New directions in central Mediterranean obsidian studies

ROBERT H. TYKOT & ALBERT J. AMMERMAN*

Mediterranean obsidian-provenance studies are changing in direction and focus of modern research, with characterization of the Sardinian sources, application of minimally destructive and inexpensive analytical techniques, analysis of complete or large parts of assemblages, and the integration of provenance data with reduction technology and use-wear traces.

Recent years have seen much new research on the sources, distribution and use of obsidian in the Mediterranean during the Neolithic. The aim of this note is to present recent work on the central Mediterranean, and to discuss new directions in obsidian studies there. There has been important field research and chemical characterization of the geological sources in Sardinia; new non- or minimally-destructive, inexpensive analytical techniques are being applied to archaeological artefacts; the analysis of large numbers of artefacts — even the comprehensive sourcing of entire assemblages — is now stressed; and much greater emphasis is placed on the integration of provenance work with studies of reduction technology (production) and use-wear (consumption). In contrast with Williams-Thorpe's (1995) review of provenance studies in the Mediterranean and Near East, we see no sign that the pace of research on obsidian has declined in the last decade, nor that it will in the next. As is common for a success story in the sciences, it is the focus of research that has naturally shifted over time.

The Monte Arci (Sardinia) obsidian sources

Unlike the other three sources of obsidian in the western Mediterranean (Palmarola, Lipari and Pantelleria — all comparatively small islands), Sardinia comprises a larger land-mass and poses a greater challenge for investigation (FIGURE 1). Obsidian beds in the Monte Arci volcanic complex were first described by della Marmora (1839–40) and later by Washington (1913); in a comprehensive survey of the Monte Arci zone, Puxeddu (1958) found 246 locations with obsidian, including four which he classified as sources, in a zone of *c.* 200 sq. km. The later realization that at least three chemical groups (SA, SB, SC) were represented among analysed archaeological material raised questions about which sources were being utilised, since only one geological source (Conca Cannas) had been analysed (Cann & Renfrew 1964; Hallam *et al.* 1976), and both translucent and opaque obsidian had long been recognized in archaeological assemblages.

Following detailed geological surveys of the entire Monte Arci complex (Beccaluva, Deriu *et al.* 1974; Beccaluva, Maccioni *et al.* 1974; Assorgia *et al.* 1976), several attempts were made to characterize chemically the multiple obsidian outcrops. Results of the first study are available only in a brief conference paper (Mackey & Warren 1983); Francaviglia (1986) provides no details about the obsidian deposits themselves; and Herold (1986) made no attempt to match chemically-defined geological source groups with archaeological materials in his unpublished dissertation.

A more recent survey of the Monte Arci zone located the SC source *in situ* for the first time (Tykot 1992), and geological material from the five sources represented among archaeological artefacts has been fully described and chemically characterized in Tykot (1995a; 1997a; 1997b; *cf.* also Herold 1986) so only a summary is necessary here (FIGURE 2):

Type SA obsidian — very glassy, black but highly translucent, with nodules up to 40 cm —

Tykot, Department of Anthropology, University of South Florida, Tampa FL 33620, USA. rtykot@luna.cas.usf.edu
Ammerman, Department of the Classics, Colgate University, Hamilton NY 13346, USA.

Received 7 March 1997, accepted 4 June 1997, revised 2 September 1997.
ANTIQUITY 71 (1997): 1000–1006

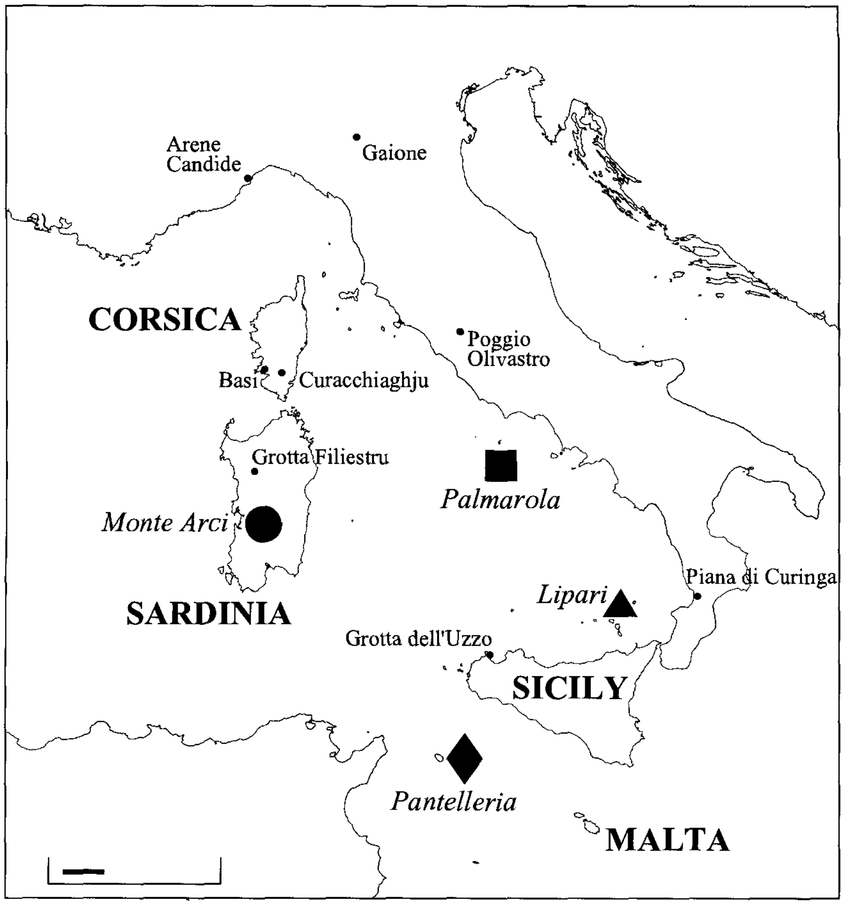

FIGURE 1. *Central Mediterranean obsidian sources and sites mentioned in the text.*

is found *in situ* near Conca Cannas and Su Paris de Monte Bingias. Individual microlite crystals are visible in transmitted light, often with some flow orientation.

Type SB1 — less glassy and black, but usually opaque — is found *in situ* at high elevations on Punta Su Zippiri and Monte Sparau North, and in the form of bombs up to 30 cm in length on the slopes of Cuccuru Porcufurau.

Type SB2 — often very glassy, ranging from transparent to nearly opaque — sometimes has phenocrysts up to 2 mm in diameter. Microlites are usually not present in the transparent variety. Type SB2 occurs in large blocks (occasionally up to 1 m in length) near Cucru Is Abis, Seddai, Conca S'Ollastu and Bruncu Perda Crobina.

Type SC1 — less glassy, black but frequently with well-defined external grey bands, and totally opaque (rare pieces have red streaks or are partially transparent but tinted brown) — is found *in situ* along the ridge from Punta Pizzighinu to Perdas Urias on the northeastern side of Monte Arci, in blocks up to 20 cm long.

Type SC2 — visually indistinguishable from SC1 — differs chemically only in its trace concentrations of strontium and a few other elements. It has only been found in detrital deposits between Perdas Urias and Santa Pinta, mixed with material of SC1 type; characterization of both SC1 and SC2 as simply SC suffices for archaeological purposes since it is unlikely that one type could have been selected over the other.

Methods of obsidian characterization and provenancing

While most provenance studies have relied on trace element analysis using INAA (e.g. Crummett & Warren 1985; Bigazzi *et al.* 1986;

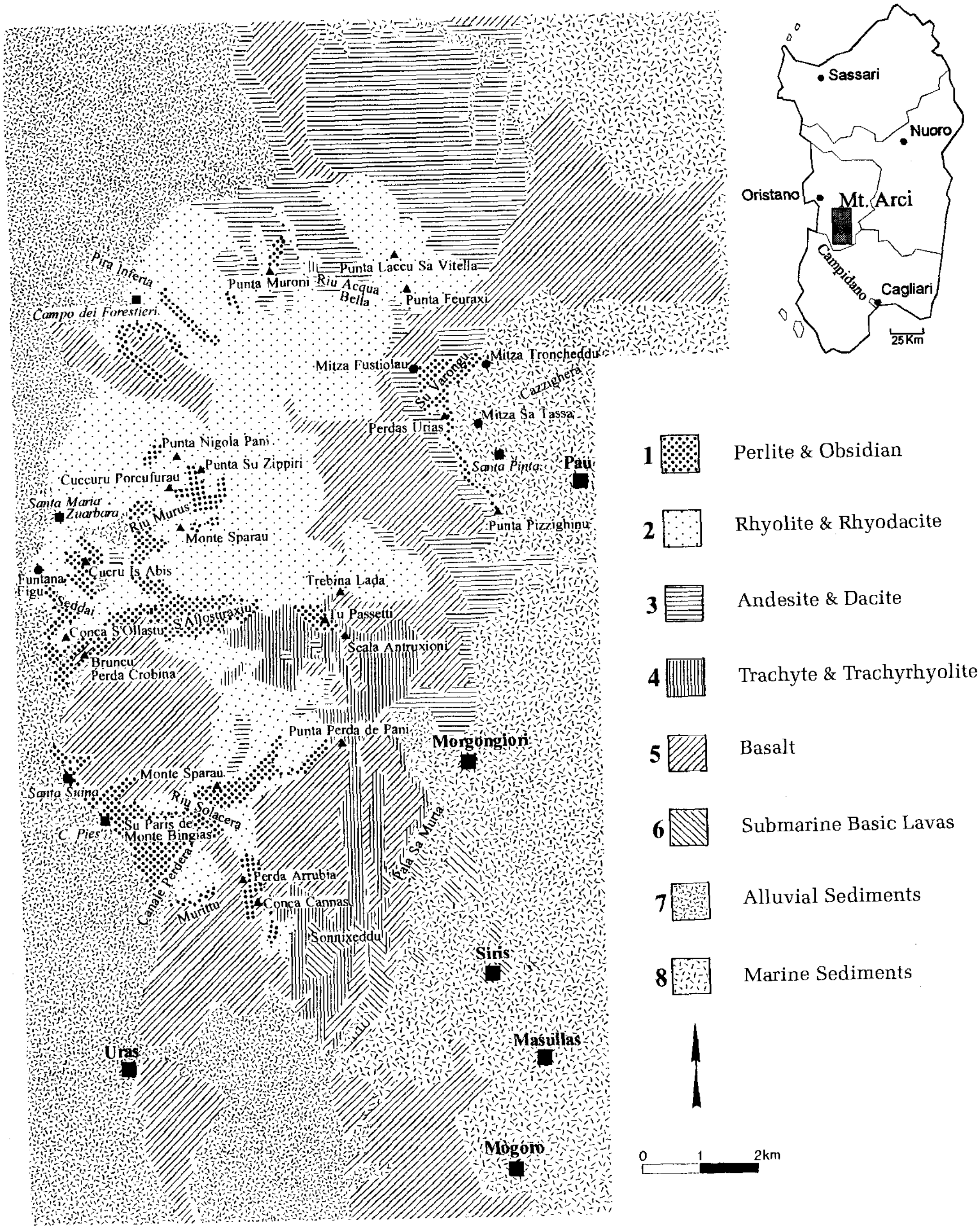

FIGURE 2. *The Monte Arci (Sardinia) obsidian sources.*

Ammerman *et al.* 1990; Bigazzi *et al.* 1992a; Meloni & Oddone 1992; Randle *et al.* 1993; Ammerman & Polglase 1993; 1997) or XRF (e.g. Francaviglia & Piperno 1987; Francaviglia 1988; Dyson *et al.* 1990; Crisci *et al.* 1994), all archaeologically significant distinctions among Mediterranean, European and Near Eastern obsidian sources (Lipari, Palmarola, Pantelleria, SA, SB1, SB2, SC, Melos, Giali, Carpathian 1 and 2, Acigöl, Çiftlik, Bingöl, Nemrut Dağ, and several other Anatolian and Armenian sources) can be made on the basis of major/minor element composition (Tykot 1995a; 1997a; Keller & Seifried 1990; Biró *et al.* 1986; Francaviglia 1986). This has permitted quantitative yet inexpensive and minimally destructive analysis (a sample 1 mm in diameter must be removed) using the electron microprobe, with wavelength dispersive X-ray spectrometers, of hundreds of archaeological artefacts from sites in the Mediterranean (Tykot 1995a; 1995b; 1996a; 1996b; 1997a; 1997b; forthcoming). Fission-track dating, a significant technique for discriminating among the four western Mediterranean islands (Arias *et al.* 1984; 1986; Bigazzi *et al.* 1992b), is unable to resolve the individual Monte Arci sources. Discrimination among the Monte Arci sources is critical: they were differentially exploited both geographically and chronologically (Tykot 1996a), and the distinction is necessary for hydration dating since the rate is source dependent (Michels *et al.* 1984; Dyson *et al.* 1990; Stevenson & Ellis in press).

Experienced investigators also can estimate the frequency of each obsidian source represented in a lithic collection by simple visual examination of the whole assemblage (for the start of controlled experiments of this kind, see Ammerman 1979). Tykot (1995a) was 100% accurate in assigning artefacts to Lipari, Pantelleria or Sardinia (none from Palmarola were present), with errors only in distinguishing the multiple Sardinian sources. In this study, 67·5% of the nearly 600 Sardinian artefacts visually examined were correctly assigned to a specific Monte Arci source, and another 16·2% to one of two possible sources (TABLE 1, top). Since many of the incorrect attributions were due to mistaking type SA and SB for each other, the overall frequency of each source represented was quite accurate (TABLE 1, bottom). The imprecision of visual determinations may be less significant than the sampling error commonly

	actual source				
	SA	**SB1**	**SB2**	**SC**	***total***
visual					
SA	102		38	6	***146***
SA?			2	2	***4***
SA/SB2	30		9	3	***42***
SB2/SA	28		4	3	***35***
SB		1	2	8	***11***
SB1					***0***
SB2	15		41	12	***68***
SB2?			8		***8***
SB/SC		1	5	11	***17***
SC		4	2	244	***250***
SC?				3	***3***
SC/SA				1	***1***
SC/SB				7	
?				2	***2***
total	***175***	***6***	***111***	***302***	***594***

	SA	**SB1**	**SB2**	**SB**	**SB/SC**	**SC/SA**	**SC**
visual	32·3	0·0	18·7	1·9	3·0	0·2	42·8
actual	29·5	1·0	18·7	0·0	0·0	0·0	50·8

TABLE 1. *Comparison of visual and actual (chemical) source attributions of Sardinian obsidian artefacts, by number (top) and by percentage (bottom)*

associated with chemical analysis of selected numbers of artefacts. Certainly, chemical analysis should be employed whenever there is any doubt in the visual attributions, or when the provenance of individual artefacts is critically important.

Research design and interpretative paradigms

The oft-cited obsidian provenance studies done at Bradford University (Hallam *et al.* 1976; Williams-Thorpe *et al.* 1979; 1984) established the limits of distribution of obsidian from individual sources, a picture which has, however, changed in recent years. In Northern Italy, for example, obsidian from Palmarola (seen only at one site near Trieste in early work) is now well documented at Arene Candide, Gaione and Fornace Cappuccini. Moreover, the small number of artefacts analysed from each site precluded the study of distribution patterns in more quantitative terms. In areas like central and northern Italy where multiple sources are likely to be present in any given lithic assemblage, the relative contributions of each source could not be determined. One early attempt to move beyond selective sampling was made at Gaione, a Middle Neolithic settlement near Parma in northern Italy (Ammerman *et al.* 1990), where attribution to source was first made for each piece in the assemblage on a visual basis and then 17 specimens were tested by INAA; the sourcing work was combined with detailed analysis of the reduction technology (Polglase 1990).

The subsequent study of Arene Candide in Liguria marked the full shift to a comprehensive approach to sourcing of obsidian at a site, when a total of 54 obsidian pieces — three times the previous number for a single site in northern Italy — was analysed by INAA at Milan (Ammerman & Polglase 1993; 1997). This study included all 26 obsidian artefacts from the Early Neolithic levels, and the results obtained proved to be quite different from earlier ones. In previous work on Arene Candide (Williams-Thorpe *et al.* 1979), only two pieces from these levels were analysed; both were attributed to Sardinia. In contrast, comprehensive sourcing showed that 15 (58%) of the Early Neolithic artefacts derived from Sardinia and 11 (42%) from Palmarola. The comprehensive approach also made it possible to document chronological change in the obsidian reaching Arene Candide; by the Late Neolithic, 7 of 8 artefacts (88%) came from Lipari. As at Gaione, the work on obsidian provenance was integrated with studies of reduction technology (only blades are present in the Late Neolithic levels) and use-wear. These studies extended our previous work on obsidian at Neolithic sites in Calabria, southern Italy (for bibliography, see Ammerman 1985). Since almost all of the obsidian artefacts in Calabria have the near-by island of Lipari as their source, there was the chance to go beyond provenance and develop studies that looked at obsidian production and tool use. In the Early Neolithic house in area H at Piana di Curinga, for example, close attention was paid to the spatial distribution of artefacts at the household level as well as reduction technology and use-wear (Ammerman *et al.* 1988; for more recent work on assessing function from use-wear, see Hurcombe 1992a; 1992b).

The research shift is also reflected in work done on Sardinia. At Grotta Filiestru (Mara) (Trump 1983), 86 randomly selected obsidian artefacts were chemically analysed, and an additional 581 visually provenanced (Tykot 1995a; 1996a). These analyses indicate that the use of clear, glassy SB2 obsidian from the western flanks of Monte Arci decreased over time, while the use of opaque, less-glassy type SC obsidian from the northeastern part of Monte Arci increased; type SA is never more than 20% of the assemblage. But in chemical analyses of 214 obsidian artefacts from Basi (Serra-di-Ferro) in Corsica (Bailloud 1969a; 1969b) type SA accounts for an average 40% of the assemblage and both SB varieties are never important; this pattern does not change significantly across nine stratigraphic levels encompassing the Early and Late Neolithic, a span of approximately 2000 years (Tykot 1995a; 1996a). Strong similarities in relative source representation between Early Neolithic sites in Sardinia, Corsica, the Tuscan archipelago and mainland Italy suggest multiple 'down-the-line' exchanges (Renfrew 1977).

In several other cases, small sample size has led to interpretative problems. Earlier work (Hallam *et al.* 1976) had indicated that type SB obsidian was particularly well represented on Corsica, especially at Curacchiaghju (Levie) where 8 of 9 analysed artefacts were from that source; in contrast, chemical analyses now of 428 artefacts from 17 sites suggests that type SB accounts for less than 20% of the obsidian in Corsica, and even less in the southern part of the island (Tykot 1995a; 1996a). In southern France, however, the preponderance of type SA obsidian suggested by earlier research (Hallam *et al.* 1976; Williams-Thorpe *et al.* 1984) has been corroborated by a recent larger-scale study (Crisci *et al.* 1994). In Sicily, the significant, continuous presence during the Neolithic of obsidian from Pantelleria at Grotta dell'Uzzo (Francaviglia & Piperno 1987) was surprising, since previous data had Lipari accounting for nearly all obsidian in Sicily and southern Italy. At Poggio Olivastro (Viterbo) (Bulgarelli *et al.* 1993) in central Italy, all 4 of the obsidian artefacts uncovered during the first excavation season are from Lipari, but none of the 213 artefacts since found are from Lipari (Tykot 1995a; 1996a)!

Distribution patterns, we now see, are only revealed by analysis of significant numbers of artefacts; such large analytical programmes need access to appropriate-sized artefact collections and, in most cases, the use of minimally destructive methods. INAA, certainly an excellent technique, is costly; XRF, using a non-destructive protocol for the analysis of selected elements (Crisci *et al.* 1994), is also viable, but it does not produce quantitative data that can be evaluated by other researchers. The combination of visual sorting and quantitative X-ray analysis using the electron microprobe permits most artefacts to be quickly and inexpensively analysed.

The status and future of obsidian research

Williams-Thorpe (1995: 240) laments that 'obsidian studies in the area under review have become rather static', and cites declining numbers of publications. Her list of publications is quite incomplete, however, in noticing only 32 items for the central Mediterranean since 1958, when we are aware of at least twice that number, including 16 from 1990–1994 (*cf.* Tykot 1995a: table IX). The efficacy of various analytical methods for obsidian provenance studies continues to be tested: examples include the use of the SEM with energy dispersive X-ray analysis (Acquafredda *et al.* 1996); back-scattered electron petrography (Kayani & McDonnell 1996a; 1996b); and precise measurements of density (Stevenson & Ellis in press). Certainly, provenance analysis of obsidian should be a routine part of archaeological investigations, and the fact that it is not is in part because of financial constraints; we hope to have demonstrated here that obsidian studies nevertheless are a vibrant part of Mediterranean archaeological research and that new analytical capabilities and interpretive possibilities justify the minimal costs necessary to investigate the exchange systems of prehistoric societies there.

References

ACQUAFREDDA, P., S. LORENZONI & E. ZANETTIN. 1996. Discrimination of Melos, Lipari, Palmarola obsidians using XRF and SEM-EDS, in G. Summers & F. Summers (ed.), *Archaeometry '94. Proceedings of the 29th international symposium on archaeometry, May 9–14, Ankara, Turkey*: 87–97. Ankara: Scientific and Technical Research Council of Turkey.

AMMERMAN, A.J. 1979. A study of obsidian exchange networks in Calabria, *World Archaeology* 11: 95–110.

1985. *The Acconia survey: Neolithic settlement and the obsidian trade*. London: Institute of Archaeology. Occasional Publication 10.

AMMERMAN, A.J., A. CESANA, C. POLGLASE & M. TERRANI. 1990. Neutron activation analysis of obsidian from two neolithic sites in Italy, *Journal of Archaeological Science* 17: 209–20.

AMMERMAN, A.J. & C.R. POLGLASE. 1993. The exchange of obsidian at Neolithic sites in Italy, in F. Healy & C. Scarre (ed.), *Trade and exchange in European prehistory*: 101–7. Oxford: Oxbow. Monograph 33.

1997. Analyses and descriptions of the obsidian collections from Arene Candide, in R. Maggi (ed.), *Arene Candide: a functional and environmental assessment of the Holocene sequence*: 573–92. Rome: Il Calamo. Memorie dell'Istituto Italiano di Paleontologia Umana 5.

AMMERMAN, A.J., G.D. SHAFFER & N. HARTMANN. 1988. A Neolithic household at Piana di Curinga, Italy, *Journal of Field Archaeology* 15: 121–40.

ARIAS, C., C. BERNARDES, G. BIGAZZI, F.P. BONADONNA, M.F. CESAR, J.C. HADLER NETO, C.M.G. LATTES, J.X. OLIVEIRA, A.M. OSORIO ARAYA & G. RADI. 1986. Identificação da proveniência de manufaturados de obsidiana através da datação com o método do traço de fissão, *Ciência e Cultura* 38: 285–308.

ARIAS, C., G. BIGAZZI, F.P. BONADONNA, M. CIPOLLONI, J.C. HADLER, C.M.G. LATTES & G. RADI. 1984. Fission track dating in archeology: a useful application, in P.L. Parrini (ed.), *Scientific methodologies applied to works of arts*: 151–9. Montedison Progetto Cultura.

ASSORGIA, A., L. BECCALUVA, G. DI PAOLA, L. MACCIONI, G. MACCIOTTA, M. PUXEDDU, R. SANTACROCE & G. VENTURELLI. 1976. Il complesso vulcanico di Monte Arci (Sardegna Centro-Occidentale): nota illustrativa alla carta geopetrografica 1: 50.000, *Bollettino della Società Geologica Italiana* 95: 371-401.

BAILLOUD, G. 1969a. Fouilles de Basi (Serra-di-Ferro — Corse): campagne 1968, *Corse Historique* 9(33): 49–64.

1969b. Fouille d'un habitat néolithique et torréen à Basi (Serra-di-Ferro — Corse): premiers résultats, *Bulletin de la Société Préhistoire Française* 66: 367–84.

BECCALUVA, L., M. DERIU, L. MACCIONI, G. MACCIOTTA & G. VENTURELLI. 1974. Il massiccio vulcanico di M.te Arci (Sardegna centro-occidentale): nota preliminare, *Rendiconti della Società Italiana di Mineralogia e Petrologia* 30(2): 1069–80.

BECCALUVA, L., L. MACCIONI, G. MACCIOTTA & G. VENTURELLI. 1974. Dati geologici e petrochimici sul massiccio vulcanico di Monte Arci (Sardegna), *Memorie della Società Geologica Italiana* 13(2): 387–405.

BIGAZZI, G., S. MELONI, M. ODDONE & G. RADI. 1986. Provenance studies of obsidian artifacts: trace elements and data reduction, *Journal of Radioanalytical and Nuclear Chemistry, Articles* 98(2): 353–63.

BIGAZZI, G., S. MELONI, M. ODDONE & G. RADI. 1992a. Study on the diffusion of Italian obsidian in the neolithic settlements, in *Atti del VIII convegno nazionale sulla attività di ricerca nei settori della radiochimica e della chimica nucleare, delle radiazioni e dei radioelementi, Torino, 16–19 giugno 1992*: 243–7. Torino: CNR and Università degli Studi di Torino.

1992b. Nuovi dati sulla diffusione dell'ossidiana negli insediamenti preistorici italiani, in Herring *et al.*: 9–18.

BIRÓ, T.K., I. POZSGAI & A. VLADER. 1986. Electron beam microanalyses of obsidian samples from geological and archaeological sites, *Acta Archaeologica Academiae Scientiarum Hungaricae* 38: 257–78.

BULGARELLI, G.M., L. D'ERME, E. PELLEGRINI & P. PETITTI. 1993. L'insediamento preistorico di Poggio Olivastro (Canino-VT): considerazioni e prospettive, *Bullettino di Paletnologia Italiana* 84: 435–80.

CANN, J.R. & C. RENFREW. 1964. The characterization of obsidian and its application to the Mediterranean region, *Proceedings of the Prehistoric Society* 30: 111–33.

CRISCI, G.M., M. RICQ-DE BOUARD, U. LANZAFRAME & A.M. DE FRANCESCO. 1994. Nouvelle méthode d'analyse et provenance de l'ensemble des obsidiennes néolithiques du Midi de la France, *Gallia Préhistoire* 36: 299–309.

CRÜMMETT, J.G. & S.E. WARREN. 1985. Appendix I: chemical analysis of Calabrian obsidian, in Ammerman (1985): 107–14.

DELLA MARMORA, A. FERRERO. 1839–40. *Voyage en Sardaigne: ou description statistique, physique et politique de cette île, avec des recherches sur ses productions naturelles et ses antiquités*. Paris: A. Bertrand.

DIXON, J.E. 1976. Obsidian characterization studies in the Mediterranean and Near East, in R.E. Taylor (ed.), *Advances in obsidian glass studies: archaeological and geochemical perspectives*: 288–333. Park Ridge (NJ): Noyes Press.

DYSON, S.L., L. GALLIN, M. KLIMKIEWICZ, R.J. ROWLAND, JR. & C.M. STEVENSON. 1990. Notes on some obsidian hydration dates in Sardinia, *Quaderni della Soprintendenza Archeologica per le Province di Cagliari e Oristano* 7: 25–42.

FRANCAVIGLIA, V.M. 1986. Characterization of Mediterranean obsidian sources by classical petrochemical methods, *Preistoria Alpina* 20 (1984): 311–32.

1988. Ancient obsidian sources on Pantelleria (Italy), *Journal of Archaeological Science* 15: 109–22.

FRANCAVIGLIA, V. & M. PIPERNO. 1987. La repartition et la provenance de l'obsidienne archéologique de la Grotta dell'Uzzo et de Monte Cofano (Sicile), *Revue d'Archéométrie* 11: 31–9.

HALLAM, B.R., S.E. WARREN & C. RENFREW. 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*. Unpublished Ph.D thesis, Universität (TH) Fridericiana Karlsruhe.

HERRING, E., R. WHITEHOUSE & J. WILKINS (ed.). 1992. *Papers of the fourth conference of Italian archaeology 3. New developments in Italian archaeology, part 1*. London: Accordia Research Centre.

HURCOMBE, L. 1992a. New contributions to the study of the function of Sardinian obsidian artifacts, in Tykot & Andrews: 83-97.

1992b. *Use wear analysis and obsidian: theory, experiments and results*. Sheffield: John Collis. Sheffield Archaeological Monographs 4.

KAYANI, P.I. & G. MCDONNELL. 1996a. An assessment of back-scattered electron petrography as a method for distinguishing Mediterranean obsidians, *Archaeometry* 38: 43–58.

1996b. The potential of the scanning electron microscope for non-destructive obsidian characterisation and hydration-rim dating research, in *Archaeological sciences 1995: proceedings of a conference on the application of scientific techniques to archaeology, Liverpool, June 1995*: 134–42. Oxford: Oxbow.

KELLER, J. & C. SEIFRIED. 1990. The present status of obsidian source identification in Anatolia and the Near East, in C. Albore Livadie & F. Widemann (ed.), *Volcanologie et archéologie: proceedings of the European workshop of Ravello, November 19–27, 1987 and March 30–31, 1989*: 57–87. PACT 25(4).

MACKEY, M. & S.E. WARREN. 1983. The identification of obsidian sources in the Monte Arci region of Sardinia, in A. Aspinall & S.E. Warren (ed.), *Proceedings of the 22nd symposium on archaeometry, University of Bradford, Bradford, UK March 30th–April 3rd 1982*: 420–31. Bradford.

MELONI, S. & M. ODDONE. 1992. Chemistry applied to archaeology: acquisition and statistical treatment of data, in Herring *et al.*: 3–8.

MICHELS, J., E. ATZENI, I.S.T. TSONG & G.A. SMITH. 1984. Obsidian hydration dating in Sardinia, in M.S. Balmuth & R.J. Rowland, Jr. (ed.), *Studies in Sardinian archaeology*: 83–113. Ann Arbor (MI): University of Michigan Press.

POLGLASE, C. 1990. Appendice I, in M. Bernabò Brea, A. Ghiretti, C. Polglase & V. Visconti, I siti neolitici lungo il torrente Cinghio (Parma), *Preistoria Alpina* 24: 140–55.

PUXEDDU, C. 1958. Giacimenti di ossidiana del Monte Arci in Sardegna e sua irradiazione, *Studi Sardi* 14–15 (1955–57): 10–66.

RANDLE, K., L.H. BARFIELD & B. BAGOLINI. 1993. Recent Italian obsidian analyses, *Journal of Archaeological Science* 20: 503–9.

RENFREW, C. 1977. Alternative models for exchange and spatial distribution, in T.K. Earle & J.E. Ericson (ed.), *Exchange systems in prehistory*: 71–90. New York (NY): Academic Press.

STEVENSON, C.M. & J.G. ELLIS. In press. Dating Sardinian archaeological obsidian, in M.S. Balmuth & R.H. Tykot (ed.), *Sardinian stratigraphy and Mediterranean chronology: studies in Sardinian archaeology* 5. Oxford: Oxbow.

TRUMP, D.H. 1983. *La Grotta Filiestru a Bonu Ighinu, Mara (SS)*. Sassari: Dessì. Quaderni della Soprintendenza Archeologica per le Provincie di Sassari e Nuoro 13.

TYKOT, R.H. 1992. The sources and distribution of Sardinian obsidian, in Tykot & Andrews: 57–70.

1995a. *Prehistoric trade in the western Mediterranean: the sources and distribution of Sardinian obsidian*. Ph.D dissertation, Harvard University. Ann Arbor (MI): University Microfilms.

1995b. Provenance of obsidian artifacts from Ustica, in R.R. Holloway & S.S. Lukesh (ed.), *Ustica 1: The results of the excavations of the Regione Siciliana Soprintendenza ai Beni Culturali ed Ambientali Provincia di Palermo in collaboration with Brown University in 1990 and 1991*: 51–3. Louvain-La-Neuve. Archaeologia Transatlantica 13.

1996a. Obsidian procurement and distribution in the central and western Mediterranean, *Journal of Mediterranean Archaeology* 9: 39-82.

1996b. The geological source of an obsidian ear (04.1941) from the Museum of Fine Arts, Boston, *Revue d'Egyptologie* 47: 177–9.

1997a. Characterization of the Monte Arci (Sardinia) obsidian sources, *Journal of Archaeological Science* 24: 467–79.

1997b. Mediterranean islands and multiple flows: the sources and exploitation of Sardinian obsidian, in M.S. Shackley (ed.), *Method and theory in archaeological obsidian studies*. New York (NY): Plenum.

Forthcoming. The provenance of obsidian found at the aceramic neolithic site of Kholetria *Ortos* (Cyprus), in A. Simmons (ed.), *Excavations at Kholetria Ortos (Cyprus)*.

TYKOT, R.H. & T.K. ANDREWS (ED.). 1992. *Sardinia in the Mediterranean: a footprint in the sea. Studies in Sardinian archaeology presented to Miriam S. Balmuth*. Sheffield: Sheffield Academic Press. Monographs in Mediterranean Archaeology 3.

WASHINGTON, H. 1913. Some lavas of Monte Arci, Sardinia, *American Journal of Science* 36: 577-90.

WILLIAMS-THORPE, O. 1995. Obsidian in the Mediterranean and the Near East: a provenancing success story, *Archaeometry* 37: 217–48.

WILLIAMS-THORPE, O., S.E. WARREN & L.H. BARFIELD. 1979. The sources and distribution of archaeological obsidian in northern Italy, *Preistoria Alpina* 15: 73–92.

WILLIAMS-THORPE, O., S.E. WARREN & J. COURTIN. 1984. The distribution and sources of archaeological obsidian from southern France, *Journal of Archaeological Science* 11: 135–46.