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Thasian marble sculptures in European and American collections: isotopic and other analyses

Robert H. Tykot, John J. Herrmann, Jr., Nikolaas J. van der Merwe, Richard Newman, and Kimberly O. Allegretto

Abstract No single analytical technique is usually sufficient to attribute a marble object unambiguously to a particular quarry source in the Mediterranean world, and a number of research groups have emphasized the importance of using a multi-method approach. One exception to this rule is Cape Vathy on the island of Thasos in the northern Aegean, an important marble source in antiquity. Cape Vathy appears to have been the only significant source of dolomitic marble used in the Mediterranean region. Stable isotope analyses of classical sculptures made of dolomitic marble are all consistent with a Thasian origin, indicating that a simple, inexpensive, and essentially non-destructive "dolomite test" can be used to determine whether a marble piece is from Cape Vathy.

Several hundred samples were collected from Greek and Roman statues and reliefs, in museums and private collections in Europe and the United States, that appeared to have been carved in marble from Cape Vathy on Thasos. X-ray diffraction (XRD) was used to test for the presence of dolomite, with the finding that 75% of the "Thasian"-appearing sculptures were in fact dolomitic. Stable isotope analyses of the dolomitic sculptures have reconfirmed their Thasian attribution; these analytical data serve to further refine the isotopic field for Thasian marble and may potentially allow the identification of discrete quarry areas exploited at different times in the past. Isotopic analyses of the calcite marble sculptures add to the more than 100 analyses that we have reported at ASMOSIA III and IV. As the number of sculptures with quarry attributions grows, contributions are made to our understanding of chronological, geographic, and art historical patterns in marble use.

INTRODUCTION

This report is based on the continuing interdisciplinary collaboration, now a decade old, between the Museum of Fine Arts, Boston, Harvard University, and, recently, the University of South Florida. This collaborative effort integrates the research interests of art historians, archaeologists, and laboratory scientists in the sources and exploitation of marble in classical antiquity, and exemplifies the purpose of ASMOSIA.

The marble used for Greek and Roman sculptures and architectural elements was obtained from many different quarries in the Mediterranean region, with the exploitation of individual quarries dependent on their geographical and political location, the color and texture of the marble, and the chronological period in question. A sculpture without archaeological provenance potentially could have been made of marble from any of more than 30 quarries in the Mediterranean region. The identification of the quarry source of a particular marble sculpture may be useful as a test of authenticity when archaeological provenance is uncertain, for the assessment of composite restorations, and as a means of corroborating stylistic analysis. The compilation of quarry provenance information on large numbers of sculptures allows the reconstruction of exploitation patterns and provides important insights into the nature of the Greek and Roman economy.

A single analytical technique, however, is rarely sufficient to attribute a provenance for a marble object unambiguously. The elemental and isotopic compositions of many quarries overlap with one another, as do the physical properties revealed by cathodoluminescence, electron paramagnetic resonance spectroscopy, and other methods.

We have previously emphasized the use of a minimally destructive, integrated approach using stylistic analysis, literary information, and archaeological data in conjunction with grain-size determination, XRD, and stable isotope analysis (Tykot *et al.*, 1993; van der Merwe *et al.*, 1995, 1999). For both XRD and stable isotope analysis, we have typically obtained powdered samples of a few milligrams or less. This approach has enabled us to analyze several hundred marble sculptures from a number of American and European collections, a number that would not have been possible if larger, solid samples were required. We are continuing to investigate auxiliary methods to clarify ambiguous provenance determinations, including trace element and isotope ratio analyses using inductively coupled plasma (ICP) mass spectrometry.

DOLOMITIC MARBLE

One of the most basic properties of marble is its mineral composition, most commonly calcite (calcium carbonate) but not infrequently dolomite (calcium-magnesium carbonate). Dolomitic marble is harder than calcitic marble, and the two can be easily distinguished using XRD on a few milligrams of marble powder, or even by simply observing the reaction rate of a sample with acid, since dolomite evolves CO_2 much more slowly. In the Mediterranean region, dolomitic marble has been identified at Crevola in the Italian Alps (Barbin *et al.*, 1991), Villette in eastern France, in Malaga province in southern Spain (Lapuente *et al.*, in this volume), and at Cape Vathy on Thasos in the northern Aegean (Herz, 1988) (Fig. 1). Most recently, a single sample of marble from Aphrodisias that we tested surprisingly turned out to be dolomitic – and extremely fine-grained.

Other marble sources contain some dolomite as an accessory mineral but are predominantly calcite. The identification of a marble sculpture as dolomitic, therefore, narrows the possible quarry sources to a handful at most. Furthermore, since it is likely that the western Mediterranean dolomitic marble sources were used primarily on a local basis, and mostly in the Roman period or later, a "dolomite test" has been considered an easy way to determine whether or not a central or eastern Mediterranean sculpture was made specifically of Cape Vathy marble.

Recent studies have shown that marble from the Cape Vathy area of northeast Thasos was widely used for sculpture throughout the central and eastern Mediterranean (Herrmann, 1990, 1992; Herrmann and Newman, 1995, 1999, in this volume). In Hellenistic times, Cape Vathy marble was used in Macedonia, northwest Asia Minor, and Egypt; during the Roman Imperial period it made its way to southern Greece and Italy as well. It saw an especially wide diffusion in the 2nd century AD, and exportation to Italy continued into the 5th century AD.

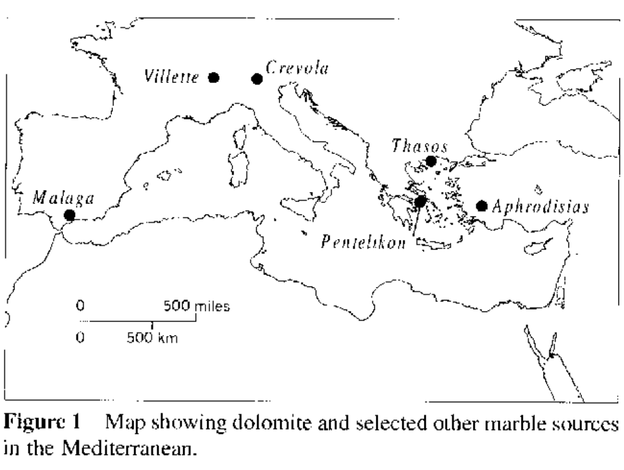

Figure 1 Map showing dolomite and selected other marble sources in the Mediterranean.

Thasos was also an important source of calcitic marble. In most cases, the difficulties of working the harder dolomite were mastered by local workshops, but in others a "Thasian" style accompanied the exported marble, and there is evidence that some figures were roughed out on Thasos and given a finishing touch at their destination. If sculptures in Thasian marble can be identified simply because they are dolomite when nearly all others are calcitic marble, this would not only serve to identify the provenance of these dolomitic sculptures positively but would also remove one important potential marble source from consideration when interpreting analytical results obtained using other techniques on calcitic marbles.

STABLE ISOTOPE ANALYSIS

The stable carbon and oxygen isotope ratios for Cape Vathy overlap with those for Paros, Prokonnesos, and other eastern Mediterranean marble sources; they apparently do not overlap with Crevola, and only partially with Villette and the Malaga sources (Fig. 2). Our one dolomitic sample from Aphrodisias falls within the Aphrodisias 1 field. While the Thasos quarries have been intensively studied, and Herz has made available the isotope data from his analyses, the number and geological context of the analyzed samples from Crevola and Villette are not available since only the outlines of the fields have been published (Barbin *et al.*, 1992: fig. 3). Details on the Malaga sources are only now being published (Lapuente *et al.*, in this volume).

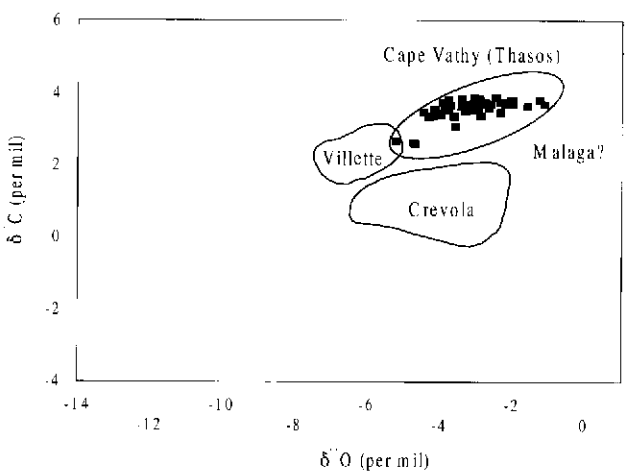

Figure 2 Stable carbon and oxygen isotope ratios of dolomite marble sources. Villette and Crevola fields after Barbin *et al.* (1992: fig. 3). Cape Vathy data from Herz (1987). For Malaga field, see Lapuente *et al.* (in this volume).

One aspect of our research has focused on the analysis of marble sculptures that appear to have been carved in marble from Cape Vathy on Thasos, for example the Museum of Fine Art's (MFA, Boston) Greco-Roman "Nelson head" (Fig. 4), found in Italy and originally identified as Parian

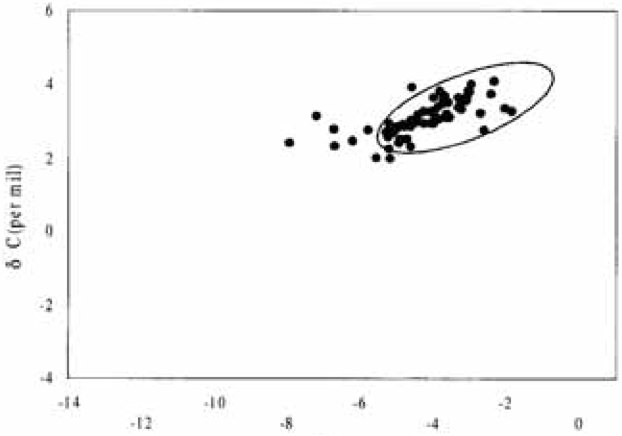

Figure 3 Stable carbon and oxygen isotope ratios of dolomite marble sculptures, shown with Cape Vathy (Thasos) isotope field. For sculptures with multiple analyses, isotopically depleted results are not illustrated.

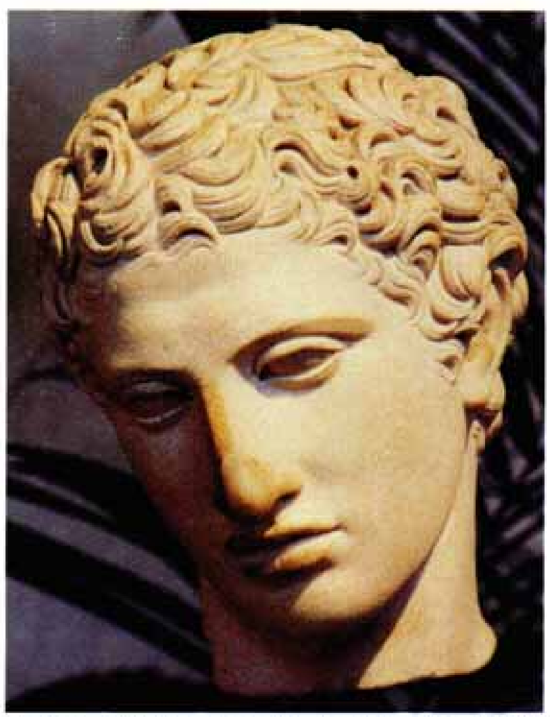

Figure 4 Museum of Fine Arts, Boston: "Nelson Head" (03.746).

marble (Comstock and Vermeule, 1976: no. 146). We first determine if the sculptures are dolomitic and then whether or not their isotopic values match geological specimens from Cape Vathy. Some 365 samples have been taken of Greek and Roman sculptures in 40 European and American collections. XRD analyses, and in some cases electron microprobe analysis, have demonstrated that nearly 75% of these samples are indeed dolomitic, thus reinforcing the premise that visual examination and knowledge of sculptural styles and practices are important complements to physical science data.

Stable isotope analysis, like XRD, can almost be a non-destructive technique. Only a few milligrams of marble powder are necessary to provide quantitative provenance information, an amount which may be removed from an already damaged or not readily visible spot on a sculpture. With both techniques, care must be taken to remove an unweathered, uncontaminated sample. For the isotopic analyses reported here, marble powder was reacted with 100% phosphoric acid in an evacuated Y-shaped glass tube at 90°C. Purified CO_2 was obtained through cryogenic distillation, sealed in glass ampoules, and analyzed on a VG stable isotope ratio mass spectrometer either at Harvard University or at the University of Cape Town.

The Cape Vathy (Thasos) marble source was initially studied and isotopically characterized by Herz (1988), who has generously shared his isotopic database with other scholars. Additional analyses by Eric Doehne (unpublished) have enlarged and better defined the field, and it would appear that it may eventually be possible to determine if different quarry areas have different isotopic ranges. If so, they could be associated with different periods of use, as is now well documented for example at Carrara.

Some dolomitic sculptures, including the Getty Kouros, were initially thought to be problematic but in fact do fall within the enlarged Cape Vathy field. Several of the 60 dolomitic sculptures that we isotopically tested, however, have depleted $\delta^{18}O$ ratios and fall outside the Cape Vathy isotopic field, as defined by analyses of geological specimens (Fig. 3; Table 1).

DISCUSSION

Rather than suggest that these sculptures are made of Thasian marble which has not been geologically sampled, it is much more likely that the isotopic depletion is due to weathering processes and/or contamination effects on our milligram size, near-surface sculpture samples. This interpretation is supported by additional analyses of powder from the same samples which produced a range of up to 2.5‰ in oxygen isotope ratios and up to 1.5‰ in carbon isotope ratios (MFA 68.768; TL 19.183; 1970.2442; 1970.267b; 1971.93). Isotopically depleted oxygen from ground or meteoric water may be incorporated during dedolomitization, while the formation of sulfates during environmental exposure also results in depleted isotope ratios, either of which could account for dolomite samples plotting to the left of the Cape Vathy isotopic field. We have specifically documented similar isotopic shifts in paired surface and interior samples from several other sculptures (Tykot *et al*., 1999 and references therein; see also Ulens *et al*., 1995, and for dolomite weathering, Doehne, 1992, 1994).

In our study, some samples were obtained prior to the recognition that exposed surfaces may be isotopically altered, while in all cases sampling was constrained by the sample location and size allowed by the host museums, which in some cases removed the samples themselves. These results emphasize the critical importance of obtaining

Table 1 Stable isotope data for dolomite marble sculptures. The lab no. column gives the Harvard Isotope sample number; the "dolomite test" column the presence of dolomite. XRD = X-ray diffraction; EM = electron microprobe.

Lab. no.	Museum or site	Museum no.	Reference	Description
58	Sackler Museum	1922.171	Vermeule and Brauer 1990: no. 20	Head of a Young Divinity, Hero, or Athlete
59	Sackler Museum	1969.175	Vermeule and Brauer 1990: no. 11	Head of a Kouros in Relief
90	MFA, Boston	08.205	Comstock and Vermeule 1976: no. 30	Three-Sided Relief (Boston Throne)
93	MFA, Boston	99.351	Comstock and Vermeule 1976: no. 167	Head of Aphrodite, Capitoline Type
111	MFA, Boston	63.2760	Comstock and Vermeule 1976: no. 344	Titus (Caesar A.D. 69–79, Emperor 79-81)
113	MFA, Boston	84.64	Comstock and Vermeule 1976: no. 111	Head from a Funerary Statue
115	MFA. Boston	41.909	Comstock and Vermeule 1976: no. 160	Dionysos
117	MFA, Boston	69.2	Comstock and Vermeule 1976: no. 242	Fragment of a Sarcophagus Relief
213	MFA, Boston	46.841	Herrmann 1992: 97	Head of a Boy
215	MFA, Boston	76.749	Comstock and Vermeule 1976: no. 257	Sarcophagus Fragment: Dionysiac Figure
223	MFA, Boston	1972.356	Comstock and Vermeule 1976: no. 243	Funerary Urn of Cassius
229	MFA, Boston	76.732	Comstock and Vermeule 1976: no. 267	Bearded Male Head
242	MFA, Boston	1980.212	Vermeule and Comstock 1988: no. 46	Funerary Relief
348	Sackler Museum	1991.64		Dionysus
358	MFA, Boston	98.641	Comstock and Vermeule 1976: no. 144	Polykleitan Hermes
359	MFA, Boston	03.744	Comstock and Vermeule 1976: no. 349	Lady of the Late Flavian Period
360a 360b	MFA, Boston	03.746	Comstock and Vermeule 1976: no. 146	Youth ("The Nelson Head")
362a 362b 362c	MFA, Boston	TL 19.183	Herrmann 1990: fig. 25	Corner of a Sarcophagus Lid
363a 363b	MFA, Boston	63.120	Comstock and Vermeule 1976: no. 105	Polyphemos
364 1528	MFA, Boston	68.768	Comstock and Vermeule 1976: no. 360	A General of the Antonine Period
365a 365b 365c	MFA, Boston	1970.242	Comstock and Vermeule 1976: no. 189	Tyche-Fortuna
367a 367b	MFA, Boston	1970.267b	Comstock and Vermeule 1976: no. 241	Fragment of a Meleager Sarcophagus (?)
368a 368b 368c	MFA, Boston	1971.93	Comstock and Vermeule 1976: no. 365	The Emperor Marcus Aurelius
1388	Polygiros Museum	A.E. 299		Portrait of a Man
1389	Polygiros Museum	A.E. 306		Portrait of a Man
1390	Polygiros Museum	A.E. 66		Statuette of a Girl
1391	Polygiros Museum	A.E. 1	Daux 1965: figs. 1, 3	Woman from a Heroon
1392	Polygiros Museum	A.E. 2	Daux 1965: fig. 2	Man from a Heroon
1393	Polygiros Museum	A.E. 4	Daux 1965: fig. 6	Portrait of a Man
1394	Polygiros Museum	A.E. 5	Daux 1965: fig. 5	Funerary Banquet Relief
1395	Thessaloniki Museum	A.E. 6738.742	Herrmann and Newman 1999: fig. 1	Temple at Thermi, threshold
1397	Thessaloniki Museum	A.E. 6735a/733		Temple at Thermi, ionic column
1398	Temple Olympian Zeus			Top of sculpture pedestal

Lab. no.	Museum or site	Museum no.	Reference	Description
1400	Kavala Arch. Mus.	62	Herrmann 1992: fig. 2	Female Portrait
1402	Kavala Arch. Mus.	6		Fragmentary Bearded Head
1404	Kavala Arch. Mus.	160	Herrmann 1999: fig. 16	Togatus
1405	Lyon Musée	w247	Herrmann and Newman 1999: fig. 13	Altar of Aufidia Antiochis
1406	Lyon Musée	CFAII no. 505	Wuilleumier 1951: no. 5	Face of God
1407	Ostia Museum	55	Calza 1947: 13, 44	Q. Aurelius Simmachus?
1409	Thasos Museum	555	Herrmann and Newman 1999: fig. 6	Small Head of Boy
1410	Thasos Museum	937	Holtzmann 1989: fig. 113	Portrait of Julian
1412	Thasos Museum	2108	Rolley 1964: figs. 22-25	Torso of Youth
1413	Thasos Museum	41		Late Male Portrait
1414	Thasos Museum	2107	Rolley 1964: figs. 10-15	Torso of Athlete
1415	Thasos Museum	556		Youth with Wreath
1416	Thasos Museum	547	Herrmann 1999: figs. 10-11	Portrait of Girl
1417	Thasos Museum	552	Holtzmann 1989: fig. 106	Small Head of Satyr
1418	Thasos Museum	37	Herrmann and Newman 1995: fig. 15	Eros Sleeping
1419	Thasos Museum	2655		Female Portrait
1420	Thessaloniki Arch. Mus.	833	Thespinis et al. 1997: no. 77	Upper Body of Athena
1421	Thessaloniki Arch. Mus.	3	Rüsch 1969: 17	Woman with Bun
1423	Thessaloniki Arch. Mus.	3134		Head of a Youth
1424	Thessaloniki Arch. Mus.	61	Rüsch 1969: 19	Portrait of a Girl
1425	Thessaloniki Arch. Mus.	1051	Rüsch 1969: 32	Portrait of a Woman
1426	Thessaloniki Arch. Mus.	6686 or 10812		Female Portrait
1427	Thessaloniki Arch. Mus.	1017	Thespinis et al. 1997: no. 80	Head of a Bearded God
1428	Thessaloniki Arch. Mus.	10118	Lewerentz 1993: S8	Man in Himation
1429	Thessaloniki Arch. Mus.	1255	Thespinis et al. 1997: no. 83	Large Herculaneum Woman
1430	Thessaloniki Arch. Mus.	1.dA.1		Classical Grave Relief
1431	Vatican Museums	3459		Head of Goddess
1432	Vatican Museums	631 (not 4165)		Portrait of Boy
1433	Vatican Museums	4549	Kashnitz-Weinberg 1936: no. 220	Unfinished Head with Pine Wreath
				average
				std. dev.
250a	MFA, Boston	76.729	Comstock and Vermeule 1976: no. 253	Fragment of a Muse Sarcophagus
250b	MFA, Boston	76.729		Fragment of a Muse Sarcophagus
878a	MFA, Boston	76.729		Fragment of a Muse Sarcophagus
878c	MFA, Boston	76.729		Fragment of a Muse Sarcophagus
879a	MFA, Boston	76.729		Fragment of a Muse Sarcophagus
879b	MFA, Boston	76.729		Fragment of a Muse Sarcophagus
880a	MFA, Boston	76.729		Fragment of a Muse Sarcophagus
				average
				std. dev.

subsurface samples even when the exposed surface appears to be clean or from a fresh break.

Even unweathered/uncontaminated samples may cause problems, if the small sample typically used for isotopic analysis is not representative of the whole sculpture. The MFA's fragment of a Muse Sarcophagus (Fig. 5) initially tested positive for dolomite, but isotopically it was not even close to the Cape Vathy field. Reanalysis by both XRD and stable isotopy of several samples from different areas of the same piece revealed a varied mineralogical composition, including some samples with significant quantities of dolomite and mica. We have concluded that it is probably made of Pentelic marble. Isotopic analyses of ten dolomitic sculptures from the J. Paul Getty Museum by Herz (in Herrmann, 1992) also revealed two with values well outside the Cape Vathy isotopic field and closer to Pentelikon or Naxos. Re-sampling and analysis of these sculptures are also desirable.

There are some additional cautionary points to be made as well concerning the identification of dolomitic marble from Thasos. At Asmosia II we reported on the isotopic analysis of eight dolomitic sculptures in the MFA and at the Harvard University Art Museums, including a head (Fig. 6) previously mounted on a Capitoline Aphrodite (Herrmann, 1992). The identification of the head as dolomitic was particularly significant since it appeared dull and fine-grained rather than glittering white and coarse-grained. The apparent conclusion to be drawn from this example is that there existed some fine-grained dolomitic marble at Cape Vathy that is no longer available today, and it is likely that additional fine-grained dolomitic sculptures in existing collections have not yet been recognized.

Finally, the isotopic characterization and distribution of dolomitic marble from Villette in France and the Malaga quarries in Spain is not yet well known, so we must be careful when dealing with sculptures from the central or western Mediterranean during the Roman Imperial period, especially the 2nd century AD.

CONCLUSION

In 1968, William Young at the MFA Research Laboratory knew of only one dolomitic marble source in the Mediterranean, and this led him to conclude that both the Boston three-sided relief (Fig. 7) and the Ludovisi Throne in Rome were of Thasian marble (Young and Ashmole, 1968). This is not the place to argue over the authenticity and relationship of these two pieces (but see Newman and Herrmann, 1995). We would, however, certainly make the same argument today, some 30 years later, that both pieces are made of marble from Cape Vathy on Thasos.

Our study suggests then that with properly obtained samples a "dolomite test" is sufficient to determine whether or not a sculpture with stylistic connections to the eastern Mediterranean is made of marble from Cape Vathy, Thasos. It appears highly unlikely that any other Mediterranean source of dolomitic marble was exploited to a significant extent in this region in antiquity.

Figure 5 Museum of Fine Arts, Boston: Fragment of a Muse Sarcophagus (76.729).

Figure 6 Museum of Fine Arts, Boston: Head of Aphrodite (99.351).

Figure 7 Museum of Fine Arts, Boston: Three-Sided Relief (08.205).

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AUTHORS' ADDRESSES

Kimberly O. Allegretto, Archaeometry Laboratory, Department of Anthropology, Harvard University, 11 Divinity Avenue, Cambridge, MA 02138, USA

John J. Herrmann, Jr., Art of the Ancient World, Museum of Fine Arts, Boston, 465 Huntington Avenue, Boston, MA 02115-5523, USA

Richard Newman, Department of Objects Conservation and Scientific Research, Museum of Fine Arts, Boston, 465 Huntington Avenue, Boston, MA 02115-5523, USA

Robert H. Tykot, Department of Anthropology, University of South Florida, 4202 East Fowler Avenue, SOC107, Tampa, FL 33620-8100, USA

Nikolaas J. van der Merwe, Archaeometry Laboratories, Peabody Museum, Harvard University, 11 Divinity Avenue, Cambridge, MA 02138, USA (currently Archaeology Department, University of Cape Town, Private Bag, Rondebosch 7701, South Africa)