The Science of Cycladic Authentication

Timeline, Testing Methods Performed and Research Results for Mediterranean Lady Sculpture

August 2019

Face view of the marble sculpture (aka Mediterranean Lady) showing the glittery mica that defines the ancient aligned regional metamorphic fabric of the calcite marble rock from which it was tooled. Identical native rocks and statues are well known from the Greek Cycladic islands.

Introduction

Starting in October 2015 the owner began a dialogue with geological and art history consultants concerning a statue purchased by the owner many years earlier at auction in the Hudson Valley. Initial discussions revolved around the unique appearance and physical properties of the marble sculpture (aka The Mediterranean Lady Statue [MLS]) and its striking similarities to verified Cycladic statue art. To verify authenticity, i.e. as a bona fide ancient work of art, a multi-disciplinary scientific research program was developed and then modified, as early results allowed the team to learn more about the object's apparent origin, to pursue directed research towards the MLS's provenance and authentication.

An initial explanation for the Mediterranean Lady statue was by a sculpture consultant who suggested the statue was originally composed of "terra cotta" then fused by the eruption of Thera volcano on Santorini island in the mid-2nd millennium BCE. A romantic vision, this consultant proposed that the Thera eruption covered the Cycladic sculpture with ash and transformed the clay-rich terra cotta material into a fused glass to explain the "glassy" texture seen especially on the left foot. Yet, the volcanic eruption of Thera on the island of Santorini is dated about 1,550 - 1,650 BCE which is outside the recognized time interval of Cycladic statue production (3,500-2,100 BCE). The ultra Plinian eruption blew Santorini island apart, produced destructive tsunami and covered the region with an areally extensive volcanic ash layer which eliminated the Minoan civilization settlement at Akrotiri and induced broad climatic change. Our scientific investigations have rebuked this impractical and temporally incorrect MLS volcanogenic model.

Figure 1 – Lateral supine view of the Mediterranean Lady statue (MLS) calcite marble sculpture.

The initial examination of the statue by our team in the owner's home in November 2015 immediately disqualified the romanticized theory of a "fused terra cotta" origin, confirming instead that the sculpture consisted of a regional metamorphic rock. Without incurring physical damage to the sculpture to provide test samples, the team concluded that the sculpture appeared to be micaceous marble. Such marbles were well known from the Greek Cyclades and typically used in authentic Cycladic statue art.

Sampling was performed in early and mid-2016 by carefully core drilling the foot (Figure 2) in order to extract fresh rock for initial analysis to determine the gross mineralogy of rock mass and to later extract a sample for microprobe geochemical analysis and for geochronologic isotopic testing.

Figure 2 – Core drilling of MLS in NYC to extract testing samples.

In 2017 and 2018 chemical analysis and isotopic testing of the drilled samples was performed at the American Museum of Natural History in NYC and also at the Lamont-Doherty Earth Observatory of Columbia University in Palisades, NY. In the meantime, marble samples from known Greek quarries were obtained from a marble importer in central Long Island who dealt directly with the quarry owners on these islands. These samples were analyzed to provide a comparative geochemical analysis of the statue rock core drilling with known modern quarry sources in the Greek Cycladic marble district (Figure 3).

Figure 3 – Typical modern quarrying operation of Cycladic marble on Naxos.

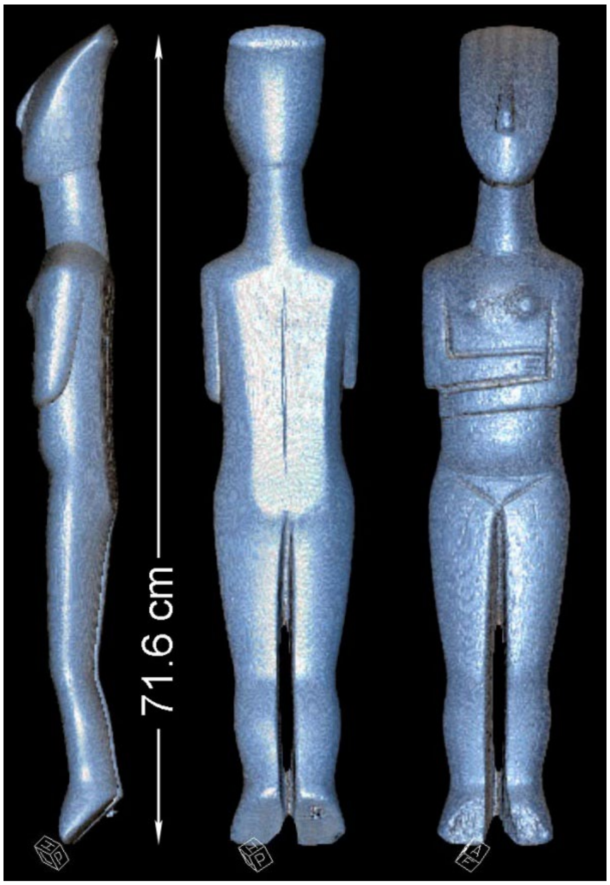
Our efforts were directed toward identifying expert members of the scientific community who could apply the most current scientific tools and methodologies deemed imperative toward demonstrating a scientific connection between the owner's Mediterranean Lady sculpture and the Greek Cycladic islands at the time of its creation. This report summarizes the results of our joint research efforts between 2015 and 2019 which included radiographic scans, photo-imaging and mineralogical and geological studies, two batteries of major, rare and trace-element geochemical analyses of the statue interior and patina materials as well as geochemical testing of modern quarry marble samples from the islands of Naxos, Paros and Thasos. Lastly, of significant proof, Cl^{36} (chlorine-36) isotope studies have established an ancient exposure (quarrying) age for the statue rock. Together the scientific test data establishes the age, probable provenance and attribution of the statue. Individual research reports referenced herein are found in the appendixes attached at the end of this report.

This report will first describe the Mediterranean Lady statue sculpture (MLS) based on our measurements and visual examination. A discussion of Cycladic civilization and Cycladic statue art follows in order to set the context for describing the integrated techniques used and the results of our scientific investigations. The report below is divided by the following major headings:

- **Physical Attributes of The Mediterranean Lady Statue (MLS)**
- **Cycladic Civilization**
- **Provenance of the Mediterranean Lady Statue**
- **The Scientific of Cycladic Authentication**
- **Summary**
- **References Cited**

Physical Attributes of The Mediterranean Lady Statue (MLS)

After preliminary testing of statue material determined the overall composition and lithology of the statue, Dr. John Melnick of our team performed cat scans (CT) of the sculpture (Figure 4). This technique, which measures density contrast showed a radiologically homogenous statue rock interior and a thin (0.3mm) but persistent weathering rind or patina surrounding the entire statue suggesting long-duration chemical weathering at or near the earth's surface over millennia (Figures 5 through 7). Precise CT measurements provide the following:



Dimensions:

71.6 cm total length [29.8”]

14.1 cm width at shoulders [5.6”]

6.8 cm depth at breast [2.8”]

7.6 cm depth at nose [3.2”]

Figure 4 – CT radiographs of calcite marble statue. (Courtesy Dr. John Melnick.)

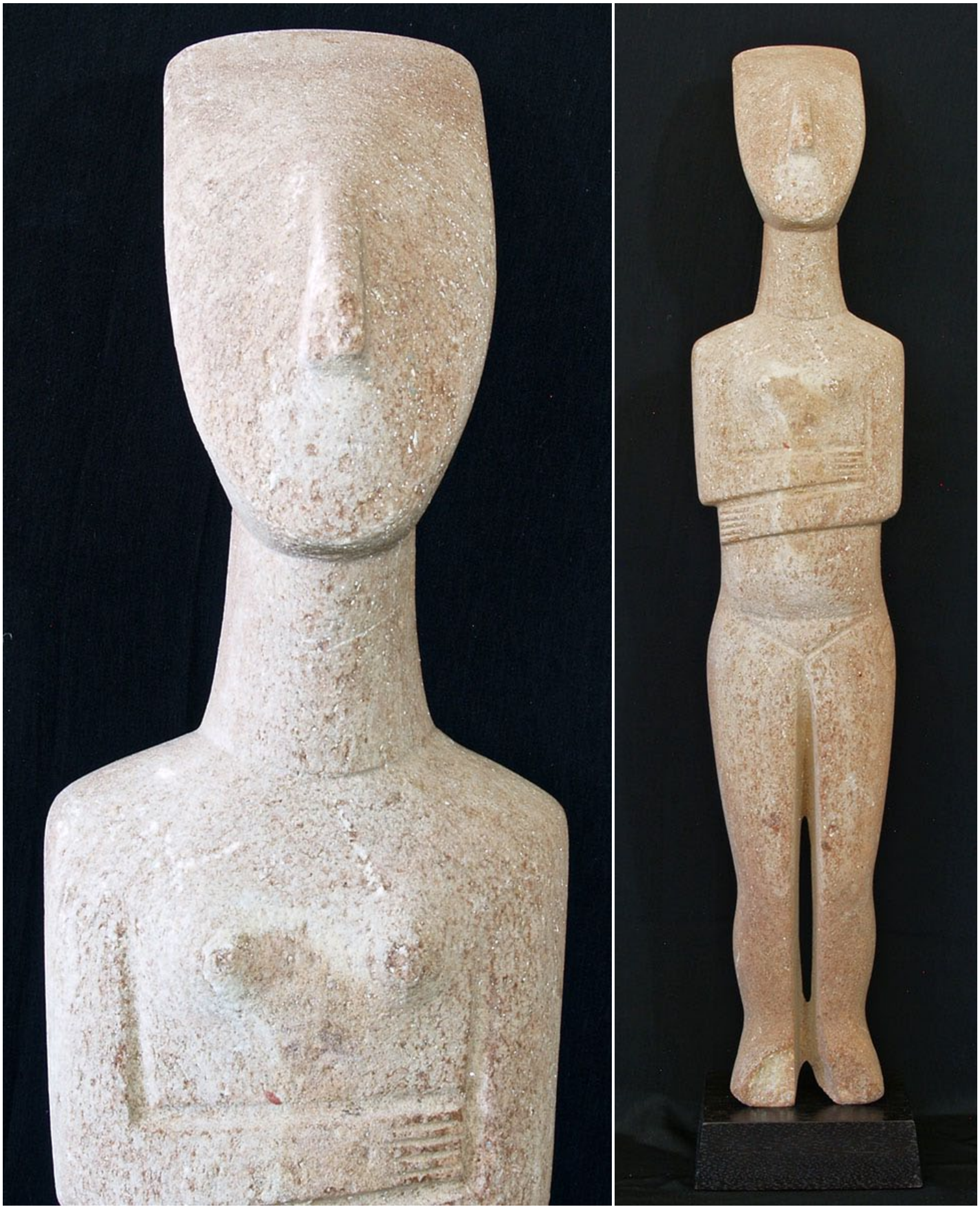


Figure 5 – Additional views of the MLS calcite marble sculpture.

Figure 6 – Profile view of The Mediterranean Lady statue head.

Figure 7 – Close-up view of the MLS's feet that shows the broken toes, ancient and modern damage to the left foot exposing the non-weathered interior calcite marble rock and the pinkish, thin (0.3 mm) outer weathering patina.

Cycladic Civilization

Geography

Geographically, the Cyclades represent an archipelago in the temperate zone, bordered by three continents. It is situated in the Aegean Sea and connected via the Hellespont (the Dardanelles), Sea of Marmara, Bosporus, the Black Sea and the Danube (Figures 8, 9).

Figure 8 – Map of the Greek Aegean region.

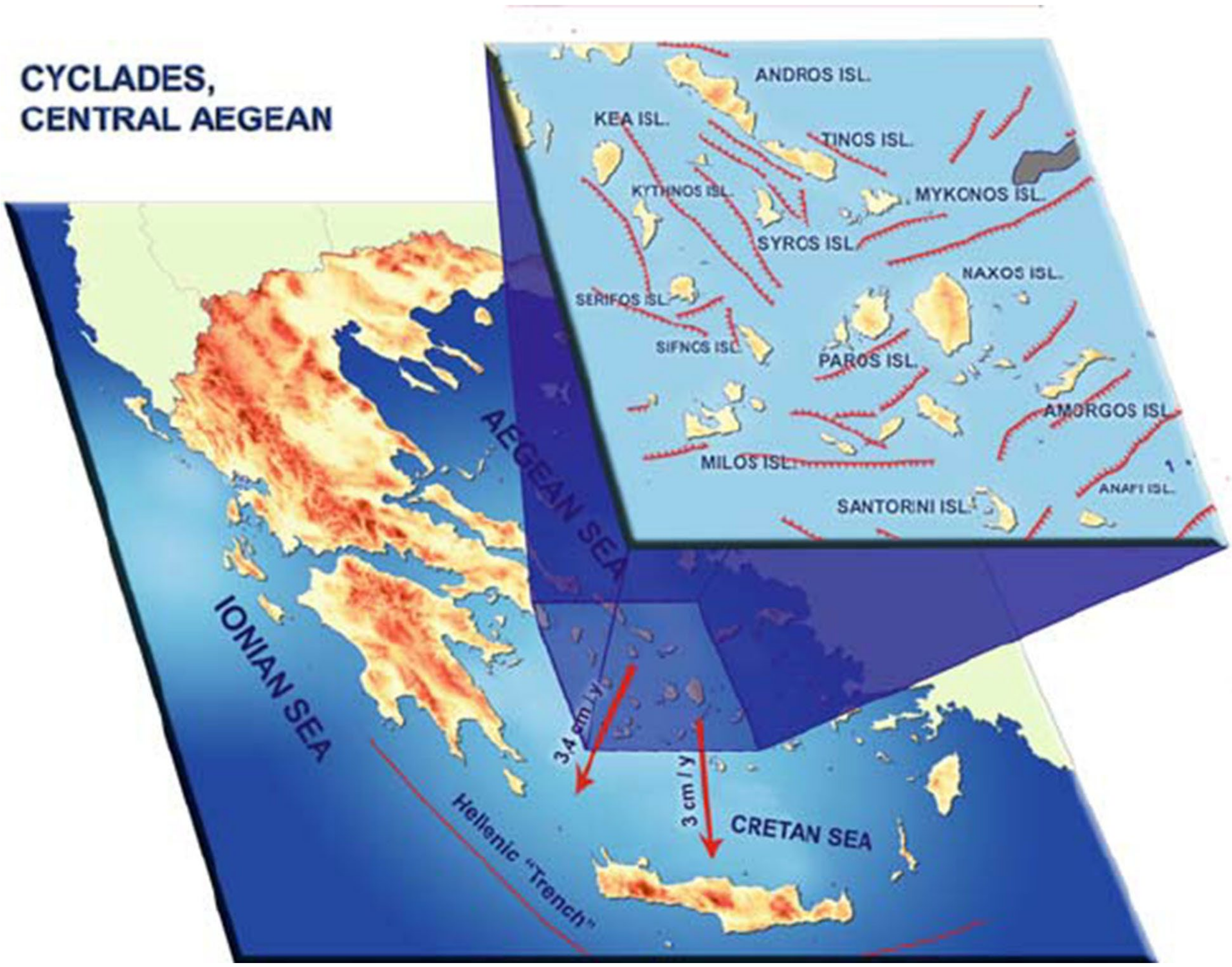


Figure 9 – Detail map of the Cycladic Islands.

Early Settlements, Culture and Resources

Scholars show archaeological evidence points to Neolithic settlements on the Cycladic Islands, Greece, as early as the sixth millennium BCE. These earliest settlers were accomplished stone sculptors - providentially, some of their work has survived time. Cycladic civilization was centered in the Aegean Sea region of Greece from roughly 3,300 to 1,000 BCE. In the third millennium BCE. a distinctive civilization, commonly called the Early Cycladic culture (ca. 3,200 – 2,300 BCE), established important settlement sites as trade flourished between the Cyclades. Few settlements from this early period have been found however much of the evidence of the culture comes from the assemblage of objects and figurines found buried with their dead. The majority of Cycladic marble sculptures were produced during this time.

Life in the Cyclades at this early stage had both advantages and disadvantages. Geographical fragmentation of the islands and the scarcity of natural resources for subsistence inevitably posed many issues for the initial settlers. However, these same disadvantages were used by the islanders to their benefit. The fragmentation led to autonomy, which is the hallmark of the Early

Cycladic period and frugality of their means of subsistence led to a maximum exploitation of island resources, and inventiveness (especially in the realm of artistic production and innovations). Additionally, the dependence of the islanders on nearby extended landmasses led to the continued development in seafaring, and inevitably, to a thriving sea trade.

Referring to natural resources, the Cyclades contain marble- and schist-dominant lithologies and volcanic materials. Most of the islands were good sources of marble, except for the volcanic islands of Thera and Melos. In antiquity and to this day the islands of Naxos and Paros, in particular, were famous for their marble quarries (See Figure 3.) but emery, which was used in the carving and shaping process, was found only at Naxos. Only the purest marbles were used in religious statues as it was considered sacrilege to use anything other than the purest white marble mined.

Naxos, the largest Greek Cycladic island in the Aegean Sea, was an ideal source of some of the finest and purest white marble in the world. (See Figures 8, 9.) The breath-taking Mediterranean Lady female figure, the focus of this report, is typical of the stylized form carved out of crystalline pure white calcite marble sculpture of the Cyclades from the Spedos or Early Cycladic II interval around 3,100 to 2,400 BCE.

Early Cycladic Statues

Naxos, the largest Cycladic island and Paros, a neighboring island, are notably ideal sources for the finest and purest white marble in the world. This breath-taking female folded-arm figure, carved from pure crystalline foliated white marble is typical of the stylized sculptures of the Cyclades of about 2,500 BCE. Archeologists have catalogued "folded arm figurines" from the Cycladic region. These female figures, probably linked with the idea of fertility and reproduction, which was often a focus of ancient Mediterranean religions, provide us with the longest-surviving examples of these still enigmatic canonical female figure types from this time period. They range from small hand-held figures to large statues of 1.5 m. The Mediterranean Lady statue is considerably large based on data available and also amazingly intact for its age. Cycladic statues, when found intact are rare. Although not all researchers are in agreement on date ranges, post-Neolithic folded arm Cycladic female statues fall into three distinctive stylistic age varieties (Figure 10):

Early Cycladic I (3,500-3,100 BCE)
Early Cycladic II (3,100-2,400 BCE), and,
Early Cycladic III (2,400-2,100 BCE)

Early Cycladic sculpture comprises predominantly female figures that range from simple modification of the stone to developed representation of human form, some with natural proportions and others more idealized. The recognition of different artistic personalities in Cycladic sculpture is based upon recurring systems of proportion and details of execution. Many statues have been found throughout the region in ancient structures. Many of these figures, especially those of the Spedos variety display a remarkable consistency in form and proportion that suggests they were planned with a compass for accuracy. Sculptors living on different islands produced the marble figurines in a similar style but with distinct detail variations that allow for identification of specific varieties as shown in Figure 11.

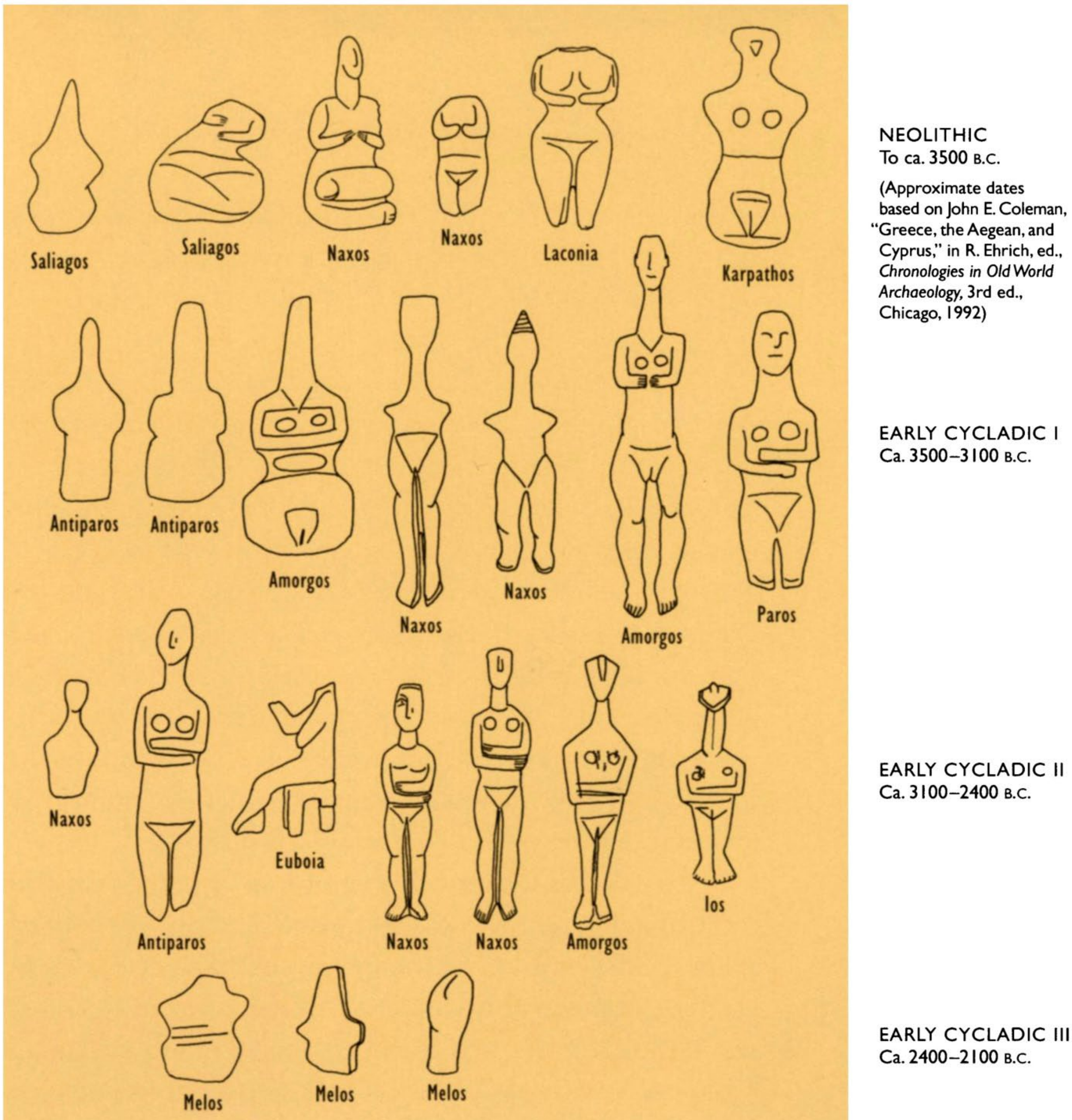


Figure 10 – Typology chart of Neolithic and Early Cycladic figures. (From Hendrix, 1997, p. 5.)

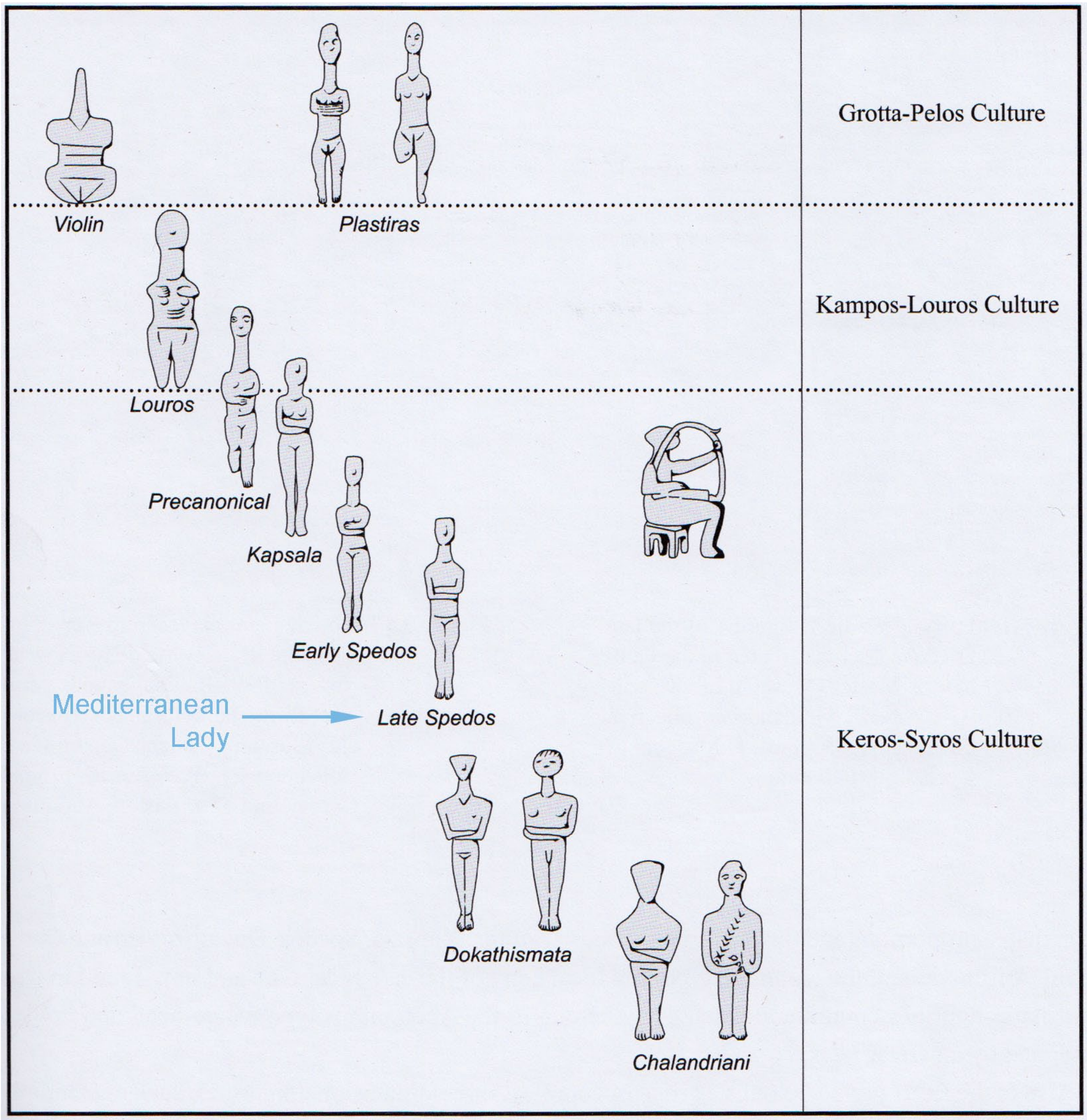


Figure 11 – Development of Cycladic figures. (From Berg, 2019, Figure 5.15, p. 141.)

The "Masters": Stone Carvers / Sculptors

The attribution of figurines with common morphological features to different "artists" and "Masters" has been the result of a meticulous typological study. The various "Masters", sometimes labeled as carvers or sculptors of these marble pieces, have been conventionally named, thereby attributing, or rather, inferring their hands to a particular piece created.

It is well recognized that sculptors living on different islands produced these marble figurines in a similar style but with distinctive variations. The recognition of different artistic personalities in Cycladic sculpture is based upon recurring systems of proportion and details of execution.

In some cases, a piece could be named after a modern day collector's family surname who possess the piece or gift the sculpture from their collection to a museum, or the museum or the city which hosts works characteristic of their style. In other cases, a piece can be named after an archaeological site excavator who brought them to light. The very term "Master", however, need not indicate an individual artist. The presence of common characteristics may equally reflect the existence of workshops or local traditions or simply the prevailing specific artistic styles in different periods.

To this day, within Cycladic culture, the female figures' role and cultural meaning remain elusive and enigmatic. Those with known archaeological contexts come mainly from graves. Most figures cannot stand, as their feet and toes point downward. It is presumed that they were meant to lie on their backs, as their folded arms suggest repose. It is presumed that in ceremonial use however, the figures would have been held or carried upright in procession.

Cultural heritage is a non-renewable resource to be managed on behalf of present and future generations. The systematic application of scientific methods in the field of archaeology and art had its origin in the European research community in the late eighteenth century, with many world-wide advancements through the present day to aid in the determination of cultural heritage.

Provenance of the Mediterranean Lady Statue

The Mediterranean Lady Statue's provenance is not known to anyone aside from the actual sculptor. The statue was purchased at an estate sale in the Hudson Valley in the early 1990s by the owner, a philanthropist in the NYC area. Thus, there is no bona fide existing chain of ownership that links the statue to a specific time interval or area of origin. Yet, based on our studies, the sculpture and the lustrous marble it is carved from appears to be attributable to a specific time interval and place of origin as explained below.

The MLS and the lustrous marble it is carved from appears to be convincingly attributable to the Spedos variety, named after the Early Cycladic burial site on the island of Naxos. The Mediterranean Lady Sculpture is style-consistent with the Keros-Syros Culture of the Late Spedos interval (ECII) characterized by a slender elongated body with folded arms (in this instance right arm on top over left), a lyre-shaped head with conical nose, small pubic triangle and a deeply incised cut-through cleft between the legs. The breasts are depicted as slight protuberances. Details of the human form are minimal, giving the figure a flat, angular geometric quality. The toes are missing. Based on the right-over-left arm placement, one might opine that the piece is transitional to the Dokathismata variety as discussed in Appendix A. (Also see Figures 10, 11, 12.)

Spedos/Late Spedos Period Provenance

A scholarly study by Anna Goldelman on the physical attributes of the Mediterranean Lady also determines that the statue type can be tied to the Spedos or Late Spedos Interval. (See Appendix B.) Her detailed report describes the unique comparative statue features that allowed for her statistical analysis which ultimately led to statue period identification. This important work is summarized in a two-page summary table (Appendix B, p. B-6, B-7) that lists the stylistic similarities.

Figure 12 – Head and upper torso views of the supine Mediterranean Lady statue.

Her study finds that the Mediterranean Lady statue possesses 88% and 85% of the feature similarities of the Spedos and Late Spedos intervals, respectively. (See Table below.) This period assignment is emphasized in her concluding statement that *"The Mediterranean Lady, with her unusual height and positioned arms, is a nearly undamaged remnant of an ancient civilization still shrouded in mystery"*.

Cycladic Era	Percent Similarity
Apeiranthos	29%
Kapsala	40%
Spedos	88%
Early Spedos	78%
Late Spedos	**85%**
Spedos/Dokathismata	58%
Dokathismata	57%
Chalandriani	32%
Postcanonical	40%
Special type	30%

Feature similarities with known Cycladic statue art styles. (From Appendix B, p. B-3.)

The Science of Cycladic Authentication

Integrated scientific studies have shown that the statue material consists of ultra pure foliated marble with a homogenous interior and thin natural patina with unique, consistent mineralogy indicating that it was not applied. The rock type is common in the Greek Hellenide geologic belt, the chemistry is identical to contemporary marble samples from Naxos island and isotopic studies prove that the material is of great age (~4,400 years old). Our conclusion that the statue is authentic is based on an integrated study of geology, mineralogy, geochemistry and isotopic analysis as described in detail below.

Geology - Lithology

Marble of various types from the Greek Cyclades are well known throughout art and architecture. They have been mined for many centuries for purposes of building construction and art. These rocks are part of the Aegean Crystalline Belt of the Hellenides, a metamorphic suite from the Eocene age (that underlies the islands (Figure 13).

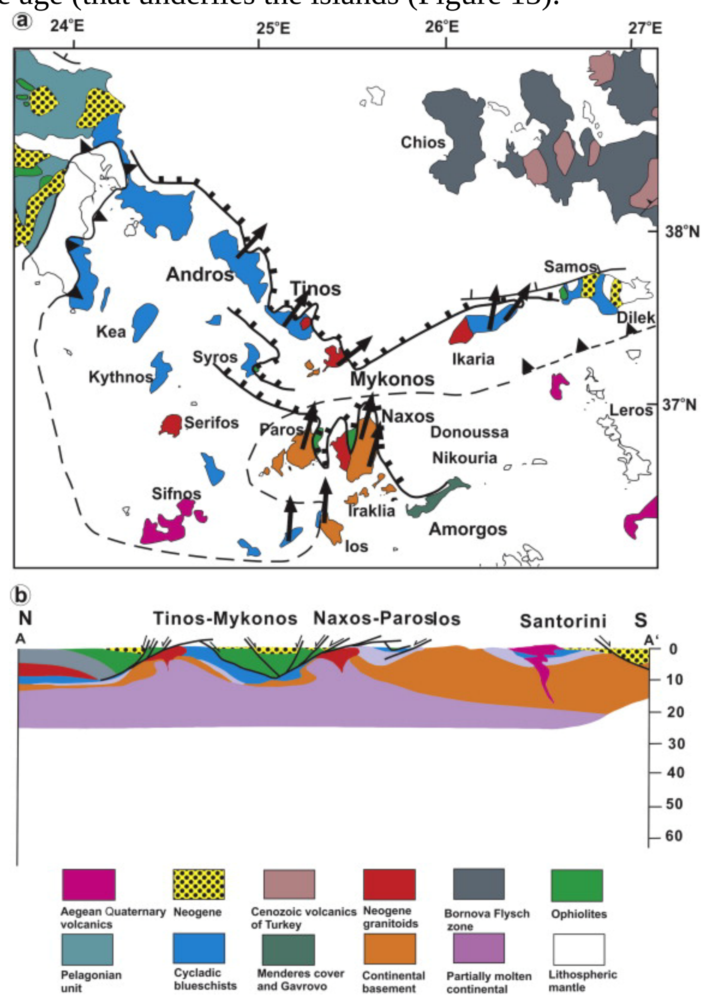


Figure 13 – Geological map and north-south section of the Greek Hellenic belt. Note the prevalence of shear zones (dark black lines with tick marks show ductile shear zones) and imbrications of rock types. (From Cao et al., 2013.)

The rocks consist of highly folded metamorphosed former shallow water marine strata and continental basement, upper mantle material in the form of ophiolite, instrusives and younger volcanics. The rocks show evidence for high pressure blueschist metamorphism and internal shearing which is commonly found in former convergent margin environments. As such, the shallow-water limestone protoliths of the metamorphosed marble rocks were drawn to great depths (increased pressure) where transformation from pure limestone into pure marble took place in a deep-seated environment that fostered internal folding and ductile shear.

Figure 14 is a geological map of Naxos island which shows highly sheared marble and schist metamorphic rocks (blue and yellow) and central and western intrusives (pink) that have caused re-metamorphism of the already metamorphosed rocks of the terrain. Also shown are the shear zones that cut through the metamorphic complex (dark black lines with tick marks). These former deep-seated rocks were brought to the Earth's surface by uplift and erosion.

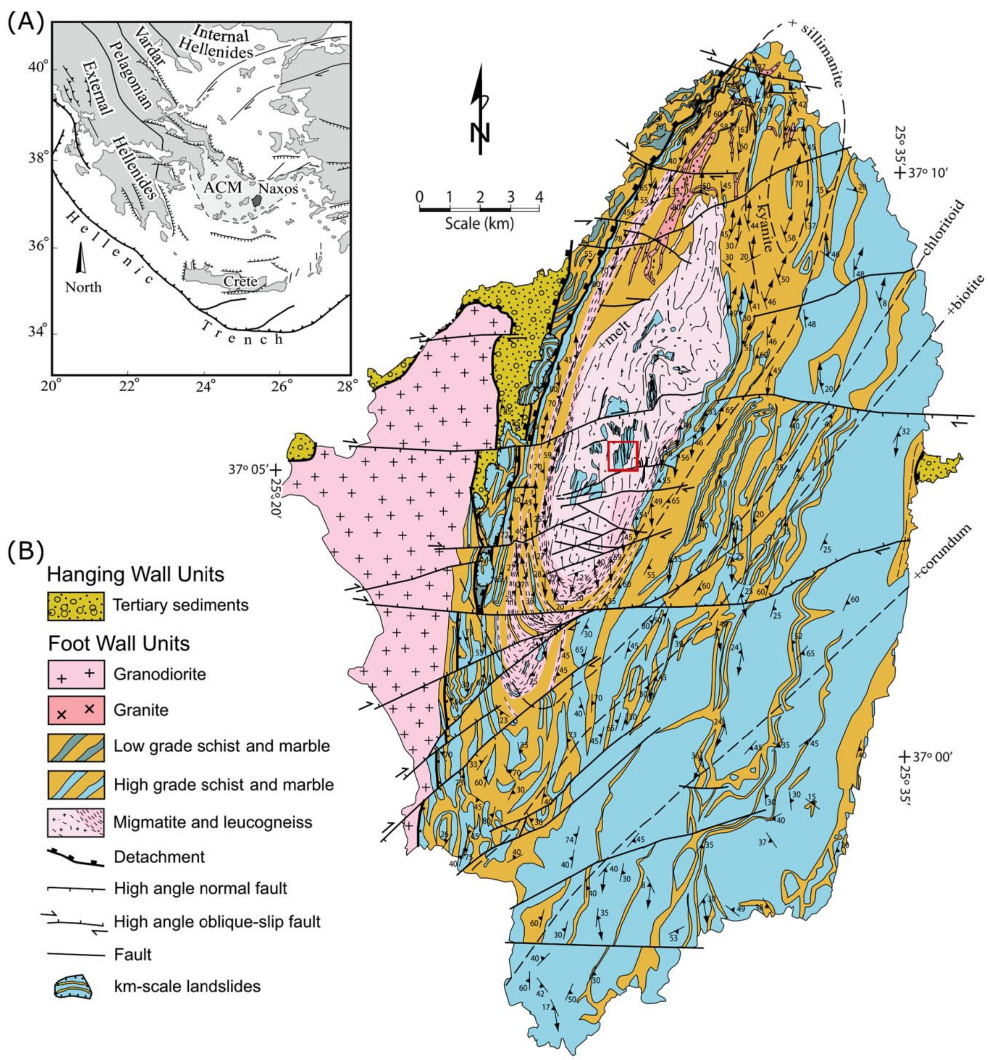


Figure 14 – Index- and geological map of Naxos island showing the dominance of low- and high-grade marble and schist (blue and yellow) and the ductile shear zones (detachment faults) and brittle strike-slip faults that cut the metamorphic complex. (From Leupold 2014, p. 2.)

Our studies show that the Mediterranean Lady statue was crafted from a well-foliated and highly laminated regional metamorphic rock that consists of fine-textured very pure white calcite marble with <1% aligned white mica (muscovite and/or sericite) and lesser quartz in the metacarbonate matrix. The rock is the product of dynamothermal metamorphism of clean calcareous sediment that originally contained minor amounts of detrital clay and quartz. The clay was transformed into muscovite and/or sericite mica by during regional metamorphism experienced during mountain building. Identical rocks extend throughout the Cycladic belt.

A distinctive mylonitic texture detected in The Mediterranean Lady Statue indicates high shear strains during metamorphism, consistent with the type of shearing found in convergent margin tectonic zones such as the Cyclades. The pronounced planar mylonitic fabric could only have been produced by deep burial (at least 5-8 km) in the earth millions of years ago and within a zone of intense shearing associated with tectonic plate convergence. This was followed by significant uplift and erosion to un-roof the rock mass where it was then quarried from the earth's surface in historic times, then tooled and crafted at some point in time. Indeed, marble quarrying for construction and artistic use has been undertaken by humans for centuries. Rocks of identical lithotype as the statue (pure calcite marble) are well known from the Cycladic belt. The statue marble is identical to published descriptions by researchers of foliated, sheared marble from the Cycladean Hellenic Belt which shows internal shear zones containing mylonitic marble.

Geochemistry of the Patina and Interior of The Mediterranean Lady Statue

Two sets of samples were drilled from the statue in early- and mid-2016 (See Figure 2.) – one was for basic major element analysis and a second sampling was taken for detailed rare- and trace elements to verify earlier measurements, for comparison to marble samples from Greek island sources (Naxos, Paros, Thasos) and also for isotopic age analysis (below). In addition, scrapings of the patina were chemically analyzed by the same techniques for chemistry and mineralogy. Such studies have been used to verify Cycladic marble statue provenance (Ebert et al., 2010).

A battery of geochemical analyses of the statue interior and patina were conducted starting in early 2016 and extending into 2017 at the American Museum of Natural History in New York City (AMNH). Backscattered electron images were used to identify rock particles for energy dispersive peak study (EDS) for the following elements: Ca, Mg, Al, Si, Fe, Cl, C, and O in order to give an overall estimate of the major element chemistry and ability to interpret rock mass mineralogy.

Statue Patina. The warm pinkish patina on the Mediterranean Lady statue is typical of all Cycladic pieces with a patina as seen in person, seen in many books and at famous museums (Gulandris, Metropolitan Museum of Art, YUAG, Katona, Chicago Art Institute, the Getty, Wadsworth Athenaeum, Smithsonian, British Museum, and Louvre). The EDS peaks indicated the presence of **calcite** ($CaCO_3$), **dolomite** ($[Ca,Mg,Fe](CO_3)_2$), **quartz** (SiO_2), **pyrite** (FeS_2) or **pyrrhotite** ($Fe_{1-x}S$), **white mica** or **muscovite** (KAl_2 $(Si_3Al)O_{10}(OH,F)_2$ in the statue scraping particles (Figure 15).

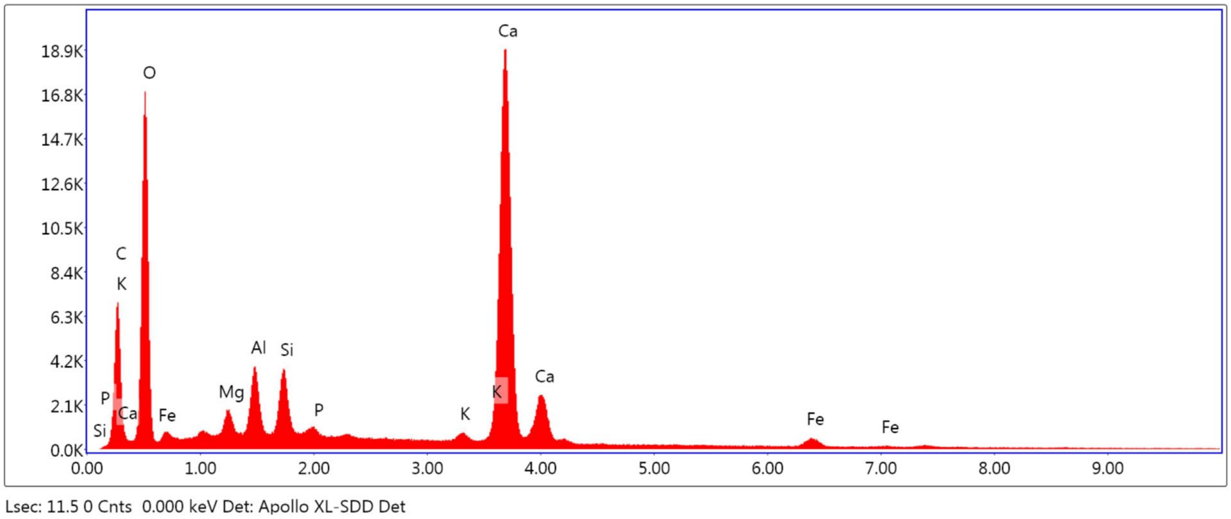


Figure 15 – EDS spectral plot showing the elements measured in the scraped statue patina. The height of the various peaks are related to elemental weight percent. Listed in order of decreasing concentration in weight % the testing showed (O = 45.53%, Ca = 33.54%, C = 13.49%, Al = 2.10%, Si = 2.03%, Fe = 1.96%, Mg = 0.71%, K = 0.37%, and P = 0.26%). Lithologic studies and the EDS peak data thus indicated the presence of **calcite** ($CaCO_3$), **dolomite** ($[Ca,Mg,Fe](CO_3)_2$), **quartz** (SiO_2), **pyrite** (FeS_2) or **pyrrhotite** ($Fe_{1-x}S$), **white mica** or **muscovite** ($KAl_2(Si_3Al)O_{10}(OH,F)_2$ as primary phases in the statue scraping particles.

Our first test in early 2016 established the presence of both calcite and dolomite in the surface (the “patina material”) of the statue which is consistent with exposure of the statue to calcium and magnesium carbonate in groundwater (soaking of the statue surface by mineral-laden groundwater) or dripping of calcium and magnesium carbonate-bearing rainwater onto statue.

In mid-2016, AMNH technicians once again chemically analyzed patina material. The results indicated that in addition to calcium carbonate (calcite) in the patina, there were also peaks for minerals dolomite and fluorite. These are common minerals produced by long burial in hydrologically active soils which virtually eliminates the possibility that the patina is “fake” or applied but indicates, rather, that the homogeneous, thin patina is a normal naturally occurring weathered rock surface. The different peaks in the test indicate that the sculpture surface is authentic as exotic minor elements found in modern paints were not detected. (See Figure 15.)

Statue Interior. The early 2016 EDS test on the statue core material was supplanted later by more precise microprobe testing in June 2018 but for the sake of completion these early 2016 results are shown below in Figure 16. The testing verified the fact that the statue was nearly pure calcite marble. Other EDS tests on impure grains showed higher Mg, Si, and Al indicative of low concentration mica and quartz as observed in the statue to flatten into the metamorphic foliation.

In February 2017, more geochemical testing of the statue interior was accomplished with scanning electron (SEM) and laser element analyses (Table 1 in Appendix C). The scanning electron microscope was used to identify the mineral grains present in the material removed during the "scraping" of the statue and the electron microprobe was used to determine the geochemistry of the statue's exterior and from the diamond core drilling of the statue's interior. This instrument also provided accurate chemical analyses of the minerals that were identified.

The early 2017 analyses verified that the rock mass of the sculpture was a very fine-textured and very pure calcite marble with a very low (<1%) amount of white mica (muscovite or sericite), silica (quartz), and other trace impurities. The testing also indicated the extreme geochemical purity of the statue marble. (See Table 1 in Appendix C.) According to the analyst, Dr. James D. Webster of AMNH, *"In short, as we had observed previously, the calcite grains (calcium carbonate, primarily) are* ***very pure****. They do contain circa 0.3 to 0.9 wt% magnesium oxide, on average, and 0.04 to 0.19 wt % iron oxides on average. Otherwise, the measured concentrations of strontium, barium, manganese, titanium, silica (silicon dioxide), sodium, potassium, and aluminum – in the calcite grains -- are very low (in the tens to hundreds of parts per million range) and generally at the lower limits of detection by the electron microprobe."*

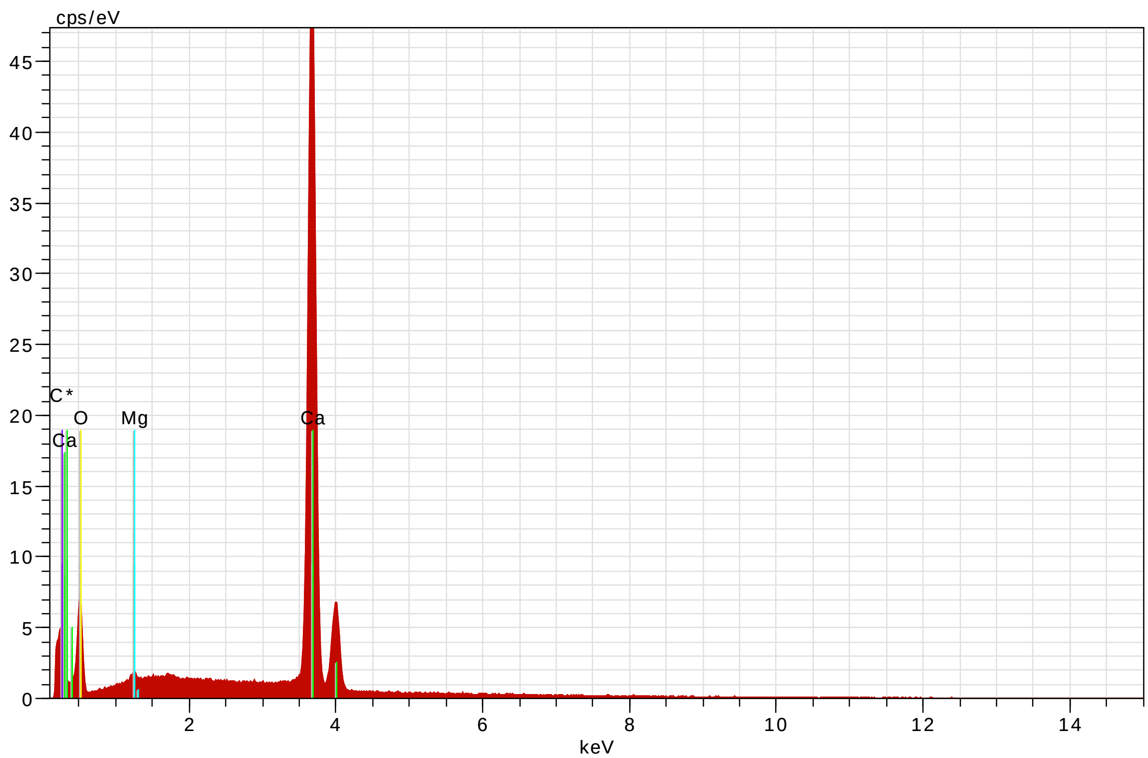


Figure 16 - EDS spectral plot showing the elements measured in the core taken from the foot of the Mediterranean Lady statue. The height of the various peaks are related to elemental weight percent. Listed in order of decreasing concentration in weight % the testing showed (Ca = 70.75%, O = 20.64%, Mg = 0.60%). Lithologic studies and the EDS peak data thus indicated the presence of **calcite** ($CaCO_3$) with very scarce **dolomite** ($[Ca,Mg,Fe](CO_3)_2$) and nothing else as primary phases in the statue interior core sample.

The low amount of magnesium (Mg) in the detection spectra showed that the statue marble was nearly 100% pure calcite marble ($CaCO_3$) without an appreciable dolomitic component. This is important because all Cycladic experts/scholars we have consulted from here to Greece agree that **only the purest marble would be used for Cycladic sculpture as it would have been considered sacrilege to use anything other than that.** The ancients were adamant that anything less than pure marble was an insult to the gods or powers that be. For this reason they selected out only the purest of materials. In this case not only was the marble pure white in color, uniformity of appearance and mineralogy but was geochemically pure as well.

The sculpture clearly exhibits a thin a natural patina consisting of limonite (iron oxide) and calcite that resulted from burial in soil and/or volcanic detritus at one or more times and shows some evidence of human handling in the form of very minor nicks and damage, especially on the left foot. Despite the contention that the statue and patina were formed from thermal (volcanic) alteration of terra cotta pottery, no near-surface thermal history could have produced the minerals and textures found within the rock mass - only high pressures found at great depth in the earth could have produced the metamorphic fabric that is so evident as traces along the sides of the sculpture - surface or near surface processes must be ruled out for the geological origin of the original internal rock mass.

Samples from three operating quarries on Naxos, Paros, and Thasos were analyzed for major-, rare- and trace-elements for comparison to identical tests performed on the statue interior (Figure 17). Tantalizing trace element similarities were detected between **the Mediterranean Lady statue marble and the Naxos quarry marble sample as indicated below**. Standard deviation and variance statistical analysis were used in understanding the pure data from the test results shown in Appendix C.

Figure 17 – Marble samples tested from known modern quarry sources on Naxos, Paros and Thasos.

Mediterranean Lady Statue (MLS) – Greek Island Quarried Marble Comparison

Statistical analysis was performed in attempts to compare metacarbonate (calcite marble) samples from three Greek islands (Naxos, Paros and Thasos) famous for statue marble quarrying to the composition of the Mediterranean Lady Statue (MLS). Seven analyses of the MLS, three analyses from Naxos island, three analyses from Paros island, and three analyses from Thasos island were analyzed for concentrations of the following rare- and trace elements. (See Table 2 in Appendix C.):

B – 11	**MgO% - 26**	**CaO% - 43**	**TiO2% - 47**	**V - 51**	**Cu - 65**	**Zn - 66**
Rb - 85	**Sr - 88**	**Y - 89**	**Ba - 137**	**Ba - 138**	**La - 139**	**Ce - 140**
Pr - 141	**Nd - 145**	**Sm - 147**	**Eu - 153**	**Gd (Dy) - 160**	**Tb - 159**	**Dy - 163**
Ho - 165	**Er - 166**	**Tm - 169**	**Yb - 172**	**Lu - 175**	**Th - 232**	**U - 238**

Note: Original analysis dataset can be found in Tables 3 and 4 in Appendix C at end of report.

Of the 28 total geochemical analyses, 11 of them exhibited results below the detection limit (BDL) and the other 17 had measurable results. The elements with significant results are highlighted below in blue.

B - 11	**MgO% - 26**	**CaO% - 43**	**TiO2% - 47**	**V - 51**	**Cu - 65**	**Zn - 66**
Rb - 85	**Sr - 88**	**Y - 89**	**Ba - 137**	**Ba - 138**	**La - 139**	**Ce - 140**
Pr - 141	**Nd - 145**	**Sm - 147**	**Eu - 153**	**Gd (Dy) - 160**	**Tb - 159**	**Dy - 163**
Ho - 165	**Er - 166**	**Tm - 169**	**Yb - 172**	**Lu - 175**	**Th - 232**	**U - 238**

Note: Original analysis dataset can be found in Tables 3 and 4 in Appendix C at end of report.

Variation analysis or variance allows for comparisons between similar data sets. Comparing the element data of the Mediterranean Lady statue vs. the Naxos, Paros, and Thasos quarry samples (See Table 2 in Appendix C) indicates that of the 17 chemical analyses with significant variance results, By an almost 2:1 margin Naxos had the lowest variance (correlation to individual elements; n=8) where Paros had 5 and Thasos had 4. As shown in Figure 18, the low variance of the Naxos sample indicates that trace elements compare well to the geochemistry of the Mediterranean Lady statue sample (n=8).

Z-Score analysis to show correlation of data was also applied to compare the three Greek Island quarry samples to the Mediterranean Lady statue. A Z-Score shows how many standard deviations a data point is from a mean or reference point. For example, a Z-Score of 1 means the data point is 1 standard deviation away from a chosen MLS analysis data value for a particular element. A Z-score of 0 means the data point matches the data point. To use an example from our dataset in Appendix C (Table 2), if a sample of Cu from Thasos has a Z-Score of 0. That means that the Cu concentration matches the MLS exactly (0.29 ppm). If the Thasos sample has a Z-Score of -1 or +1 that means that the Cu content is one full standard deviation of 0.29 ppm away from the MLS sample measurement for that element. Thus, the MLS values are the standard that deviations are compared to. As it turns out the actual Cu concentration for Thasos is 0.27 thus a Z-score of – 0.02 ppm is recorded in Table 3 of Appendix C.

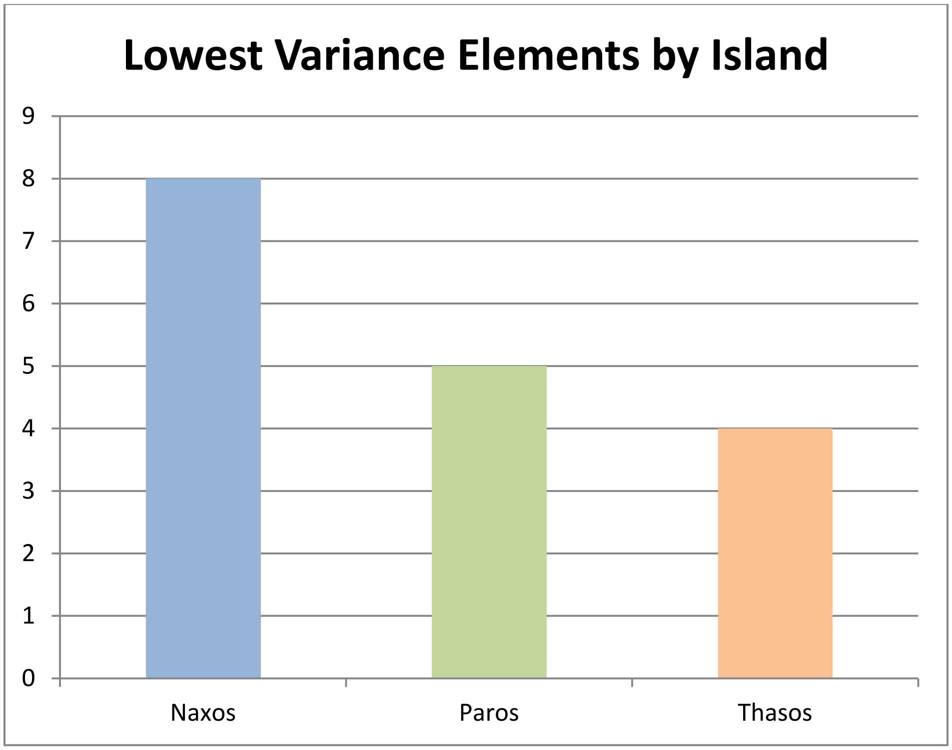


Figure 18 – Bar chart showing the relative closeness in chemistry between The Mediterranean Lady statue and the Naxos, Paros and Thasos geochemical signatures based on variance analysis. (Dataset in Appendix C.)

The multiple analyses of the Naxos, Thasos, and Paros samples were averaged in Table 3 to create one datapoint per element. The Z-scores of the Naxos, Thasos, and Paros were then compared to the MLS sample data which essentially becomes the standard for comparison. The length of the color bar away from the horizontal axis in Figure 19 shows the amount of deviation from the MLS standard. Clearly, the Naxos elements (green) show the lowest Z-scores of all of the elements measured. The slope of the Z-score per island is also included on the graph. A Slope of 0 indicates a perfect match to the MLS. The steeper the slope in the positive or negative direction the less correlation the samples have to the MLS. The Naxos slope is closest to horizontal and also closest to a 0.0 slope value – it indicates that the geochemistry of the Mediterranean Lady statue matches the unique geochemistry of the Naxos island sample.

The "0" line on the Y-axis represent the chemical composition of the MLS Statue. Each Island's Z-score/element measured is shown on the graph. The further the per element value is from the "0" line the lower the correlation to the MLS composition. The slope of the Z-scores also shows the overall correlation to the MLS statue. The island of Paros (green) is the least correlative (-0.0759x slope) to the MLS. The island of Thasos (orange) also shows a weak correlation to the

MLS (0.0745x slope). But the chemical compositions of the Naxos sample tests (blue) are clearly the most correlative to the MLS composition (-0.0216x slope) establishing a trace- and rare element geochemical link between the Mediterranean Lady statue and the modern Naxos quarry sample. Data and calculation spreadsheets for the variance and Z-score calculations are shown in Table 4, Appendix C.

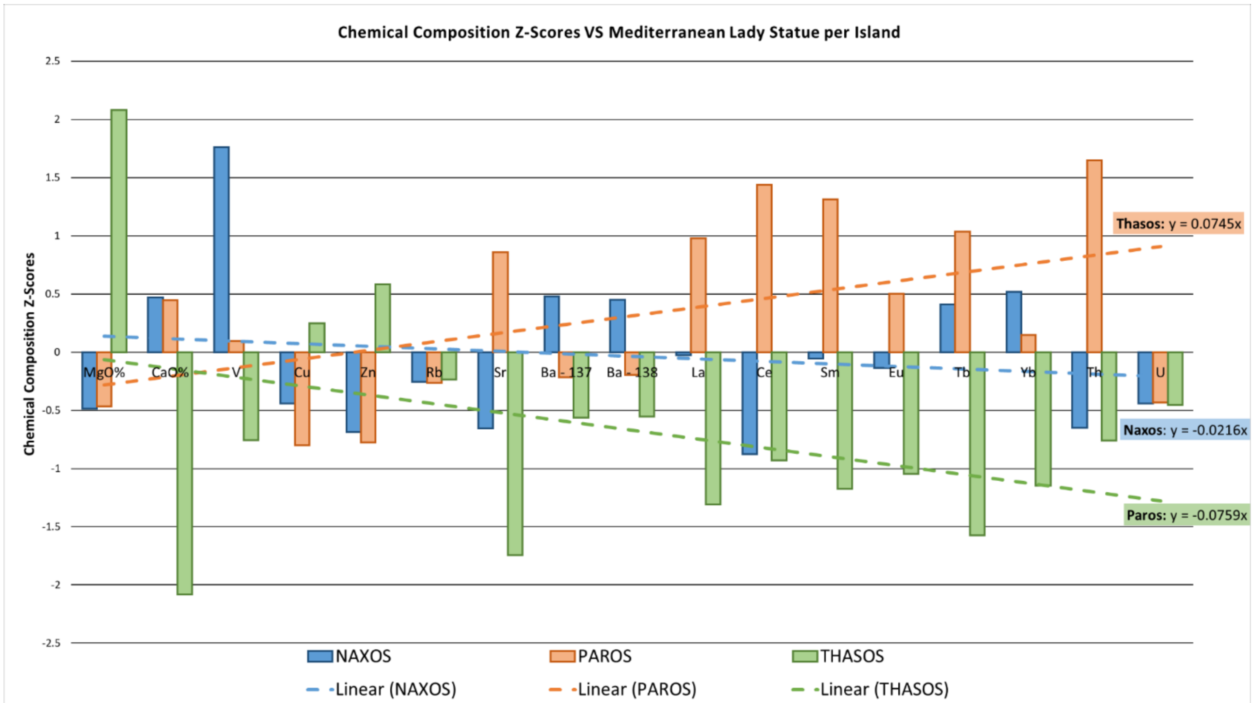


Figure 19 – Z-score plot of the three Cycladic island samples compared to the Mediterranean Lady statue (MLS = horizontal "0" axis). Note how the Naxos sample conforms closely to the MLS with a nearly flat slope (y = 0.0216x) closest to the MLS "0" Z-score axis. Explanation in text.

The graphical plots of Figures 18 and 19 have shown that the actual Mediterranean Lady statue material (MLS) is closest to the Naxos quarry sample. What is more, the lithology and geochemistry indicate that the statue material is linked to the geological underpinning of the Hellenide Belt of the Aegean region, and from Naxos island in particular. At this point we had demonstrated a provenance link to the Greek Hellenides geologically, lithologically and geochemically but to add to this dataset we were also able to provide an age range on the Mediterranean Lady statue using isotopic dating to place these geological and geochemical correlations in temporal context.

Isotopic Age Determination

Cosmic ray penetration within the upper few meters of the earth's surface produces cosmogenic radionuclides. In particular, calcium atoms in the marble convert to the isotope Cl^{36} (chlorine-36) at a known decay rate and exposure ages can therefore be accurately calculated by measuring element-isotopic ratios. Laser ablation testing by Dr. Joerg M. Schaefer at the Lamont-Doherty Earth Observatory (LDEO) of Columbia University in Palisades, NY in late 2018 indicated an age of 4,400 +/- 1,800 years before present for the marble statue. The report on this study by Dr. Schaefer is included in Appendix D.

The +/- 1,800 year error range is the result of the small sample size as well as instrument errors related to excess chlorine-36 but the exposure age range extreme of 3,600 years (6,200 – 2,600 years before present) still places the age of the rock exposure to ancient times. Statistically, the far extremes of the range are less and less significant and thus, we adopt the 4,400 years before present exposure age measured Cl^{36} isotope analysis as a reliable approximate age value for the Mediterranean Lady statue. Note that this age assignment nicely overlaps the late Spedos age range interval of 3,100-2,400 BCE. As such, we consider this test as proof of the great antiquity of the statue and argue, along with the geological and geochemical data that it comes from the Cycladic islands (probably Naxos) and cannot possible be a modern replica.

Summary

The MLS marble is extraordinarily pure from a chemical standpoint consisting of 99% calcite with 1% combined oxides of Mg, Si, Fe, and K. The chemistry indicates an ultra-pure white calcite interior with very little dolomite (Ca, Mg carbonate) nor silicates - common phases in most non-pure marbles. By contrast, the warm pinkish patina contained calcite plus dolomite and fluorite, naturally occurring weathering minerals whose presence eliminates the possibility that the patina is fake or applied.

Most impressive was the penetrative laminated texture typical of sheared (mylonitic) rocks and the speckled look of the aligned mica flakes lying within the regional foliation as shown on the cover. The flakes shimmer in low light through the patina of the reclined sculpture producing an unusual "glowing" optical effect with low-angle light.

Mylonitic marbles are well known in the eroded mountain belts that traverse the Greek Cyclades and rocks of identical lithotype as the statue (pure calcite marble) are well known from the Cycladic belt. The artisanal chemical testing program, developed to investigate the patina and the interior marble and various Greek marble quarries, determined that the rock mass was from that region. Our integrated studies have provided a sound basis for people to recognize this work of art as an authentic piece created during the Aegean Bronze Age civilization. The tests have confirmed that the statue is of appropriate age, physiography, carving style, lithology and mineralogical- and chemical purity - and is deemed an authentic ~4,400 year old statue of the late Spedos (II) Period.

In closing, very little in this report is based on opinion since they are reliant upon personal prejudice. Rather, we have reported on the scientific facts which force the conclusion that the MLS is authentic based on its size, shape, lithology, carving style, geology, major-, rare- and trace element geochemistry and Cl^{36} isotope dating. Together, these measurements indicate that the MLS is genuine and provides a sound basis for scholars and collectors alike to recognize the Mediterranean Lady sculpture as a particularly stunning, formidable and authentic work of art created over four thousand years ago during the Aegean Bronze Age civilization in Greece, yet remaining intact for posterity to view. In Latin, *"Res Ipsa Loquitur"* – (The thing [MLS] speaks for itself).

MLS Research Program and Summary Report Directed and Produced By:

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Genevieve Glasson, BA, and
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Appendix A

Appendix A

Positioning and Placement of Folded Arms in Cycladic Sculpture

Many Cycladic art objects now in western museums or owned by private collectors have no provenance of any description. These objects are, nevertheless, part of the few tangible remains of a culture which no longer exists and, without a form of writing, the members of that culture are unable to explain for themselves the true significance of these objects. Today, we are left to ponder the function, faces, sizes, arm positions and whether they were lain down or positioned upright. These enigmatic sculptures continue to fascinate more than three millennia after their original creation.

- Cycladic female sculpted sculptures from this period were predominantly simplified abstracted forms that scholars separated into two different varieties: Spedos variety and the Khalandriani (in some instances referred to as Chalandriani) variety.
- Both varieties were represented with folded arms known as the FAF (folded-arm form).
- The Spedos variety typically has left arm placed on top of right arm.
- The Khalandriani (Chalandriani) variety has arms folded with both left or right arm on top.
- This Mediterranean Lady sculpture that we have attributed to the Spedos variety has an elongated and stylized body form – mesmerizing in its interpretation of the realistic female body shapes, abstraction not-withstanding.
- This piece is a particularly rare example of the Spedos variety, the reason being that the right arm is placed atypically on top of the left arm and the overall size of the sculpture is much bigger than most. Yes, atypical for the Spedos variety but not uncommon for the Khalandriani (Chalandriani) variety.
- A plausible reason for the right arm placed on top of left arm is most likely attributable to it being carved in a transitional phase or, quite simply, an artist exercising “artistic license”: a matter of a master carver taking liberties beyond the dictum of the time and to “change-it-up”; since his hand would have attended to many similar works during his lifetime and breaking out of the rote mold for a true artist is not unheard of!
- Perhaps, this special piece was also a deeply personal work this time around, hence the unusual size. (Most pieces that remain almost entirely intact today are significantly smaller.)
- It is not uncommon in the Khalandriani (Chalandriani) variety to have the right arm placed on top of the left arm.

See: https://scholarexchange.furman.edu/art231/32/

Excerpt from link above: “Although the female form is shown in a more simplified, abstracted state, two different varieties appear. These are known as the Spedos variety and the Khalandriani (Chalandriani) variety. [4] The “1. Marble Female Figure” and “Upper Part of a Marble Female Figure” represent these respectively. Spedos figures are characterized by a larger variation in geometric shapes, more body divisions with the waist, knees, and ankles, a backward tilted head with an oval face, a large long nose, arms crossed with **the left arm placed on top of the right**, and an overall sense of a slim, elongation of the body.[5]The Khalandriani figures on the other hand are characterized by a sense of angularity with a squared off torso and repetition of triangles and ninety degree angles which can be seen in the shoulders and arms. These figures also lack the sense of elongation and are shorter and more squat which also makes them appear more self-contained than the Spedos figures**. The arms, although also crossed, are crossed with the right arm on top of the left. [6**]

EXAMPLES OF RIGHT ARM PLACED ON TOP OF LEFT ARM

#1 - Female marble figurine from Crete. (Koumasa variety, EC II; 2,800–2,200 BCE.)

Right arm placed above left arm.

Archaeological Museum of Chania)
(https://en.wikipedia.org/wiki/Cycladic_art)

#2 - Attributed to the Goulandris Master. (Right Arm Above Left Arm.)

Right arm placed above left arm.

Attributed to the Goulandris Master. (Collection of the Australian National Gallery).
Greece Cyclades Islands
Female figure c. 2,700 BC- 2,300 BCE

https://artsearch.nga.gov.au/detail.cfm?IRN=89366&PICTAUS=True

Dimensions (cm) : 54.6 h x 14.9 w x 5.4 d
Purchased 1982; Accession no NGA 82.2232
Provenance: Sold at auction, Sotheby & Co. London, 12 July 1971, lot 132; when bought by Robin Symes, Ltd, London; with Delplace Gallery, Brussels, December 1971; from whom bought by Maurice Bonnefoy, New York and Garennes-sur-Eure, France, December 1971; from whom bought by the Australian National Gallery, December 1982.

#3 - Attributed to the Goulandris Master. (Left Arm Above Right Arm.)


n

Left arm placed above right arm.

NOTE: Argument for artistic license – both items #2 and #3 internationally claim "Goulandris Master" yet folded arm positions are opposite.

https://commons.wikimedia.org/wiki/File:Idol_EC_II_Goulandris_Master,_MCA_NG_251_080965.jpg

#4 - Attributed to the Goulandris Master. (Right Arm Above Left Arm.)

Right arm placed above left arm.

https://vads.ac.uk/x-large.php?uid=623&sos=0
https://vads.ac.uk/large.php?uid=623&sos=0

https://www.google.com/url?sa=i&source=images&cd=&ved=2ahUKEwjArZiS4ZfkAhXqRd8KHWy8Ar4QjRx6BAgBEAQ&url=https%3A%2F%2Fvads.ac.uk%2Flarge.php%3Fuid%3D623%26sos%3D0&psig=AOvVaw3W49s4h67SwdV06qo-Le59&ust=1566606956792760

SUMMARY

Items #2, #3 and #4 which are in international collections, all attributed to the Goulandris Master, clearly show the folded-arm position in both left on top of right and right on top of left. Stylized form also appears to be of the Spedos variety. Surely, this is an example of artistic license in evidence!

Appendix B

Determining the Typology of a Cycladic Statue Known as the Mediterranean Lady

by Anna Goldelman

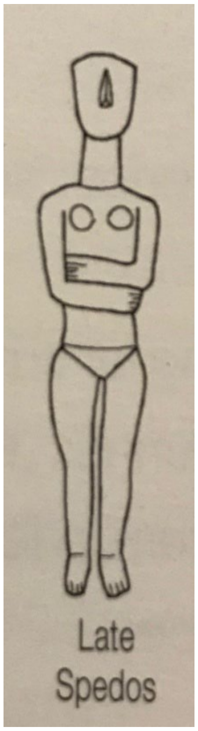
As small as they can be, Cycladic statues hold a host of mysteries in their being. Presenting a wide variety of features, they can discomfort a viewer with their eerie lack of features, symmetrically carved profiles, and beautifully (tenderly) rendered reproduction of the human form. Often female in appearance—indicated by the incised pubic area and breasts present on a majority of the statues—their exact use is still unknown, due to an unfortunate history of smuggling, black market sales, and relatively recent discovery.

First carved from marble around 5300 B.C., it is rare for Cycladic statues to remain fully intact, but amazingly a few are still present today as full figurines. One such statue, which is missing only its toes, is the center of this study, which aims to provide a hypothesis regarding the statue's typology within Cycladic history. This study finds that the statue is an example of the Late Spedos variety, as determined by the analysis in this manuscript.

Peggy Sotirakopoulou's book (2005), *The "Keros Hoard": Myth or Reality?*, provides a basic path to unraveling the mystery of the Cycladic statue in question. Sotirakopoulou's outline of Cycladic figurines and their many forms allows us to reach a conclusion as to the designation of the statue.

Sotirakopoulou informs the reader that there are three types of Cycladic figurines: schematic, naturalistic, and hybrid (page 52-63). This particular statue is very clearly a naturalistic figurine, due to its anthropomorphic nature (it clearly portrays a human). Within the naturalistic type, there are five further designations: Plastiras, Louros, precanonical, canonical, and postcanonical (page 55-60). Canonical statues typically have the following characteristics (those that the statue in question also has are bolded): **nude**, standing, **head tilted back, flat crown of head**, **nose depicted in relief**, hair and eyes and eyebrows painted, **neck clearly separated from head and body by incisions**, **breasts shown in relief, arms folded over stomach** (left over right), **belly bulges** or covered in wrinkles, **pubic triangle is incised**, **incision or groove or cleft separates legs**, **legs joined and slightly bent at knees**, **spine and finger** and toes **incised**, and the **feet are inclined and appear to stand on tip toe**. Occasionally, canonical statues have their ears shown in relief, **groove marks lower end of belly**, leg cleft often pierced between lower legs, and knees and ankles incised. Rarely, their mouths are depicted by a horizontal incision or in low relief. Canonical statues stand anywhere from **7 centimeters to 1.5 meters tall**, with the tallest height being greater than any of the other types included in this set of categorizations. Unfortunately, some of the specific characteristics included in Sotirakopoulou's outline of canonical statues are impossible to see on the particular statue by simply looking at it: any paint residue has long since faded from the naked human eye, and the feet have been damaged so no indications of toes remain. Interestingly, the rather unusual feature of arms crossed right over left (a vast majority of these statues have their left arm placed over the right) is attributed by Sotirakopoulou to the postcanonical designation, as well as the fact that one arm is horizontal and the other is diagonal. There are other examples of canonical Cycladic figurines posed with their right arm over left, and four of these exceptionally rare statues are exhibited in the Metropolitan Museum of Art, the Louvre, the British Museum, and the Getty Museum.

Sotirakopoulou further expands the canonical category into the Kapsala, Spedos, Dokathismata, Chalandriani, and Koumasa varieties (page 56-59). Interestingly, this is where an initial foray into understanding the statue's exact categorization becomes difficult, as a few features are shared between the varieties (this will be explored later as well). According to the evidence gathered thus far, and by using Sotirakopoulou's descriptions of the varieties, the statue mostly belongs within the Spedos variety. Sotirakopoulou divides the Spedos variety into Early and Late; within her initial descriptions, the statue seemingly belongs to the Early Spedos variety although, as seen shortly, there is some contention to this designation. The Early Spedos variety is described by the following characteristics (bolded in the same manner as before): **bulging thighs and lower legs, relatively narrow waist, flexed knees, nearly straight contours of profile, flat surfaces of front and back, inclined feet, pubic triangle indicated by incised triangle** or slightly curved groove at lower end of belly or two oblique incisions at groin or contours of raised upper thighs**, plasticity,**[1] **limited use of incised details.** Their heads are usually **lyre-shaped**, and there is a **deep leg cleft perforated between lower legs and sometimes thighs.** Occasionally, they have **incised fingers**. Figurines of the Spedos variety also provide the largest examples of all canonical statues, with the largest at 1.5 meters; other varieties only reach up to 35 centimeters. Thus, the height of this statue also points to its Spedos variety make.



Within the Spedos variety are several categorizations, and Sotirakopoulou focuses on Early and Late Spedos. There is much overlap between the two varieties, there are some specific indicators of Late Spedos, such as nearly straight contours on all sides (although many examples of the variety have curved outer contours, like the statue in question), **lyre shaped head, angular shoulders, use of incision over plasticity to indicate anatomical details, incised triangle for pubic area**, no perforated leg cleft, and the **feet are only carved separately at front**. Interestingly, the statue at the center of this study also shares some characteristics of the Kapsala variety (roundedness of body parts, head distinguished from neck, shoulders only slightly wider than pelvis, and the usual Kapsala feature of the leg cleft being perforated between the lower legs).

Illustration Credit: Image taken from Sotirakopoulou (2005). Chart of typological development of Cycladic figures.

Using as many of Sotirakopoulou's tables as possible (Table 13-14, 21-22, 24-30, 32-37, 39-45, 47-52, 55-56, 58-59, 61-64, 66-71), which describe usual and unusual "morphological characteristics of the figurines" found in the Keros Hoard, we are able to establish that, according to the author's unfortunately undescribed (quantitatively or qualitatively) categorizations of fifty-eight features such as chin roundedness, differentiation of head from neck, abdomen length, and knee indication, the particular Cycladic statue in question agrees with 88% of features noted on figurines of the Spedos variety. More specifically, 78% of the features noted on Early Spedos figurines are similar to that of the statue, while 85% of Late Spedos

[1] "Plasticity" refers to the artistic style of indicating anatomical features such as joints and the pubic area by means of depicting the body's natural contours, rather than using incised lines. On this statue, the use of plasticity to indicate the knees, and similarly the decision to incise the lines of the pubic triangle rather than indicate it plastically, are important features which help identify this statue as belonging to the Spedos period.

characteristics noted by Sotirakopoulou are also seen on the statue. The following chart further demonstrates the percentages of feature similarities with the varieties included in Sotirakopoulou's charts:

Cycladic Era	**Percent Similarity**
Apeiranthos	29%
Kapsala	40%
Spedos	88%
Early Spedos	78%
Late Spedos	85%
Spedos/Dokathismata	58%
Dokathismata	57%
Chalandriani	32%
Postcanonical	40%
Special type	30%

For the purpose of this study, the statue was compared to examples that Sotirakopoulou provided for each of the described feature, since the author neglected to provide concise definitions for most of the less obvious features. As a result, the provided percentages of similarity should not be taken as definitive values; unfortunately, as is often the case in archaeology and studies that require some amount of interpretation, both the author and this hopeful researcher may have made mistakes in creating and using these systems of categorization. It should be noted, though, that all of the descriptive language of this section of the analysis is taken from Sotirakopoulou's book.

Of the features described in the charts, the most common of those shared among the varieties (appearing in 6 varieties) include sloping shoulders, forearms indicated in low relief, an indicated spine. Other features appearing in 5 varieties included a rounded, protruding chin, the head indicated by a curved incision in the front, the neck being titled forward, angular shoulders, upper arms indicated in relief, upper arms depicted in a rectangular fashion from the back, indicated fingers, pubic area indicated by a broad triangle, buttocks separated by the leg cleft, lower legs having a straight front profile and curved back, ankles indicated plastically, and feet having a convex top shape.

From the above chart, the reader can see that the statue is best attributed to the Spedos variety. It is more difficult to say, though, whether the statue was produced during the Early or Late Spedos Variety, with 78% and 85% similarity respectively. Of the features included in these calculations, 77% belong to both of the varieties. Contributing to the differences are the following features commonly attributed to figurines of the Early Spedos Variety: upper thighs are attached, and lower legs separated by a cutout; meanwhile, the statue has the following characteristics from the Late Spedos Variety: head equally wide at cheeks and forehead, short nose, a tall, slender neck that is tilted forward, forearms crossed over the stomach/belly area, wide forearms, and the contours of outer thighs are curved.

Throughout Sotirakopoulou's book, she mentions that several features which are also present on the statue are indicative of the Late Spedos variety, such as the head being equally wide at the cheeks and forehead, and the head being concave in the back. However, other features noted above distinctly point *away* from the Late Spedos variety, such as the perforated leg cleft, and the lack of straight contours on all sides; the photographed examples she provides of Late Spedos statues also tend to have indicated joints, whereas those of the statue are indicated plastically.

The third volume of the series *The sanctuary on Keros and the origins of Aegean ritual practice*, edited by Colin Renfrew et al. (2018) and entitled *The Marble Finds from Kavos and the Archaeology of Ritual* provides a further understanding of the statue. Early in the book, Renfrew provides an example of a statue of the Kapsala variety, and one of the Spedos variety (page 9-10). At a first glance, the statue from the Kapsala variety seems more like the statue in question; however, the features that Renfrew attributes to the Kapsala variety in general do not align as closely with the statue that is the focus of this study. The features are (bolded in the same manner as earlier): narrow across shoulders and arms, **round modeling,** head convex from the front, head plump in profile, head has a rounded crown, **head is distinguished from the neck**, breasts are squarish, **clearly shaped breasts**, breasts are close to the arms, **well-rounded torso**, shoulders are not angular, **shoulders are a little wider than hips**, **thighs do not bulge, rounded buttocks, buttocks are in relief, knees are pronouncedly flexed, legs are separated** below the knee, **legs are rounded**, slight indication of the knees themselves, feet are lightly arched, feet are often flat on the ground, **few incisions on the body**, little emphasis on the pubic area, and the pubic area indicated plastically. His description of the Spedos variety figurines, while not clearly depicted in the example image, much more closely relate to the statue of this study: thick, **well built in profile**, **rounded sculpting**, **thick head in profile, vertical surface at the crown of the head, lyre-shaped head,** head broadens at the crown, **face is convex, rounded chin, relatively straight body, legs flexed, waist is modeled, waist is narrower than thighs,** waist is distinguished from thighs by an incised line, line does not disappear, **shoulders are rounded, knees are indicated plastically,** arms are modeled rather than incised or cuts, **incisions are limited,** and the pubic triangle is not marked.

Through this brief analysis of the statue in question, taken into consideration in relation to the works of Sotirakopoulou and Renfrew, we can posit that the Cycladic statue is an example of the Spedos variety, specifically falling into the Late Spedos variation of Cycladic work. This conclusion is reached through a qualitative and quantitative analysis of the statue's features, especially relying on the features as designated by incisions, plasticity, and contours of the statue. While some contradictions in the exact designation of Early and Late Spedos do remain within academic texts, and the statue presents some features from neither of these periods, the majority of the characteristics from this marvelous example of ancient art, and most likely worship, definitively allow us to interpret the statue as an example of the Late Spedos variety of naturalistic, canonical Cycladic sculpture.

The Mediterranean Lady is an exceptional example of Cycladic art, and the statue's academic and cultural applications cannot be understated. Many questions revolve around the mysterious features of Cycladic figurines – features which this statue possesses. Why are most Cycladic statues female? Is it important that, of all facial features, only the nose represented, while the mouth and eyes would have been painted on? Is it possible that the stomach pouch relates to the Ancient Egyptian understanding of excess weight as representative of wealth? And perhaps most importantly, what were these figurines created for? The Mediterranean Lady, with her unusual height and positioned arms, is a nearly undamaged remnant of an ancient civilization still shrouded in mystery.

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Biography of the writer:

Anna Goldelman received her A.A. degree from Bard College in 2015, and a B.A. in Biology and Anthropology with Honors from Williams College in 2019. Correct identification and interpretation of two ancient Mayan anthropomorphic figurines during a curatorial course at Williams College, "Seeds of Divinity," provided the analytical training necessary for the present study of the Cycladic statue. The thesis submitted for the course, entitled "In, On, and Through: Interactions Between Humans and the Divine" can be found at *unbound.williams.edu.* The students also co-curated an exhibit on ancient Mesoamerican ritual relics based on the thesis.

Similarity Between Mediterranean Lady and Canonical Cycladic Varieties

Body part	Statue characteristic	Apeiranthos	Kapsala	Spedos	Early Spedos	Late Spedos	Spedos/ Dokathismata	Dokathismata	Chalandriani	Postcanonical
Head	Lyre-shaped	-	-	1	1	1		1		
	Equally wide at cheeks and forehead	-	-	1		1	-		-	-
Nose	Short	-	-	1		1				
	Conical/semi-conical	-	-	1	1	1		1		
	High on face	-	-	1	1	1				
Chin	Rounded, protruding	-	-	1	1	1	1	1		
Head/neck distinction	Curved incision - front		-	1	1	1	1	1		
	Continuous curved incision - back		-		1	1				
Neck	Truncated conical	1	-	1	1	1	1	1	1	1
	Tall, slender		-	1		1	1	1		1
	Tilted forward	1	-	1		1	1	1		
Neck/torso distinction	U-shaped incision – front; V-shaped incision - back		-	1	1	1	1			
Torso	Trapezoidal	-	1	-	1		1	1		1
Shoulders	Sloping	-	1	-	1	1	1	1	1	1
	Angular	-		-	1	1	1	1	1	1
Breasts	Faint protrusions	-		-		1			1	1
Upper arms	In relief	-	1	-	1	1	1		1	
	Wide front, slender back	-	1	-	1	1				
Elbows	Slightly protruding	-		-	1	1		1	1	1
Forearms	Stomach-belly positioned	-		-		1				
	Right over left	-		-						1

Body part	Statue characteristic	Apeiranthos	Kapsala	Spedos	Early Spedos	Late Spedos	Spedos/ Dokathismata	Dokathismata	Chalandriani	Postcanonical
	Positioned diagonally	-		-	1	1		1		
Fingers	Indicated	-	-	-	1	1	1	1	1	-
Abdomen	Bulging	-		-	1	1	1	1		1
Pubic area	Broad pubic triangle	-		-	1	1	1	1	1	1
Leg cleft	Begins at apex pubic triangle	-		-	1	1				
Spine	Begins lower than V of neck	-		-	1	1	1			1
	Ends above buttocks	-		-	1	1	1		1	
Buttocks	Angular protrusion	-	-	-	1	1		1	1	
	Separated by leg groove	-	-	-	1	1	1	1	1	1
Thighs	Joined at upper	-	-	-	1			1		
	Slightly curved outer contours	-	-	-		1	1	1		
Knees	Indicated plastically *(outer contours, bent legs)*	-	-	-	1	1	1			
Lower legs	Outer contours markedly curved	-	-	-	1	1				
	Profile contours straight front, curved back	-	-	-	1	1	1	1	1	
Ankles	Indicated plastically	-	-	-	1	1	1	1	1	
Feet	Joined at back, carved separately front	-	-	-	1	1	1			
	Convex top	-	-	-	1	1	1	1	1	
Overall similarity		**29%**	**40%**	**88%**	**78%**	**85%**	**58%**	**57%**	**32%**	**40%**

Notes: "1" indicates that the feature occurred on examples of the variety, a blank space indicates that the feature does not occur on examples of the variety, and "-" indicates that the author did not include an analysis for the given feature within a variety. Not all features are included in this chart. Analysis is from Sotirakopoulou (2005).

Appendix C

Initial AMNH Geochemical Tests - February 2017

Table 1 / Appendix C

Mediterranean Lady Statue - Chemistry of Drilled Rock Material and Scraped Patina Material

Statue Material														
Data Point	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**CaO**	**K_2O**	**TiO_2**	**MnO**	**FeO**	**SrO**	**BaO**	**CO_2**	**Total**	**Comment**
169 / 1 .	0.04169	1.28492	0.58375	0.98884	50.35516	0.01669	0.00143	0.01485	0.27871	0.00001	0.0163	47.26836	100.8507	April 2016 drill material
170 / 1 .	0.00001	1.15256	0.32388	1.30536	49.81647	0.02336	0.01517	0.01097	0.23717	0.00001	0.00001	47.26836	100.1534	April 2016 drill material
171 / 1 .	0.01821	0.98183	0.15613	1.352	49.72962	0.005	0.06582	0.01032	0.30993	0.01829	0.00001	47.26836	99.91554	April 2016 drill material
138 / 1 .	0.00001	0.37999	1.58966	0.32146	52.41203	0.02516	0.02665	0.00489	0.07755	0.00001	0.07346	47.26836	102.1792	April 2016 drill material
149 / 1 .	0.03897	0.98759	0.30658	1.33249	47.2589	0.0519	0.09499	0.00001	0.27309	0.00001	0.00814	47.26836	97.62103	April 2016 drill material
150 / 1 .	0.01557	0.67735	0.00002	0.15754	49.75386	0.01658	0.00002	0.00001	0.17724	0.02842	0.00272	47.26836	98.09769	April 2016 drill material
Means (n=6)	**0.02**	**0.91**	**0.49**	**0.91**	**49.89**	**0.02**	**0.03**	**0.01**	**0.23**	**0.01**	**0.02**	**47.27**	**99.80**	
Normalized	**0.02**	**0.91**	**0.49**	**0.91**	**49.99**	**0.02**	**0.03**	**0.01**	**0.23**	**0.01**	**0.02**	**47.36**	**100.00**	
Exterior Scraping														
Data Point	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**CaO**	**K_2O**	**TiO_2**	**MnO**	**FeO**	**SrO**	**BaO**	**CO_2**	**Total**	**Comment**
244 / 1 .	0.02526	8.8357	0.04561	0.12803	12.35312	0.01803	0.05092	0.02553	1.87597	0.00001	0.03807	47.26836	70.6646	exterior scraping material
245 / 1 .	0.01673	19.42278	0.02236	0.00813	28.86823	0.00526	0.00002	0.09921	2.9086	0.03025	0.02229	47.26836	98.67221	exterior scraping material
273 / 1 .	0.09536	0.68991	0.05776	0.93071	34.63624	0.03379	0.00002	0.2035	13.83893	0.00001	0.00001	47.26836	97.75461	exterior scraping material
236 / 1 .	0.042	0.82323	0.44616	0.17046	46.61105	0.00666	0.00002	0.07883	2.23646	0.00001	0.00001	47.26836	97.68327	exterior scraping material
294 / 1 .	0.00957	0.73613	0.00777	0.00002	48.98037	0.00332	0.00002	0.00001	0.17703	0.00001	0.00001	47.26836	97.18262	exterior scraping material
264 / 1 .	0.00001	0.70486	1.68972	0.11105	49.37134	0.00001	0.00002	0.02027	0.14107	0.00001	0.08526	47.26836	99.39201	exterior scraping material
265 / 1 .	0.00001	0.84751	0.14103	0.07591	52.35872	0.00001	0.03822	0.00001	0.14274	0.00001	0.03198	47.26836	100.9045	exterior scraping material
269 / 1 .	0.02821	0.839	1.28867	0.14229	44.72176	0.02304	0.02245	0.00001	0.37906	0.00001	0.00001	47.26836	94.71288	exterior scraping material
Means (n=8)	**0.03**	**4.11**	**0.46**	**0.20**	**39.74**	**0.01**	**0.01**	**0.05**	**2.71**	**0.00**	**0.02**	**47.27**	**94.62**	
Normalized	**0.03**	**4.35**	**0.49**	**0.21**	**42.00**	**0.01**	**0.01**	**0.06**	**2.87**	**0.00**	**0.02**	**49.96**	**100.00**	

Table 2

Raw Geochemical Data for Mediterranean Lady Statue (MLS) and Various Greek Island Samples

Samples	MLS - 1	MLS - 2	MLS - 3	MLS - 4	MLS - 5	MLS - 6	MLS - 7	NAXOS - 1	NAXOS - 2	NAXOS - 3	PAROS - 1	PAROS - 2	PAROS - 3	THASOS - 1	THASOS - 2	THASOS - 3
MgO% - 26	0.4901	0.4495	0.5060	0.3859	0.2251	0.2520	0.4861	0.3655	0.3791	0.3671	0.5290	0.5399	0.5288	18.9488	18.9439	18.6383
CaO% - 43	55.6700	55.6700	55.6700	55.6700	55.6700	55.6700	55.6700	55.3720	55.3720	55.3720	55.1400	55.1400	55.1400	30.7320	30.7320	30.7320
TiO2% - 47	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V - 51	2.5297	0.1205	0.2119	0.0982	0.1102	0.1598	0.1073	3.1241	3.2529	3.1518	1.0337	1.3652	1.0778	0.1017	0.1164	0.1758
Cu - 65	0.2379	0.3889	0.2560	0.1391	0.2099	0.1672	0.6652	0.2103	0.1773	0.1604	0.1530	0.1237	0.1307	0.2504	0.2594	0.3067
Zn - 66	1.7965	7.2289	1.1531	0.9262	1.8692	1.0202	1.1942	0.1455	0.1614	0.7709	0.1754	0.2578	0.1839	2.1733	2.7602	2.6268
Rb - 85	2.9574	-0.0294	-0.0452	-0.0081	0.0007	-0.0049	0.0267	-0.0009	-0.0072	0.0005	-0.0079	-0.0045	-0.0108	0.0055	0.0074	0.0288
Sr - 88	241.2473	229.3596	206.9202	220.1834	199.7492	249.2166	238.8234	114.2330	114.8175	115.5114	240.4088	244.3231	243.7402	22.5272	22.2654	23.4377
Y - 89	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ba - 137	4.9620	0.2138	0.1235	0.1940	0.2579	0.2375	0.2073	1.2743	1.2284	1.3786	0.4211	0.5311	0.4924	0.0549	0.0938	0.0840
Ba - 138	5.4141	0.2364	0.1551	0.1739	0.2587	0.2217	0.2316	1.3556	1.3115	1.4421	0.4971	0.6210	0.5160	0.0682	0.0962	0.0851
La - 139	0.1702	0.1929	0.2812	0.1372	0.2665	0.4859	0.2290	0.2189	0.2375	0.2436	0.2962	0.3597	0.3542	0.0920	0.0931	0.1184
Ce - 140	0.2369	0.2796	0.3707	0.1613	0.3349	0.6666	0.3408	0.1499	0.1455	0.1549	0.5116	0.6029	0.6177	0.1246	0.1380	0.1592
Pr - 141	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nd - 145	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sm - 147	0.0125	0.0257	0.0358	0.0150	0.0360	0.0551	0.0317	0.0293	0.0295	0.0313	0.0503	0.0470	0.0496	0.0119	0.0172	0.0144
Eu - 153	0.0154	0.0062	0.0065	0.0069	0.0022	0.0122	0.0059	0.0047	0.0060	0.0087	0.0091	0.0089	0.0079	0.0031	0.0025	0.0046
Gd(Dy) - 160	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Tb - 159	0.0038	0.0058	0.0064	0.0032	0.0045	0.0072	0.0062	0.0058	0.0052	0.0067	0.0068	0.0070	0.0074	0.0018	0.0030	0.0025
Dy - 163	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ho - 165	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Er - 166	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Tm - 169	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Yb - 172	0.0129	0.0170	0.0515	0.0101	0.0409	0.0222	0.0246	0.0350	0.0249	0.0281	0.0180	0.0262	0.0305	0.0045	0.0087	0.0147
Lu - 175	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Th - 232	0.0047	0.0078	0.0010	0.0029	0.0092	0.0092	0.0046	0.0005	0.0014	0.0019	0.0100	0.0315	0.0171	0.0003	0.0009	0.0001
U - 238	0.0064	0.0217	0.0005	0.0007	0.0865	0.0151	0.0224	0.0007	0.0003	0.0004	0.0004	0.0009	0.0005	0.0001	0.0005	0.0000

June 2018 Laser Element Analysis (American Museum of Natural History)

Variance of Minor- and Trace Elements for Mediterranean Lady Statue (MLS) and Various Greek Island Samples — Table 3

Final Concentrations AVG (ppm)

Atomic # --->	26	43	47	51	65	66	85	88	89	137	138	139	140	141	145	147	153	160	159	163	165	166	169	172	175	232	238
	MgO%	**CaO%**	**TiO2%**	**V**	**Cu**	**Zn**	**Rb**	**Sr**	**Y**	**Ba**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd(Dy)**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Th**	**U**
Mediterranean Lady Statue (MLS) Sample	0.40	55.67	BDL	0.48	0.29	2.17	0.41	226.50	BDL	0.89	0.96	0.25	0.34	BDL	BDL	0.03	0.01	BDL	0.01	BDL	BDL	BDL	BDL	0.03	BDL	0.01	0.02
Naxos	0.37	55.37	BDL	3.18	0.18	0.36	0.00	114.85	BDL	1.29	1.37	0.23	0.15	BDL	BDL	0.03	0.01	BDL	0.01	BDL	BDL	BDL	BDL	0.03	BDL	0.00	0.00
Paros	0.53	55.14	BDL	1.16	0.14	0.21	-0.01	242.82	BDL	0.48	0.54	0.34	0.58	BDL	BDL	0.05	0.01	BDL	0.01	BDL	BDL	BDL	BDL	0.02	BDL	0.02	0.00
Thasos	18.84	30.73	BDL	0.13	0.27	2.52	0.01	22.74	BDL	0.08	0.08	0.10	0.14	BDL	BDL	0.01	0.00	BDL	0.00	BDL	BDL	BDL	BDL	0.01	BDL	0.00	0.00

Atomic # --->	26	43	47	51	65	66	85	88	89	137	138	139	140	141	145	147	153	160	159	163	165	166	169	172	175	232	238
Chemical Variance to MLS (Z-Score)	**MgO%**	**CaO%**	**TiO2%**	**V**	**Cu**	**Zn**	**Rb**	**Sr**	**Y**	**Ba**	**Ba**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd(Dy)**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Th**	**U**
Naxos	0.03	0.30	BDL	-2.70	0.11	1.81	0.42	111.65	BDL	-0.41	-0.41	0.02	0.19	BDL	BDL	0.00	0.00	BDL	0.00	BDL	BDL	BDL	BDL	0.00	BDL	0.00	0.02
Paros	-0.13	0.53	BDL	-0.68	0.16	1.96	0.42	-16.32	BDL	0.40	0.41	-0.08	-0.24	BDL	BDL	-0.02	0.00	BDL	0.00	BDL	BDL	BDL	BDL	0.00	BDL	-0.01	0.02
Thasos	-18.44	24.94	BDL	0.35	0.02	-0.35	0.40	203.76	BDL	0.81	0.87	0.15	0.20	BDL	BDL	0.02	0.00	BDL	0.00	BDL	BDL	BDL	BDL	0.02	BDL	0.01	0.02

Raw Concentration Data from Table 2

Samples	MLS - 1	MLS - 2	MLS - 3	MLS - 4	MLS - 5	MLS - 6	MLS - 7	NAXOS - 1	NAXOS - 2	NAXOS - 3	PAROS - 1	PAROS - 2	PAROS - 3	THASOS - 1	THASOS - 2	THASOS - 3
MgO%	0.49	0.45	0.51	0.39	0.23	0.25	0.49	0.37	0.38	0.37	0.53	0.54	0.53	18.95	18.94	18.64
CaO%	55.67	55.67	55.67	55.67	55.67	55.67	55.67	55.37	55.37	55.37	55.14	55.14	55.14	30.73	30.73	30.73
V	2.53	0.12	0.21	0.10	0.11	0.16	0.11	3.12	3.25	3.15	1.03	1.37	1.08	0.10	0.12	0.18
Cu	0.24	0.39	0.26	0.14	0.21	0.17	0.67	0.21	0.18	0.16	0.15	0.12	0.13	0.25	0.26	0.31
Zn	1.80	7.23	1.15	0.93	1.87	1.02	1.19	0.15	0.16	0.77	0.18	0.26	0.18	2.17	2.76	2.63
Rb	2.96	-0.03	-0.05	-0.01	0.00	0.00	0.03	0.00	-0.01	0.00	-0.01	0.00	-0.01	0.01	0.01	0.03
Sr	241.25	229.36	206.92	220.18	199.75	249.22	238.82	114.23	114.82	115.51	240.41	244.32	243.74	22.53	22.27	23.44
Ba	4.96	0.21	0.12	0.19	0.26	0.24	0.21	1.27	1.23	1.38	0.42	0.53	0.49	0.05	0.09	0.08
Ba	5.41	0.24	0.16	0.17	0.26	0.22	0.23	1.36	1.31	1.44	0.50	0.62	0.52	0.07	0.10	0.09
La	0.17	0.19	0.28	0.14	0.27	0.49	0.23	0.22	0.24	0.24	0.30	0.36	0.35	0.09	0.09	0.12
Ce	0.24	0.28	0.37	0.16	0.33	0.67	0.34	0.15	0.15	0.15	0.51	0.60	0.62	0.12	0.14	0.16
Sm	0.01	0.03	0.04	0.01	0.04	0.06	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.01	0.02	0.01
Eu	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Tb	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Yb	0.01	0.02	0.05	0.01	0.04	0.02	0.02	0.04	0.02	0.03	0.02	0.03	0.03	0.00	0.01	0.01
Th	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.00	0.00	0.00
U	0.01	0.02	0.00	0.00	0.09	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Variance and Z-Score Element Analysis Spreadsheet Data

Table 4

ReplicateSamples	MLS - 1	MLS - 2	MLS - 3	MLS - 4	MLS - 5	MLS - 6	MLS - 7	NAXOS - 1	NAXOS - 2	NAXOS - 3	PAROS - 1	PAROS - 2	PAROS - 3	THASOS - 1	THASOS - 2	THASOS - 3	MEAN	STANDARD DEVIATION
M043 Conc.	55.67	55.67	55.67	55.67	55.67	55.67	55.67	55.372	55.372	55.372	55.14	55.14	55.14	30.732	30.732	30.732		
MgO%	0.490127021	0.449484066	0.506000848	0.385916227	0.225117553	0.251998842	0.48611976	0.365452571	0.379148755	0.367125893	0.529022955	0.539936782	0.52878231	18.94883996	18.94388212	18.63826519	3.877201303	7.190496838
CaO%	55.67	55.67	55.67	55.67	55.67	55.67	55.67	55.372	55.372	55.372	55.14	55.14	55.14	30.732	30.732	30.732	50.838875	9.661082832
V	2.529715144	0.120505517	0.211944447	0.098242164	0.110230969	0.159801861	0.107313241	3.124087715	3.252865281	3.151751563	1.033717816	1.365238629	1.077840943	0.101736561	0.116432987	0.175817023	1.046077616	1.210188649
Cu	0.237946858	0.388909555	0.255957818	0.139091843	0.209947282	0.167217844	0.665197755	0.21026304	0.177289331	0.160415036	0.153007736	0.123660504	0.130728055	0.25037467	0.25943994	0.306730585	0.239761116	0.129600369
Zn	1.796524686	7.228857394	1.153118641	0.926188279	1.869212441	1.020223146	1.194221933	0.145452119	0.161431057	0.770933134	0.175416113	0.257829782	0.18392594	2.173275026	2.76021645	2.626760441	1.527724161	1.701171025
Rb	2.957390978	-0.029394843	-0.045172674	-0.008145295	0.000747451	-0.004868861	0.026678777	-0.000868434	-0.007177293	0.000463995	-0.007905973	-0.004480578	-0.010815926	0.005515719	0.007357751	0.028849929	0.18176092	0.716870142
Sr	241.2473241	229.3596142	206.9202195	220.183387	199.7492005	249.2165662	238.8233966	114.2330161	114.8175458	115.5114323	240.408802	244.3230638	243.7401698	22.52716592	22.26543049	23.43772806	170.4227539	84.58447426
Ba	4.96196003	0.213765198	0.123463145	0.194003198	0.257936401	0.237511257	0.20733261	1.274344088	1.228354743	1.378580768	0.421094479	0.531126666	0.492393022	0.054873946	0.093785831	0.084023297	0.734659292	1.172710308
Ba	5.414135611	0.236354608	0.15514646	0.173892723	0.258683788	0.221715056	0.231610428	1.355611843	1.311451557	1.442102545	0.497067602	0.621036368	0.515975466	0.068243398	0.096170267	0.085139787	0.792771094	1.277066347
La	0.170245218	0.192947468	0.281179459	0.137201777	0.266512334	0.485890947	0.22902542	0.218927375	0.237531297	0.243630452	0.296209042	0.359702863	0.354236555	0.092019299	0.093100052	0.118396669	0.236047264	0.102970085
Ce	0.236921398	0.279600348	0.370655759	0.161302292	0.334884019	0.666607257	0.340842135	0.149917883	0.145453971	0.154884884	0.511593607	0.602895791	0.617653551	0.124562793	0.137956371	0.159178812	0.312181929	0.184609686
Sm	0.01249433	0.025708708	0.035775989	0.014987665	0.036043916	0.055139015	0.031742561	0.029332765	0.029494415	0.031298558	0.050251849	0.047028437	0.049610123	0.011860677	0.017220584	0.014392133	0.030773858	0.01384863
Eu	0.015442732	0.006230098	0.006549538	0.006863827	0.002236276	0.012220116	0.005865021	0.004701115	0.006014692	0.008723433	0.009107088	0.008929975	0.007876145	0.003058625	0.002528607	0.004584387	0.00693323	0.003379854
Tb	0.003828167	0.005776178	0.006385057	0.003210564	0.004496984	0.007242395	0.006179139	0.005801771	0.005247562	0.006738772	0.006753106	0.006972545	0.007408411	0.001756735	0.002954892	0.002501013	0.00520333	0.00177737
Yb	0.012886882	0.017048745	0.051528119	0.010093515	0.040851014	0.022220075	0.024599301	0.035011878	0.024940133	0.02808055	0.018009024	0.026192585	0.030504589	0.004536581	0.008722676	0.014733714	0.023122461	0.012036565
Th	0.004684914	0.007763226	0.000969944	0.00294264	0.009238804	0.009248701	0.004604814	0.000524032	0.001427917	0.001917253	0.010040584	0.031502206	0.017103277	0.000256667	0.000907802	7.10791E-05	0.006450241	0.007948401
U	0.006403166	0.021658969	0.000536053	0.000694817	0.086470908	0.015083122	0.02240337	0.000651635	0.000307338	0.000397349	0.000383322	0.00092573	0.00045984	7.09254E-05	0.000463564	0	0.009806882	0.021184936

NORM	MLS - 1	MLS - 2	MLS - 3	MLS - 4	MLS - 5	MLS - 6	MLS - 7	NAXOS - 1	NAXOS - 2	NAXOS - 3	PAROS - 1	PAROS - 2	PAROS - 3	THASOS - 1	THASOS - 2	THASOS - 3
M043 Conc.	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE	Z - SCORE
MgO%	-0.471048713	-0.476701028	-0.468841101	-0.485541563	-0.507904229	-0.504165782	-0.471606013	-0.488387494	-0.486482732	-0.488154781	-0.46563936	-0.464121548	-0.465672827	2.096049688	2.095360189	2.052857295
CaO%	0.500060406	0.500060406	0.500060406	0.500060406	0.500060406	0.500060406	0.500060406	0.469215002	0.469215002	0.469215002	0.445201131	0.445201131	0.445201131	-2.081223746	-2.081223746	-2.081223746
V	1.225955581	-0.764816378	-0.689258794	-0.783212975	-0.773306416	-0.732345123	-0.775717386	1.717096008	1.823507159	1.739955129	-0.010213119	0.263728315	0.026246591	-0.780325494	-0.768181581	-0.719111516
Cu	-0.013998866	1.150833439	0.1249742	-0.776766869	-0.230044355	-0.55974587	3.282680757	-0.227607958	-0.482034001	-0.612236528	-0.669391453	-0.8958355	-0.841302079	0.081894477	0.151842343	0.516738262
Zn	0.158009113	3.351299281	-0.220204503	-0.353601063	0.200737183	-0.298324512	-0.19604274	-0.812541492	-0.803148587	-0.444864753	-0.794927746	-0.746482488	-0.789925411	0.379474406	0.724496403	0.646046908
Rb	3.871872876	-0.29455232	-0.31656165	-0.264910204	-0.252505243	-0.260339733	-0.216332268	-0.254759326	-0.263559886	-0.25290065	-0.26457636	-0.259798097	-0.268635607	-0.245853734	-0.243284186	-0.213303613
Sr	0.837323525	0.696781068	0.43149131	0.588295116	0.346711933	0.931539896	0.808666641	-0.66430321	-0.657392607	-0.649189134	0.827410098	0.87368646	0.866795195	-1.748495682	-1.751590049	-1.73773056
Ba	3.604727194	-0.444179684	-0.521182549	-0.461031246	-0.406513772	-0.423930814	-0.449664916	0.460202995	0.420986707	0.549088271	-0.267384717	-0.173557463	-0.20658663	-0.579670309	-0.546489152	-0.554813914
Ba	3.618734866	-0.435698966	-0.499288573	-0.484609412	-0.41821422	-0.447162388	-0.43941387	0.44072945	0.406149974	0.508455533	-0.231549044	-0.134475963	-0.216743342	-0.567337553	-0.545469567	-0.554106926
La	-0.63904042	-0.41856619	0.438303946	-0.959943727	0.295863306	2.426371524	-0.068193046	-0.166260798	0.014412274	0.073644577	0.58426462	1.200888574	1.147802201	-1.398736002	-1.388240205	-1.142570633
Ce	-0.407673799	-0.176489016	0.316743022	-0.817289932	0.122973447	1.919863121	0.155247571	-0.878957385	-0.903137652	-0.852051964	1.080179931	1.574748696	1.654689031	-1.016301696	-0.943750906	-0.828792469
Sm	-1.319952093	-0.365750934	0.361200422	-1.139910077	0.380547258	1.759391174	0.069949416	-0.104060329	-0.092387692	0.037888216	1.406492298	1.173731922	1.3601537	-1.36570769	-0.97867257	-1.18291302
Eu	2.517712865	-0.20803625	-0.113523242	-0.020534128	-1.389691269	1.56423507	-0.316051662	-0.660417563	-0.271768361	0.529668945	0.643181147	0.59077865	0.278981182	-1.1463822	-1.3031992	-0.694953985
Tb	-0.773706972	0.322300737	0.664873362	-1.121188074	-0.397411081	1.147236748	0.549017883	0.336699801	0.024885877	0.863883643	0.871948338	0.995411151	1.240642059	-1.939154571	-1.265036772	-1.520402129
Yb	-0.85037377	-0.504605444	2.359947262	-1.082447212		-0.074970398	0.1226961	0.98777489	0.151012457	0.41191893	-0.424825277	0.255066421	0.613308549	-1.544118376	-1.196336806	-0.696938704
Th	-0.222098362	0.165188582	-0.689484233	-0.44129647	0.350833176	0.352078367	-0.232175893	-0.745585107	-0.631866007	-0.570301919	0.451706244	3.151824315	1.34027397	-0.779222609	-0.69730233	-0.802571724
U	-0.160666804	0.559458263	-0.437614192	-0.43011999	3.618798981	0.249056208	0.594596473	-0.432158336	-0.448410295	-0.444161485	-0.444823612	-0.419220137	-0.441211703	-0.459569774	-0.441035909	-0.462917688

ReplicateSamples	NAXOS - 1	NAXOS - 2	NAXOS - 3	PAROS - 1	PAROS - 2	PAROS - 3	THASOS - 1	THASOS - 2	THASOS - 3
MgO%	-0.488387494	-0.486482732	-0.488154781	-0.46563936	-0.464121548	-0.465672827	2.096049688	2.095360189	2.052857295
CaO%	0.469215002	0.469215002	0.469215002	0.445201131	0.445201131	0.445201131	-2.081223746	-2.081223746	-2.081223746
V	1.717096008	1.823507159	1.739955129	-0.010213119	0.263728315	0.026246591	-0.780325494	-0.768181581	-0.719111516
Cu	-0.227607958	-0.482034001	-0.612236528	-0.669391453	-0.8958355	-0.841302079	0.081894477	0.151842343	0.516738262
Zn	-0.812541492	-0.803148587	-0.444864753	-0.794927746	-0.746482488	-0.789925411	0.379474406	0.724496403	0.646046908
Rb	-0.254759326	-0.263559886	-0.25290065	-0.26457636	-0.259798097	-0.268635607	-0.245853734	-0.243284186	-0.213303613
Sr	-0.66430321	-0.657392607	-0.649189134	0.827410098	0.87368646	0.866795195	-1.748495682	-1.751590049	-1.73773056
Ba	0.460202995	0.420986707	0.549088271	-0.267384717	-0.173557463	-0.20658663	-0.579670309	-0.546489152	-0.554813914
Ba	0.44072945	0.406149974	0.508455533	-0.231549044	-0.134475963	-0.216743342	-0.567337553	-0.545469567	-0.554106926
La	-0.166260798	0.014412274	0.073644577	0.58426462	1.200888574	1.147802201	-1.398736002	-1.388240205	-1.142570633
Ce	-0.878957385	-0.903137652	-0.852051964	1.080179931	1.574748696	1.654689031	-1.016301696	-0.943750906	-0.828792469
Sm	-0.104060329	-0.092387692	0.037888216	1.406492298	1.173731922	1.3601537	-1.36570769	-0.97867257	-1.18291302
Eu	-0.660417563	-0.271768361	0.529668945	0.643181147	0.59077865	0.278981182	-1.1463822	-1.3031992	-0.694953985
Tb	0.336699801	0.024885877	0.863883643	0.871948338	0.995411151	1.240642059	-1.939154571	-1.265036772	-1.520402129
Yb	0.98777489	0.151012457	0.41191893	-0.424825277	0.255066421	0.613308549	-1.544118376	-1.196336806	-0.696938704
Th	-0.745585107	-0.631866007	-0.570301919	0.451706244	3.151824315	1.34027397	-0.779222609	-0.69730233	-0.802571724
U	-0.432158336	-0.448410295	-0.444161485	-0.444823612	-0.419220137	-0.441211703	-0.459569774	-0.441035909	-0.462917688

ReplicateSamples	MgO%	CaO%	V	Cu	Zn	Rb	Sr	Ba - 137	Ba - 138	La	Ce	Sm	Eu	Tb	Yb	Th	U
NAXOS - 1	-0.488387494	0.469215002	1.717096008	-0.227607958	-0.812541492	-0.254759326	-0.66430321	0.460202995	0.44072945	-0.166260798	-0.878957385	-0.104060329	-0.660417563	0.336699801	0.98777489	-0.745585107	-0.432158336
NAXOS - 2	-0.486482732	0.469215002	1.823507159	-0.482034001	-0.803148587	-0.263559886	-0.657392607	0.420986707	0.406149974	0.014412274	-0.903137652	-0.092387692	-0.271768361	0.024885877	0.151012457	-0.631866007	-0.448410295
NAXOS - 3	-0.488154781	0.469215002	1.739955129	-0.612236528	-0.444864753	-0.25290065	-0.649189134	0.549088271	0.508455533	0.073644577	-0.852051964	0.037888216	0.529668945	0.863883643	0.41191893	-0.570301919	-0.444161485
PAROS - 1	-0.46563936	0.445201131	-0.010213119	-0.669391453	-0.794927746	-0.26457636	0.827410098	-0.267384717	-0.231549044	0.58426462	1.080179931	1.406492298	0.643181147	0.871948338	-0.424825277	0.451706244	-0.444823612
PAROS - 2	-0.464121548	0.445201131	0.263728315	-0.8958355	-0.746482488	-0.259798097	0.87368646	-0.173557463	-0.134475963	1.200888574	1.574748696	1.173731922	0.59077865	0.995411151	0.255066421	3.151824315	-0.419220137
PAROS - 3	-0.465672827	0.445201131	0.026246591	-0.841302079	-0.789925411	-0.268635607	0.866795195	-0.20658663	-0.216743342	1.147802201	1.654689031	1.3601537	0.278981182	1.240642059	0.613308549	1.34027397	-0.441211703
THASOS - 1	2.096049688	-2.081223746	-0.780325494	0.081894477	0.379474406	-0.245853734	-1.748495682	-0.579670309	-0.567337553	-1.398736002	-1.016301696	-1.36570769	-1.1463822	-1.939154571	-1.544118376	-0.779222609	-0.459569774
THASOS - 2	2.095360189	-2.081223746	-0.768181581	0.151842343	0.724496403	-0.243284186	-1.751590049	-0.546489152	-0.545469567	-1.388240205	-0.943750906	-0.97867257	-1.3031992	-1.265036772	-1.196336806	-0.69730233	-0.441035909
THASOS - 3	2.052857295	-2.081223746	-0.719111516	0.516738262	0.646046908	-0.213303613	-1.73773056	-0.554813914	-0.554106926	-1.142570633	-0.828792469	-1.18291302	-0.694953985	-1.520402129	-0.696938704	-0.802571724	-0.462917688

AVERAGES	MgO%	CaO%	V	Cu	Zn	Rb	Sr	Ba - 137	Ba - 138	La	Ce	Sm	Eu	Tb	Yb	Th	U
NAXOS	-0.487675002	0.469215002	1.760186099	-0.440626162	-0.68685161	-0.257073287	-0.65696165	0.476759324	0.451778319	-0.026067982	-0.878049	-0.052853268	-0.134172326	0.408489774	0.516902093	-0.649251011	-0.441576705
PAROS	-0.465144578	0.445201131	0.093253929	-0.802176344	-0.777111882	-0.264336688	0.855963918	-0.215842937	-0.194256116	0.977651798	1.436539219	1.313459307	0.50431366	1.036000516	0.147849897	1.647934843	-0.435085151
THASOS	2.081422391	-2.081223746	-0.755872863	0.250158361	0.583339239	-0.234147178	-1.745938764	-0.560324458	-0.555638015	-1.309848947	-0.929615024	-1.175764427	-1.048178462	-1.574864491	-1.145797962	-0.759698888	-0.45450779

Appendix D

Appendix D

The Sculpture Project: A minimum age derived from cosmogenic nuclide dating

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We here report a novel application of cosmogenic nuclide dating to a straight-forward archeological question: How old is the pristine marblesculpture shown in Fig. 1?

Figure 1. Marble Statue: 1,000s of years old or a recent forgery?

Principle Idea: Cosmic rays penetrate the upper few meters of the earth surface and produce characteristic cosmogenic nuclides {Gosse, 2001 #939}, including the radionuclide chlorine-36 (half-life ~ 300,000 years) produced from the interaction of cosmic ray neutrons and calcium atoms in the marble. As a function of time of the exposure to open sky and hence to the cosmic ray neutrons, the number of chlorine-36 atoms retained in the marble increaseswith time {Granger, 2013 #1895}. As we know the rate of production of these cosmogenic chlorine-36 atoms in marble rather well{Stone, 1996 #429}, we can calculate an 'exposure age' from the measured chlorine-36 atoms from a sample, in this case part of the statue in Fig. 1 (see 'Methods' below). The time-range of chlorine-36 exposure dating is typically about 1000 – 1,000,000 years and most studies are focused on natural rock samples used in paleoclimate and geomorphology projects. We report one of the first applications of this method on an archeologic sample {Ivy-Ochs, 2002 #1058}.

The original marble block of which the statue was created, was most likely deeply buried in the quarry and thus shielded from cosmic rays, so nochlorine-36 was produced until a quarryman took the block out of the quarry and a sculptor made the statue. This was our time zero (t=0) when the cosmogenic clock starts ticking and chlorine-36 isotope production in the statue begins.

If the statue was subsequently always relatively close to the surface, and thus the cosmic neutrons kept bombarding the statue, the amount of chlorine-36 produced from calcium over, for example, 3,000 years, would be about 60,000 atoms/g of chlorine-36 in marble, which we could detect. The basic idea behind the geochemistry and analytics underlying cosmogenic chlorine-36 dating is simple: (i) carefully decontaminate the sample in the laboratory by successive leaching in diluted nitric and hydrofluoric acid; (ii) digest the decontaminated sample and extract the chlorine; (iii) analyse the chlorine isotope composition using isotope-dilution techniques {Stone, 1996 #429}. The actual isotopic ratio measurement of the three chlorine isotopes chlorine-35, -36 and -37 is done by accelerator mass spectrometry (AMS). The challenge is that the amounts of cosmogenic chlorine-36 are tiny compared to the natural chlorine isotopes 35 and 37, and only very few AMS facilities are capable of measuring such small amounts of chlorine-36. As we expected very low levels of cosmogenic chlorine-36 close to the detection limit, we processed four independent blanks with the statue sample.

However, we do not know the whereabouts of the statue after it was sculptured and it is likely that it was underground for at least part of the time, so the production of chlorine-36 in the statue may have been interrupted during these times of burial, or at least reduced. In turn, the amount of chlorine-36 we measure is therefore a lower bound, and the‘chlorine-36 exposure age’ we calculate is a minimum age.

Methods: For our experiment, we used the material that was drilled from the foot area of the statue, and we received 2.1 g of the sample. The elemental analyses performed at the AMNH indicated that the statue is made of ultra pure calcite marble, ideal for chlorine-36 dating due to very low baseline levels (~1 ppm) of natural chlorine in the sample.

Results: Our results are shown in Table 1. Surprisingly, there is a clear cosmogenic chlorine-36 excess above blank, indicating a period of exposure at or close to the earth’s surface of the statue. Calculating an exposure age from this cosmogenic chlorine-36 excess yields a minimum age of 4,400 ± 1,800 years.

	Total Chlorine-36 in sample (atoms)	±	**Blank corrected 36Cl (atoms/g)**	±	**Chlorine-36 exposure age (years)**	±
Blank	411,000	45,400				
Statue	577,000	48,200	79,200	31,600	**4,400**	**1,800**

Table 1. Chlorine-36 of the statue sample measured at the Center of Accelerator Mass Spectrometry at the Lawrence Livermore National Laboratory (CAMS), together with the mean value of four independent blank measurements. Note that the large errors are an effect of the significant blank correction of more than 50%.

What does this exposure age mean?

The simplest explanation of the measured chlorine-36 excess and the resulting minimum exposure age of 4,400 ± 1,800 years is that the statue is indeed ancient and was at or near the earth’s surface most of the time after, for example in a temple. We cannot exclude that chlorine-36 was produced in the quarry prior to the sculpturing of the statue, however this seems unlikely for two main reasons:

(i) ancient marble quarries tend to be deep-seated and the cosmogenic nuclide production is limited to the upper meters so it is only a very small fraction of the marble, if any, that is subject to cosmogenic nuclide production in the quarry.

(ii) The resulting exposure age of 4,400 ± 1,800 years places the age of the quarried marble well within the interval where these famous Cycladic statues were actually created in the Greek Mediterranean region.

These encouraging results thus deliver an argument that the statue is indeed several thousand years old (range of 2,600-6,200 years*) and highlights the potential of cosmogenic nuclide dating in modern archeology.

*** A note to the error bars:** The substantial errors are a result of the relatively low chlorine-36 excess and the related relatively high blank-correction. This could be improved by (i) increasing the sample amount, and (ii) reducing the chlorine-36 blank level (the CAMS group is working on this). We are optimistic that the precision of dating of ancient art pieces could be considerably increased in the near future.