Alessandro Usai. Its earliest occupation dates to the Monte Claro phase of the Chalcolithic (ca. 2700–2200 B.C.). This initial phase of occupation is represented by two circular residential stone structures that underlay later Nuragic Bronze Age construction (Fig. 2). A Chalcolithic burial was also found approximately 180 m northwest of the settlement (Atzeni, 1996). The site is dated on the basis of its characteristic ceramic assemblage, the Monte Claro pottery differing from the preceding Abealzu–Filigosa phase of the Chalcolithic in that they are decorated and well-fired, often resembling the form and decoration of Beaker pottery from mainland France (Webster, 1996: 52). Although copper artifacts are found at many Monte Claro phase sites throughout Sardinia (Melis, 2000), Bingia 'e Monti produced no metal objects.

Table 1
The periods, cultural phases, and absolute dates (calibrated) of Sardinian prehistory (after Tykot, 1994: 129).

Period		Cultural phase		Absolute dates
Mesolithic		Grotta Corbeddu		11000–6000 B.C.
Neolithic	Early	Su Carroppu		6000–5300 B.C.
		Filiestru-Grotta Verde		5300–4700 B.C.
	Middle	Bonu Ighninu		4700–4000 B.C.
	Late	San Ciriaco		4000–3200 B.C.
		Ozieri		
Chalcolithic	Early	Sub-Ozieri		3200–2700 B.C.
		Filigosa		
		Abealzu		
	Middle	Monte Claro	Beaker A	2700–2200 B.C.
	Late			
Bronze Age	Early	Bonnanaro A	Beaker B	2200–1900 B.C.
	Middle	Bonnanaro B		1900–1600 B.C.
		Nuragic I		1600–1300 B.C.
	Late	Nuragic II		1300–1150 B.C.
	Final	Nuragic III		1150–930 B.C.

Approximately 500 chipped stone artifacts were recovered from the Monte Claro strata at Bingia 'e Monti, of which about 85% was obsidian. The remaining artifacts were made of black/gray rhyolites of likely local origin (see Tykot, 1997: 469–470) and a small number of chert flakes. Fig. 3 shows some examples of the obsidian artifacts.

3. The Bingia 'e Monti obsidian study

Obsidian is an igneous rock and a type of volcanic glass that is usually black in color. It is an excellent raw material for the flaking of stone tools and was widely exploited by prehistoric peoples on the island of Sardinia from the Neolithic onwards (Tykot, 1996). The obsidian source at Monte Arci in west-central Sardinia is often classified as a single 'source', but researchers have identified at least nine chemically distinct outcrops (Tykot, 1997), four of which are commonly reported in the literature as compositional groups, namely: SA, SB1, SB2, and SC. While geo-archaeological studies have documented the existence and exploitation of primary *in situ* outcrops, secondary SC obsidian deposits have also been identified by Lugliè et al. (2006) south of the main SC conglomerate (Fig. 4). The differentiation between these subsources is archaeologically relevant because it has been shown that there are differences in the exploitation of these subsources through both time and space.

While it has long been recognized that obsidian is present at many Chalcolithic sites in Sardinia (Puxeddu, 1958), only obsidian from nine of them has been elementally analyzed (see Table 2). Such studies are informative in that they determine where the products of the four obsidian subsources were distributed; however, they have tended to focus on one aspect of obsidian consumption, i.e. the raw materials involved, without considering the specific forms in which the obsidian circulated (nodule, core, end-

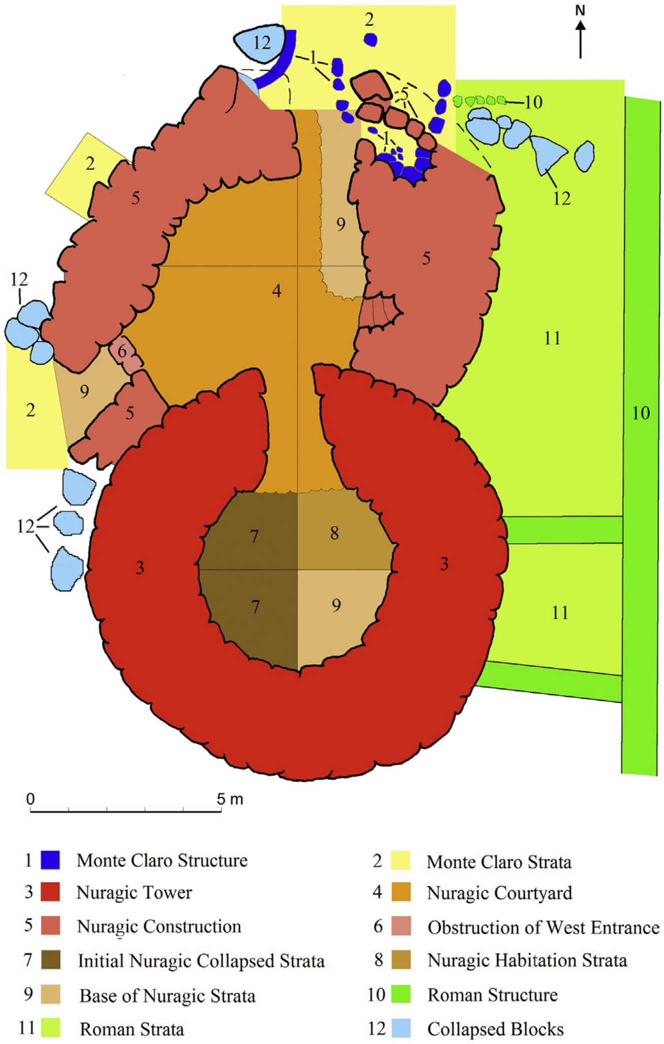

Fig. 2. Plan of the excavation at Bingia 'e Monti (A. Usai). Note that the area inside the nuraghe was not completely excavated.

product, etc), the techniques by which they were worked, and the form of the final tools. Following leads from elsewhere (cf. Carter et al., 2013; Freund, 2013; Lugliè, 2011; Tykot, 1996), this paper advocates a form of artifact characterization that integrates all of these considerations in order to appreciate the full range of socio-economic processes and cultural traditions that underpin the archaeological record.

4. Sampling

All of the lithics recovered from the excavation were bagged together according the unit and stratum from which they were recovered. To answer the relevant research questions, just over a third ($n = 154$) of the obsidian artifacts were randomly selected for analysis. In order to get a representative sample of artifacts recovered throughout the Monte Claro strata, both inside and outside the structures, all of the materials were laid out in their provenience-specific bags and one-third of the bags (i.e. every third) were randomly selected for analysis. This percentage was chosen because it would result in a robust enough sample to make valid interpretations while still fitting within logistical constraints such as time and money.

Since it was necessary to catalogue and photograph the entire assemblage before export, it can be confirmed that the selected material is representative of the whole in that the assemblage is mainly composed of flakes as well as highly cortical cores and angular waste. Out of this selection, eight artifacts were too small to be run by EDXRF (cf. Davis et al., 1998), but were nevertheless included in the typological analysis as their presence in the assemblage has important implications.

5. Analytical procedures

The artifacts were analyzed non-destructively at the McMaster Archaeological XRF Laboratory (MAX Lab) using a Thermo Scientific ARL Quant'X EDXRF spectrometer. Before analysis, each piece was given a unique 'Mac' number and subsequently cleaned in an ultrasonic tank with distilled water for ten minutes following the analytical protocols and methods devised by Shackley (2005: appendix).

The spectrometer is equipped with an end window Bremsstrahlung, air cooled, Rh target, 50 W, X-ray tube with a ≤7.6 micron (0.3 mil) beryllium (Be) window, an X-ray generator that operates from 4 to 50 kV in 1 kV increments (current range, 0–1.98 mA in 0.02 mA increments), and an Edwards RV8 vacuum pump for the analysis of elements below titanium (Ti). Data is acquired with a pulse processor and analog to digital converter. In this case, the samples were run under two analytical conditions. The samples were first run under a Mid Zb analysis condition with the X-ray tube operated at 30 kv using a 0.05 mm (medium) Pd filter in an air path for 200 s livetime to generate X-ray intensity Kα-line data for elements iron (Fe), zinc (Zn), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). The second was a High Zb analysis condition with the X-ray tube operated at 50 kv using a 0.63 mm (thick) Cu filter in an air path to detect the element barium (Ba). These elements have already been shown to be successful in distinguishing between the various West Mediterranean sources and subsources (see Crisci et al., 1994; Francaviglia, 1988; De Francesco et al., 2008; Freund and Tykot, 2011).

Trace element intensities were converted to concentration estimates by employing a least-squares calibration line ratioed to the Compton scatter established for each element from the analysis of international rock standards. These comprise AGV-2 (andesite), BCR-2 (basalt), BHVO-2 (hawaiite), BIR-1a (basalt), GSP-2 (granodiorite), QLO-1 (quartz latite), RGM-2 (rhyolite), SDC-1 (mica schist), STM-2 (syenite), TLM-1 (tonalite), and W-2a (diabase) from the US Geological Service [USGS], plus JR-1 and JR-2 (both obsidian) from the Geological Survey of Japan. In turn, the USGS standard RGM-2 is analyzed during each sample run to check machine calibration and accuracy. The data was then translated directly into Excel for Windows software for manipulation and analysis. Artifacts displaying anomalous values were re-run to ensure accuracy and precision. The quantitative results were ultimately compared with data generated from geo-referenced *in situ* geological samples of obsidian using the same instrumentation. Qualitative spectral overlays were also used to confirm the quantitative sourcing discrimination.

In addition to elemental characterization, each artifact was analyzed techno-typologically. This included recording attributes pertaining to flaking type (platform, bulb, lip etc.), to understand how the blanks had been knapped. Artifacts were also categorized as nodules, cores, flakes, blades, or angular waste, data that along with presence of cortex (divided into distinct percentage categories) allowed for the reconstruction of the obsidian reduction sequences. Only the percentage of dorsal cortex was recorded on the flake categories. This in turn allowed for the identification of the various forms in which obsidian entered the site prior to its

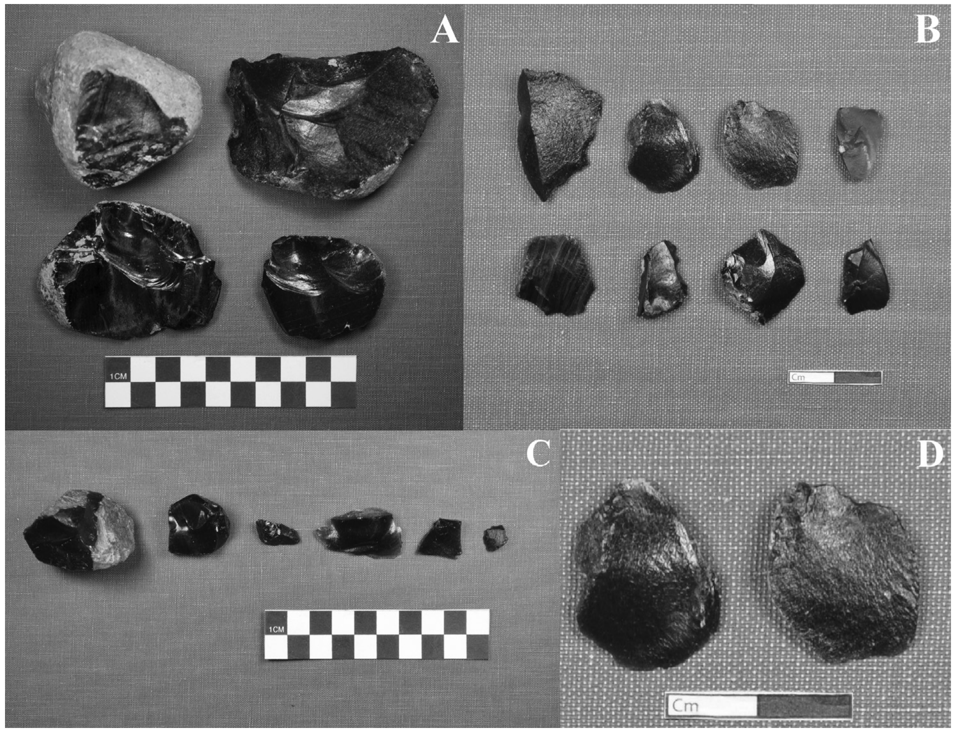

Fig. 3. Examples of artifacts from Bingia 'e Monti including, A) cores; B) lunates; C) SA obsidian artifacts; D) closeup of two Kombewa lunates (D. Aubert).

reduction. Finally, any form of deliberate modification in the form of retouch was documented as a means of describing Chalcolithic tool types.

6. Results

Using the data from Table 3, a bi-variate plot of the elemental ratios of rubidium (Rb) and strontium (Sr) to niobium (Nb) was produced to discriminate the various Sardinian source products (see Freund and Tykot, 2011), and to then to allocate each artifact to the source from which it originated (Fig. 5). Of the 146 artifacts analyzed, 138 were shown to be made of obsidian that came from the SC subsource. Seven artifacts were made of SA obsidian, while only a single artifact's raw material matched the chemistry of geological samples from the SB2 subsource. No SB1 obsidian was present in the studied assemblage. The percentage of SC obsidian is especially high when compared to other Chalcolithic sites near the SC subsource, although the Bingia 'e Monti data is not radically different from the general trend of the predominance of SC obsidian in archaeological assemblages in southern Sardinia. The abundance of SC obsidian at the site is likely a reflection of Bingia 'e Monti's proximity to the source, less than 15 km distant, compared to 18 km and 20 km, from the SA and SB source regions respectively (Fig. 1).

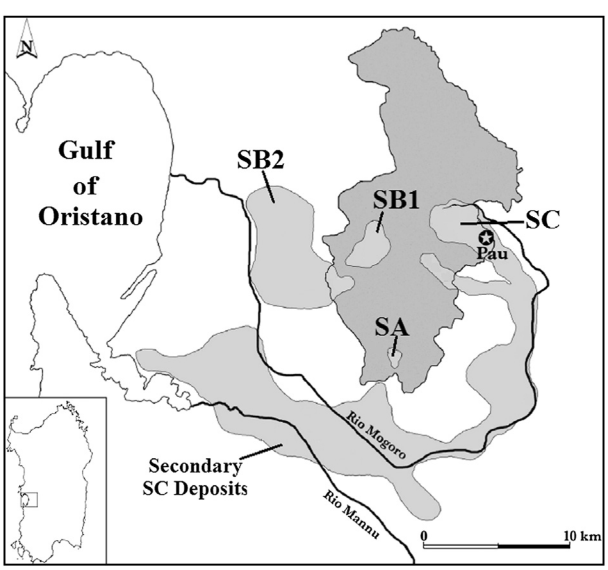

Fig. 4. Geological map of the Monte Arci obsidian source on the island of Sardinia (after Lugliè et al., 2006: 1000).

The analyzed artifacts comprise the full range of reduction debris related to the manufacture of flakes by direct percussion; in contrast to the Neolithic, blade technology was absent. The entire assemblage ($n = 154$) weighed 0.9 kg and contained one raw nodule, 20 cores, 118 flakes, and 15 pieces of angular waste. Fifty-five percent of artifacts had at least some cortex. When divided by source, the SC assemblage was composed of one nodule, 18 cores, 107 flakes, and 12 pieces of angular waste. Twenty SC artifacts displayed more than 80% cortex. Two of the seven artifacts made of SA obsidian were cores and the other five were either flakes or angular waste (see Fig. 3c, d). Both cores contained cortex, one between 60% and 80% and the other between 1% and 20% cortex. The sole artifact of SB2 obsidian was in the form of a retouched flake and displayed no cortex. The range of blank types suggests that the SA and SC obsidian was worked on-site, with the high occurrence of cortical debris indicating that these raw materials were procured in the form of raw nodules, the raw material having likely been procured by the inhabitants of Bingia 'e Monti direct from the source, only some 18 km and 15 km away (SA and SC respectively).

Just under a third of the artifacts were modified ($n = 44$), mainly in the form of simple marginal retouch. This included 29% ($n = 40$) of the SC artifacts and 29% ($n = 2$) of the SA artifacts. The sole SB2

Table 2
Results from previous sourcing studies on obsidian from Chalcolithic Sardinia (SA, SB and SC = sources; LN = Late Neolithic).

Site	Period	Artifacts analyzed	SA	SB	SC	Method	Citation
Bingia 'e Monti	Chalcolithic	146	7	1	138	XRF	This work
Cantoniera Frumini	Chalcolithic	20	9	2	9	Visual; XRF	Tykot, 1995, 2010
Monte d'Accodi	Chalcolithic	12	9	0	3	EMP-WDS	Tykot, 1995
Palmas Arborea	Chalcolithic	8	6	0	2	Visual; XRF	Tykot, 1995, 2010
Scaba 'e Arriu	LN-Chalcolithic	31	10	0	21	Visual	Ragucci and Usai, 2004; Usai, 2010
Serra de Castius	Chalcolithic	20	10	1	9	Visual; XRF	Tykot, 1995, 2010
Stazione La Gumarense	LN-Chalcolithic	18	8	2	8	Visual; XRF	Tykot, 2010
Su Casteddu Becciu	Chalcolithic?	16	6	1	9	Visual; XRF	Tykot, 1995, 2010
Su Coddu	LN-Chalcolithic	9	3	0	6	Visual	Tykot, 1995
Terramaini	LN-Chalcolithic	10	2	0	8	Visual	Tykot, 1995

artifact was a retouched perforator. While most of these artifacts can be considered the products of a low-skilled technology that were subsequently modified for the task at hand, there is one particular tool type in the assemblage that deserves further attention, the lunate (Fig. 3b). Lunates are best defined as small elliptical flakes with a natural or artificially backed margin. All of the eight lunates present in the assemblage were made of SC obsidian. Four SC lunate flake cores were also present (bottom right of Fig. 3a).

An important distinction must be made here with regard to reduction sequences surrounding lunate technology. While small elliptical backed pieces can be produced through an unspecialized manner of direct percussion, another method of production was also utilized. The Kombewa reduction strategy described and

Table 3
Elemental data of Bingia 'e Monti obsidians and *in situ* geological specimens as determined by EDXRF in parts per million (ppm). RGM-2 standard data is also included. Note that 'Mac' numbers are not consecutive because several pieces turned out not to be obsidian, but rather the rhyolites mentioned in the text, often similar to opaque SC obsidians.

Sample	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Type	Category	Sample	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Type	Category
SAPrim.001	12,104	92	254	29	41	100	57	161	SA	Geological	Mac063	14,264	66	166	136	27	244	34	1302	SC	Ang. Waste
SAPrim.002	11,809	84	242	26	36	90	50	134	SA	Geological	Mac064	14,719	82	163	132	26	248	26	1127	SC	Flake
SAPrim.003	13,492	100	267	27	41	97	50	158	SA	Geological	Mac065	13,825	65	163	117	24	240	26	1137	SC	Flake
SAPrim.004	14,825	121	290	32	45	106	54	139	SA	Geological	Mac066	10,522	68	215	26	32	84	44	155	SA	Core
SAPrim.005	12,486	93	262	29	37	99	49	162	SA	Geological	Mac067	13,460	66	165	118	23	246	29	1198	SC	Ang. Waste
SAPrim.006	11,988	84	252	29	37	101	50	168	SA	Geological	Mac068	14,457	64	145	146	21	224	26	1130	SC	Flake
SAPrim.007	12,904	94	275	31	38	99	54	171	SA	Geological	Mac072	15,949	78	172	145	28	261	30	1109	SC	Flake
SAPrim.008	13,124	131	246	27	33	95	51	154	SA	Geological	Mac075	13,237	115	153	106	23	210	22	874	SC	Flake
SAPrim.009	11,853	86	254	29	36	96	53	179	SA	Geological	Mac076	14,750	62	166	139	26	254	28	1171	SC	Flake
SAPrim.010	13,289	94	267	28	40	102	51	132	SA	Geological	Mac078	13,820	67	168	120	23	234	29	1115	SC	Flake
SAPrim.011	12,424	86	260	30	35	91	57	125	SA	Geological	Mac079	14,248	94	155	127	26	232	25	1136	SC	Flake
SAPrim.012	12,094	86	254	31	36	98	50	180	SA	Geological	Mac080	15,697	87	181	141	23	255	27	1154	SC	Flake
SAPrim.013	12,826	93	265	31	37	94	60	162	SA	Geological	Mac081	11,359	87	229	28	31	88	46	141	SA	Flake
SAPrim.014	11,396	73	244	29	33	92	47	143	SA	Geological	Mac084	15,405	83	191	142	27	255	34	1127	SC	Flake
SAPrim.015	11,934	84	256	30	37	99	60	163	SA	Geological	Mac086	13,768	66	163	131	27	238	29	1145	SC	Core
SB1Prim.002	13,516	72	231	79	28	169	35	564	SB1	Geological	Mac087	14,815	73	181	125	24	249	30	1177	SC	Flake
SB1Prim.003	11,666	53	216	58	30	128	38	412	SB1	Geological	Mac088	14,269	80	167	112	27	230	32	1037	SC	Flake
SB1Prim.004	14,317	58	227	82	23	191	31	676	SB1	Geological	Mac089	13,428	73	158	108	25	231	25	1102	SC	Flake
SB1Prim.005	13,530	67	233	75	26	172	34	563	SB1	Geological	Mac091	14,173	63	173	121	25	256	30	1172	SC	Flake
SB1Prim.006	15,563	83	258	72	34	143	48	360	SB1	Geological	Mac092	13,655	61	166	116	25	240	27	1263	SC	Flake
SB2Prim.001	12,275	61	237	49	25	138	28	352	SB2	Geological	Mac093	13,062	60	161	110	25	237	31	1168	SC	Core
SB2Prim.002	13,531	69	271	54	22	134	29	279	SB2	Geological	Mac094	17,251	75	197	132	30	268	36	1251	SC	Core
SB2Prim.003	11,611	55	250	38	24	121	30	219	SB2	Geological	Mac095	13,529	63	167	120	25	232	26	1137	SC	Flake
SB2Prim.005	11,800	56	237	50	24	139	31	346	SB2	Geological	Mac096	16,272	83	173	135	23	246	28	1101	SC	Flake
SB2Prim.007	10,904	42	215	34	24	113	29	214	SB2	Geological	Mac097	14,313	68	165	119	23	237	31	1114	SC	Flake
SB2Prim.008	12,184	52	251	34	23	118	28	193	SB2	Geological	Mac098	14,065	69	162	121	24	245	32	1208	SC	Core
SB2Prim.009	11,710	48	237	42	25	122	27	251	SB2	Geological	Mac099	13,656	70	155	118	23	232	29	1074	SC	Flake
SB2Prim.010	10,718	48	221	34	24	114	29	222	SB2	Geological	Mac101	16,252	80	187	135	24	268	27	1194	SC	Flake
SB2Prim.011	12,209	50	235	56	22	144	30	420	SB2	Geological	Mac102	17,153	81	173	162	23	254	29	1115	SC	Flake
SB2Prim.012	12,089	55	250	34	28	125	34	216	SB2	Geological	Mac103	15,590	64	157	165	28	252	35	1199	SC	Ang. Waste
SB2Prim.013	11,850	54	222	48	25	132	25	334	SB2	Geological	Mac104	13,081	85	156	110	27	225	24	1143	SC	Flake
SB2Prim.014	10,839	54	208	35	26	110	26	234	SB2	Geological	Mac105	13,696	61	165	116	26	236	31	989	SC	Core
SB2Prim.015	11,407	48	235	50	25	137	27	435	SB2	Geological	Mac106	13,017	72	158	108	28	221	28	1080	SC	Ang. Waste
SB2Prim.016	11,681	56	252	40	21	124	33	233	SB2	Geological	Mac107	14,441	60	173	127	24	249	27	1139	SC	Core
SB2Prim.017	12,149	53	237	56	25	145	27	398	SB2	Geological	Mac108	15,101	72	181	119	29	243	28	994	SC	Core
SCPrim.001	15,818	79	186	133	27	259	37	1216	SC	Geological	Mac109	13,868	69	171	118	28	249	27	1081	SC	Flake
SCPrim.002	15,000	70	180	130	26	257	30	1233	SC	Geological	Mac110	16,029	76	183	142	27	261	31	1142	SC	Core
SCPrim.003	15,095	71	182	121	26	253	33	1060	SC	Geological	Mac111	11,257	100	216	24	31	98	43	111	SA	Flake
SCPrim.004	14,513	65	179	128	27	256	26	1214	SC	Geological	Mac112	13,808	77	167	116	26	237	29	1104	SC	Flake
SCPrim.005	14,558	66	176	124	24	254	31	1228	SC	Geological	Mac113	14,417	66	173	118	28	245	31	1112	SC	Flake
SCPrim.006	15,546	75	179	131	29	254	30	1164	SC	Geological	Mac114	11,395	53	221	44	22	130	26	342	SB2	Flake
SCPrim.007	15,952	63	187	135	25	271	29	1386	SC	Geological	Mac115	14,199	67	172	122	24	244	33	1173	SC	Flake

Table 3 (*continued*)

Sample	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Type	Category	Sample	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Type	Category
SCPrim.008	14,196	61	170	123	24	245	31	1172	SC	Geological	Mac116	12,391	83	252	31	35	96	56	130	SA	Core
SCPrim.010	15,321	73	181	132	27	258	32	1142	SC	Geological	Mac117	12,873	51	154	117	28	233	28	1181	SC	Flake
Mac001	14,336	60	160	132	24	240	28	1080	SC	Flake	Mac118	15,208	80	170	142	22	257	30	1175	SC	Flake
Mac002	16,771	70	182	152	24	255	32	1144	SC	Flake	Mac119	14,638	62	176	122	25	252	29	1218	SC	Flake
Mac003	14,382	76	175	122	23	255	34	1168	SC	Flake	Mac120	12,577	62	157	118	22	232	30	1141	SC	Flake
Mac004	15,696	71	190	132	28	264	32	1185	SC	Flake	Mac121	12,809	55	148	111	21	224	27	1142	SC	Ang. Waste
Mac005	13,750	68	167	114	26	241	32	1130	SC	Flake	Mac122	14,021	69	171	120	28	246	32	1189	SC	Flake
Mac006	16,980	77	189	148	23	261	28	1083	SC	Flake	Mac123	13,896	72	176	118	24	250	30	1227	SC	Flake
Mac007	15,988	61	168	152	25	255	30	1059	SC	Flake	Mac124	14,764	64	174	116	23	244	26	997	SC	Core
Mac008	15,446	87	181	134	25	256	32	1269	SC	Flake	Mac125	13,696	64	165	117	23	234	29	1156	SC	Flake
Mac009	14,799	67	168	137	25	243	28	1081	SC	Flake	Mac126	14,018	74	169	115	27	247	27	1154	SC	Ang. Waste
Mac010	12,013	84	254	30	38	97	51	156	SA	Flake	Mac127	16,321	67	175	148	29	261	29	1134	SC	Flake
Mac011	17,958	70	191	153	28	269	33	1262	SC	Flake	Mac128	14,573	63	170	126	22	257	28	1194	SC	Flake
Mac013	16,407	72	170	156	24	262	30	1259	SC	Flake	Mac129	15,502	64	170	143	25	261	29	1345	SC	Flake
Mac014	15,069	67	172	135	26	253	32	1187	SC	Flake	Mac130	14,517	61	172	122	27	247	29	1081	SC	Flake
Mac017	16,658	71	177	154	26	260	32	1206	SC	Flake	Mac131	14,786	99	175	118	29	247	31	1134	SC	Flake
Mac018	13,530	76	167	119	28	241	29	1101	SC	Flake	Mac132	13,511	58	157	138	26	250	29	1380	SC	Flake
Mac019	14,880	73	165	142	26	243	27	1189	SC	Flake	Mac133	14,408	70	158	122	22	235	26	1087	SC	Flake
Mac020	15,194	104	178	130	28	255	31	1190	SC	Flake	Mac135	12,946	62	152	117	22	221	29	1110	SC	Flake
Mac022	14,095	60	149	148	27	244	30	1223	SC	Flake	Mac137	14,416	71	170	130	20	252	29	1169	SC	Flake
Mac023	12,463	78	255	29	36	102	51	154	SA	Flake	Mac138	16,350	78	184	135	25	259	33	964	SC	Flake
Mac024	15,206	71	173	132	25	246	30	1153	SC	Flake	Mac139	15,473	69	179	133	24	260	32	1157	SC	Flake
Mac025	15,760	76	184	128	24	255	32	1194	SC	Flake	Mac140	14,733	72	178	130	25	253	29	1151	SC	Flake
Mac026	15,348	77	175	139	27	252	32	1218	SC	Ang. Waste	Mac141	14,229	70	148	139	24	229	30	1248	SC	Flake
Mac027	15,162	68	177	128	23	237	29	1008	SC	Flake	Mac142	13,863	61	158	122	26	234	29	1157	SC	Core
Mac028	17,625	84	197	134	26	258	33	1113	SC	Flake	Mac145	15,422	71	179	130	28	261	32	1181	SC	Core
Mac029	14,373	70	170	126	25	246	31	1113	SC	Flake	Mac146	13,980	72	164	120	26	242	30	1206	SC	Flake
Mac030	16,564	73	179	159	30	269	33	1222	SC	Flake	Mac147	14,987	69	166	141	25	252	28	1150	SC	Flake
Mac031	13,086	70	151	106	28	227	27	1125	SC	Ang. Waste	Mac148	13,906	60	172	122	25	250	30	1192	SC	Ang. Waste
Mac032	15,235	64	179	126	26	254	31	1046	SC	Core	Mac150	15,598	64	170	151	26	260	31	1328	SC	Flake
Mac033	14,304	71	168	118	24	242	32	1086	SC	Flake	Mac151	14,747	61	164	141	24	244	29	1130	SC	Flake
Mac034	12,767	60	143	122	23	216	24	1026	SC	Flake	Mac152	15,485	73	177	124	28	248	34	1051	SC	Flake
Mac035	14,961	69	185	125	26	260	32	1279	SC	Flake	Mac153	14,656	66	179	121	26	251	33	1232	SC	Flake
Mac036	14,481	69	169	139	25	254	31	1221	SC	Flake	Mac154	16,572	80	195	130	33	267	32	1197	SC	Flake
Mac037	14,131	64	155	140	27	238	32	1178	SC	Core	Mac155	15,869	63	172	134	23	246	29	1004	SC	Core
Mac038	13,689	61	174	117	29	249	29	1197	SC	Flake	Mac156	15,076	73	179	128	26	244	29	1191	SC	Flake
Mac039	16,584	80	193	132	27	265	29	1158	SC	Flake	Mac157	13,916	56	160	118	27	243	29	1137	SC	Ang. Waste
Mac040	14,254	70	172	122	27	244	35	1106	SC	Ang. Waste	Mac158	14,213	70	169	121	27	250	31	1241	SC	Flake
Mac041	14,506	65	169	130	23	238	32	1074	SC	Flake	Mac159	14,390	59	173	117	26	250	32	1163	SC	Flake
Mac042	17,329	79	181	168	23	261	33	1232	SC	Core	Mac160	13,267	63	159	116	28	242	33	1254	SC	Flake
Mac043	13,893	74	146	132	24	225	26	1309	SC	Ang. Waste	Mac161	14,617	64	172	125	25	243	27	1101	SC	Core
Mac044	15,840	73	181	134	26	254	28	1120	SC	Core	Mac162	14,621	68	162	111	26	239	27	1098	SC	Flake
Mac045	13,977	79	159	121	22	231	31	1093	SC	Flake	Mac164	15,221	68	178	123	26	250	30	1126	SC	Flake
Mac046	14,804	69	180	121	28	249	35	1093	SC	Flake	Mac166	15,027	65	170	123	28	243	31	1031	SC	Nodule
Mac047	14,260	69	176	125	26	248	31	1128	SC	Flake	Mac167	12,509	58	152	104	23	222	28	1084	SC	Flake
Mac048	15,495	82	170	131	31	248	27	1142	SC	Flake	Mac168	15,759	69	179	156	28	260	28	1166	SC	Flake
Mac049	15,356	76	185	128	28	255	32	1117	SC	Flake	Mac170	14,804	64	163	132	25	239	30	1126	SC	Core
Mac050	15,502	77	184	126	27	257	28	1145	SC	Flake	RGM-2	13,970	34	142	101	25	226	7	797	–	Standard
Mac051	13,821	73	172	118	30	243	31	1127	SC	Flake	RGM-2	13,988	33	146	103	25	227	9	794	–	Standard
Mac052	16,076	82	168	147	23	254	28	1136	SC	Flake	RGM-2	13,958	41	143	101	26	230	9	763	–	Standard
Mac053	14,739	65	171	124	27	250	34	1145	SC	Flake	RGM-2	13,974	44	147	103	23	226	10	773	–	Standard
Mac055	18,302	92	191	139	26	263	33	1191	SC	Flake	RGM-2	13,927	38	142	102	23	224	9	780	–	Standard
Mac056	13,402	73	159	121	26	248	31	1246	SC	Flake	RGM-2	13,967	35	145	102	25	232	7	777	–	Standard
Mac057	13,348	67	154	113	21	227	26	1101	SC	Flake	RGM-2	13,925	36	144	103	26	228	14	812	–	Standard
Mac058	13,994	71	172	124	26	251	32	1148	SC	Flake	RGM-2	13,982	40	142	105	23	228	10	825	–	Standard
Mac059	11,017	84	218	29	35	94	50	151	SA	Ang. Waste	RGM-2	13,990	33	144	103	25	229	11	830	–	Standard
Mac060	13,720	74	164	116	26	238	31	1098	SC	Flake	RGM-2	13,977	41	144	104	25	225	11	829	–	Standard
Mac061	13,639	62	149	140	26	234	26	1160	SC	Flake	RGM-2	14,004	37	146	100	20	231	12	795	–	Standard
Mac062	14,218	78	172	120	25	249	27	1113	SC	Flake											

illustrated by Inizan et al. (1999: 68–71) occurs when a generally convex, semi-circular flake is removed from a core and subsequently used as a flake-blank for the creation of regularly shaped thin flakes. Lunates of this type typically have an obtuse platform angle and are traditionally associated with the Nuragic phases of the Bronze Age (see Freund and Tykot, 2011; Locci, 2004), where functional analysis has shown that they were often used for plant processing (Hurcombe, 1992). At Bingia 'e Monti, two Kombewa lunates were recovered (Fig. 3d). As such, this study pushes back the initial appearance of Kombewa technology in Sardinian obsidian assemblages to at least the Monte Claro phase of the Chalcolithic, although more evidence from additional sites is needed to confirm this assessment.

7. Discussion

The results from the Bingia 'e Monti study suggest that the residents of the site obtained obsidian directly from the SA and SC source areas. These two raw materials were mainly reduced on-site in exactly the same way using a relatively unskilled percussive technique for the manufacture of simple flake tools. In contrast, SC obsidian was the sole raw material used for the creation of lunates,

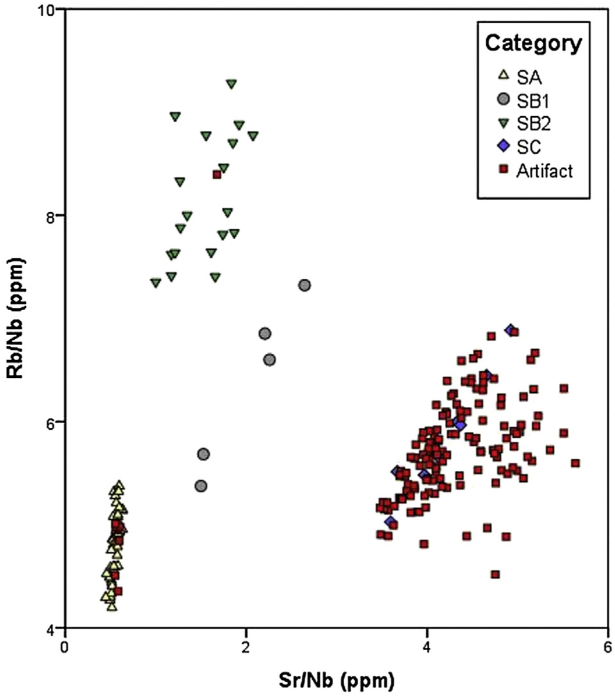

Fig. 5. Bi-variate plot of the elemental ratios of rubidium (Rb) and strontium (Sr) to niobium (Nb) in parts per million (ppm).

which is similar to lunate production in the Bronze Age Nuragic period (Freund and Tykot, 2011: 161).

The reduction strategies at Bingia 'e Monti contrast with the earlier Middle and Late Neolithic periods of Sardinia, where SC obsidian workshops produced core blanks that were circulated amongst populations on Sardinia and Corsica, while SA obsidian was specifically prepared as polyhedral blade cores for export to Corsica and further afield to populations in southern France (Lugliè, 2009; Lugliè et al., 2011; Vaquer, 2007). While the dominance of SC obsidian at Bingia 'e Monti (95%) is in line with general trends in Sardinia that began in the Late Neolithic (Tykot et al., 2008) and subsequently continued into the Nuragic phases of the Bronze Age (Freund and Tykot, 2011; Michels et al., 1984), the prevalence of SC obsidian in Chalcolithic assemblages is not universal. Indeed, previous analyses of obsidian at other Chalcolithic sites show that SA material was also commonly used (see Table 2). One must note, however, the dubious dating of many Chalcolithic sites.

To understand these differences, it is necessary to consider these sites' locations. Fig. 6 shows a map of Chalcolithic sites where at least eight obsidian artifacts have been elementally or visually characterized, displaying the proportions of the subsources represented at each. Note that other studies do not make the distinction between the SB1 and SB2 subsources and have thus been lumped together as just 'SB'. The map makes it apparent that there is a spatial patterning to the consumption of SA and SC obsidian. In general, sites to the north of the Monte Arci obsidian sources have more SA obsidian while assemblages to the south are mainly composed of SC material.

The end of the universal dominance of SC obsidian in Sardinia from the Late Neolithic to the Chalcolithic could be related to the concomitant collapse of organized obsidian workshops near the source areas (Lugliè, 2003). Without these workshops in place – crafting areas conceivably organized by specialists who also structured the materials' subsequent distribution – the entire network of obsidian circulation could have been reconfigured to more local modes of procurement. While broad similarities in both the composition of obsidian assemblages and in the reduction of the raw materials in the Late Neolithic have led scholars to posit that these objects were obtained through a model of down-the-line exchange (e.g. Tykot et al., 2008: 182), it is not known whether this is the case in the Chalcolithic. While we do know that Sardinian raw materials were procured at distance during the Chalcolithic at sites on mainland Corsica and Italy (Bigazzi and Radi, 1998; Hallam et al.,

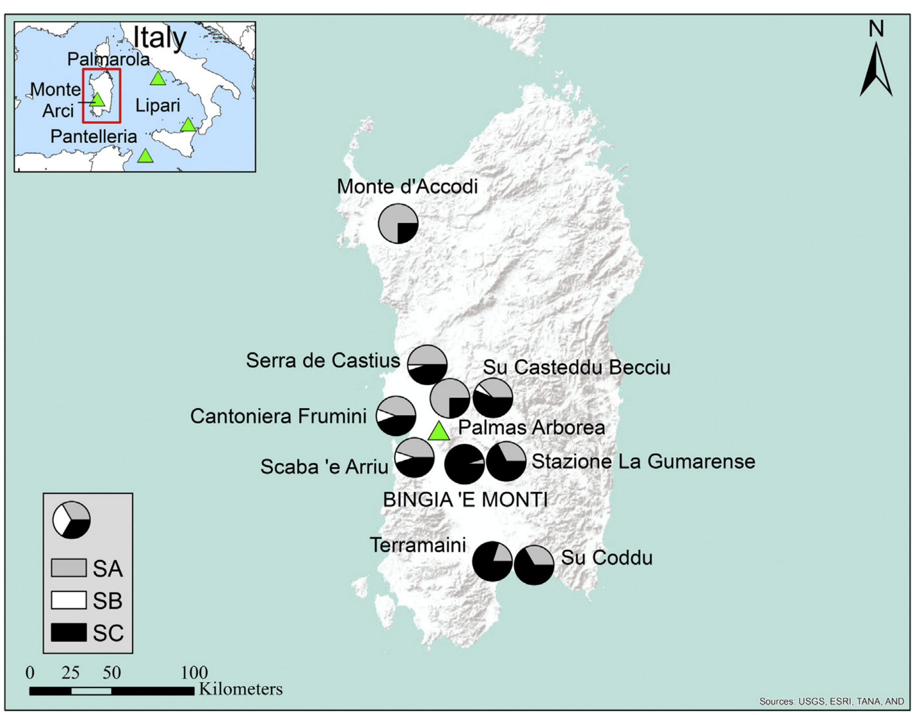

Fig. 6. Map of the spatial distribution of the various subsources in Chalcolithic archaeological assemblages with eight or more analyzed artifacts.

1976; Randle et al., 1993), it is difficult to say whether intra-island obsidian procurement at this time was the result of formalized exchange, especially with the lack of techno-typological data from this period.

This is an important question considering the role obsidian exchange likely played in creating and maintaining social relations across space (Renfrew, 1993). A reconfiguration of obsidian circulation networks from the Late Neolithic to the Chalcolithic could signal a larger shift in the socio-political landscape, where communities became more isolated and/or individually empowered, and more local traditions emerged.

8. Conclusions

This study represents an initial step towards a more comprehensive understanding of the nature of obsidian exploitation in Chalcolithic Sardinia (ca. 3200–2200 B.C.). Through a multi-facetted analysis of 154 obsidian artifacts from Bingia 'e Monti in south-central Sardinia, this paper argues that the site's residents obtained readily available SA and SC obsidian directly from the source areas and reduced the material on-site. While most of these artifacts can be considered the products of a largely unskilled and unstandardized technology that used both SA and SC obsidian, SC obsidian was specifically selected for the production of backed lunates. This is also the first documented case of Kombewa lunates in the Chalcolithic. By integrating these results within broader patterns of Chalcolithic obsidian distribution and use, it is further shown that obsidian exploitation at this time differs from earlier periods, possibly related to a reconfiguration of larger interaction spheres, where communities became more isolated and sub-regional traditions took form.

By employing an integrated elemental and techno-typological characterization, a wide range of archaeological questions can be addressed, far more than would be possible by chemical sourcing alone. Moving forward, it is critical to integrate data from all stages of an artifact's life history, including procurement, reduction, use, and discard, to more fully appreciate the cultural and socio-economic conditions that mediated its circulation, use, and value. It is only then that we can we make more informed archaeological interpretations about the nature of obsidian exchange in Chalcolithic Sardinia.

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